PARSONS LAKE GAS DEVELOPMENT

LAND TENURE SUBMISSION

GULF OIL CANADA LIMITED

DECEMBER 1975

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SUBMISSION FOR

LAND TENURE

for

Department of

Indian and Northern

Affairs

by

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1.0 OVERVIEW SUMMARY

Gulf Oil Canada Limited desires to produce and process natural gas near Parsons Lake in the Northwest Territories. Gulf's proposal is being made to the Department of Indian Affairs and Northern Development (DIAND); the specific site information contained herein will support an environmental impact assessment being made by DIAND and help prepare for a Land Tenure Agreement between the Government of Canada and Gulf Oil Canada Limited.

This proposal will outline, with as much detail as is currently available, Gulf Canada's plans for the proposed gas development system. The proponent is striving to minimize any possible adverse effects such a system might have on the environment of the area. Results of work completed to date indicate that the proposed development can be implemented for the benefit of Canadians and with effective precautions against any serious or long-term environmental disturbance.

The site of the proposed facilities will be described in detail later. Generally, the well clusters and gathering systems would be located on the east side of Parsons Lake, with a processing plant and related support facilities approximately 2 miles east of the lake and 50 miles north of the town of Inuvik, N.W.T. This includes an outline of required surface facilities from wellhead through gas processing plant to plant outlet, with the specific locations and descriptions of well clusters, gathering systems, roads, gas processing facilities, and other support facilities such as roads, airstrips, docks, living accommodations, communications, etc.

DIAND has indicated to Gulf Oil Canada Limited that the required specific site information related to this project will be integrated with information from other specific site proposals for gas development as part of the over-all Mackenzie Delta gas development assessment to be subjected to the Environmental Assessment and Review Process (EARP) and to the public.

Gulf Canada has provided all the information it has available for this purpose. It should, however, be recognized and emphasized that planned detailed design and site specific information will serve to complement the results of this proposal. Such additional information will be provided as and when it is available.

2.0 PROJECT PROPOSAL

Gulf Oil Canada's proposal for natural gas producing and processing facilities in the Parsons Lake area is a specific site application, and is part of the joint application for "Approval in Principal" of a Mackenzie Delta gas development system made to DIAND in November 1974 on behalf of Gulf Oil Canada Limited, Imperial Oil Limited, and Shell Canada Limited.

2.1 DEVELOPMENT OVERVIEW

Reasons for Development

Gulf Canada's proposed Parsons Lake Development would produce natural gas from the fields in the Parsons Lake area, and process it to specifications required for delivery to appropriate markets.

Demand for Natural Gas

Various cases have been presented relative to the natural gas supply/demand situation. The National Energy Board (NEB) is currently reviewing, among other matters, natural gas supply and demand in connection with the proposed Mackenzie Valley gas pipeline. Information provided to NEB and the conclusions drawn from it referenced with this application. Gulf Oil Canada Limited provided DIAND, in October 1975, with its latest estimates of natural gas reserves and deliverability for the Parsons Lake area.

It is generally acknowledged, and was noted by NEB in its report of April 1975, that Canadian natural gas supplies will not be sufficient both to meet indicated near- and longer-term domestic demands and to support existing export commitments. There is increasing awareness of the rapidly approaching energy shortage in Canada. Sound conservation programs and development of available frontier supplies of natural gas are needed to help avert a more serious situation.

Stated Government policy is to meet Canada's obligations to existing U.S. customers as far as possible. Some curtailment of export contracts, as well as restraints in the growth of gas demand in Canada, will be required until supplies of frontier gas are made available. Current discovered reserves in the Mackenzie Delta, including those in the Parsons Lake area, hold the greatest promise for supplying Canadians with additional energy in time to alleviate the shortfall Gulf Canada contends that Mackenzie Delta reserves can and should be economically exploited at the earliest possible date, and in time to supply a natural gas pipeline from the Mackenzie Delta.

The current indicated schedule for development provides for possible completion of the facilities by mid-1981.

Role of Facilities

Production facilities proposed in this application are in line with the estimates of natural gas reserves and deliverability submitted to DIAND in October 1975. Specific locations are outlined. Drilling during the winter of 1975-76 is expected to confirm reserve estimates and locations for well clusters. Gas would be produced at four to six clusters and transported to a central processing facility via aboveground transmission lines. A central gas processing plant with all necessary self-sufficient support facilities is proposed for a site southeast of Parsons Lake and north of the tip of Hans Bay on Eskimo Lakes. Roads and a communication system would interconnect the well clusters with the processing facility. A dock and an airstrip would be located close to the plant to handle supply. Processed gas would be fed to a lateral line and thence to a Mackenzie Valley pipeline.

Extraction (Gas Production)

Four to six well clusters are currently proposed in the Parsons Lake area. Each cluster would contain from two to four producing wells, and all activities would be carried out and facilities placed on prepared gravel-fill pads. Description and design of the well clusters are contained in Volume 3 of the November 1974 Application for Approval in Principal. Specific site detail is found later in this Application.

Processing

Facilities would be installed at the central processing facility in the Parsons Lake area to process in coming raw-gas feed by removing excess water and liquid hydrocarbons, then compressing and cooling the product to meet sales-gas specifications. Details of the plant design considerations were provided in the November 1974 Application for Approval in Principal; additional detail is found later in this application.

Transportation

Gathering Systems

Locations of the proposed gathering lines are detailed in this Application; general descriptions are provided in the November 1974 Application for Approval in Principal. Raw natural gas would be transported from the well clusters to the processing plant on above-ground lines grounded on piles which would be frozen into the permafrost. Lines would be designed to provide for full thermal expansion of the exposed line, and all pipe would be thermally insulated to minimize heat losses.

Goods and Services

An airstrip is proposed near the processing facility to provide necessary linkage with the outside world. The dock and staging site in the Hans Bay area of Eskimo

Lakes would allow water shipment of necessary materials and supplies. It is planned that all facilities contained in this Application for the Parsons Lake area would be linked by roads to accommodate vehicular traffic. Design detail of pads, roads, airstrips, etc., will be outlined later in this Application.

This Application by Gulf Oil Canada Limited relates to producing facilities necessary to exploit natural gas reserves in the Parsons Lake area only. Provisions for orderly future expansions will be allowed in the basic design of facilities.

Project Length

Deliverability forecasts were provided with the estimates of natural gas reserves and deliverability submitted to DIAND in October 1975. A more detailed development schedule forms part of this Application.

Pre-Construction

It is estimated that pre-construction planning will be completed by the end of 1976. This pre-construction planning, includes conceptual studies required by Gulf Canada, preparation of process flow sheets, material balances, utility balances, bills and material for all major equipment, price quotations and delivery or completion times for all major goods and services, scaled block layouts of processing facilities, architectural designs for the permanent staff accommodations and recreational facilities, and a construction and completion schedule for the work along with final design specifications, plans and concepts.

Construction

Construction and installation of all related facilities is scheduled for an onstream date of mid-1981.

Industrial Proponents Declaration

Gulf Oil Canada Limited is proposing this portion of the Mackenzie Delta Gas Development System in a manner that would optimize benefits both to the Developer and to the Canadian people, with cognizance of and regard for the required environmental safeguards and for those areas of influence that might affect the people directly involved. Due and appropriate measures would be taken to minimize any possible adverse effects of this proposed development.

2.2 FACILITIES

2.21 Location Maps

The following maps are included in this application:

1. General Plan (1 : 250,000)
2. Location Plan (1" = 2,000')
3. Orthophoto Map (1" = 400')
4. Geotechnical Map (1 : 50,000)
5. Wildlife Habitat Maps (1 : 50,000)
6. Aquatic Resources Map (1 : 50,000)
7. Location Map - Water Sampling Sites (1 : 50,000)
8. Vegetation Map (1 : 50,000)

2.22 Production Systems

Wellheads

Drilling operations would leave each well complete to the christmas tree and the lower master valve. During installation of the cluster facilities, the wells would be further equipped to bring them up to operating standard. A second master valve and operator would be added for automatic fail-safe and/or remote-control operation, along with control sensors and manifolding to operate down-hole safety shut-in valves. We do not, at present, foresee a need for wellhead refrigeration equipment;

however, should our on-going investigations into degradation of permafrost by long-term well operations indicate that the region immediately around the upper well-bore might thaw, a mechanical system would be installed along with the necessary control and monitoring equipment, to refrigerate the top 50'-60' of the conductor pipe.

Flowlines

Each wellhead would be served by an insulated flowline installed above ground on pile supports. These flowlines would be designed to carry full wellhead shut-in pressure and would terminate at the upstream flange of the flow-control valve at the test manifold. Their size has not yet been determined but is envisaged as in the 4" to 6" range.

Flow-Control Valves

Each flowline would be equipped with a full-bore control valve of a rating adequate to sustain maximum wellhead pressure. The prime function of this valve would be to regulate the production from each well, but it would also serve as a pressure-reducing station and as a block valve. All equipment downstream of the flow-control valves would have a nominal ANSI 600 rating (1440 psig). Each valve would be equipped with an actuator, and with a controller that would be tied into safety pilots for fail-safe operation, and the local remote terminal unit for positioning by command from the computer control system.

Test Manifold

The downstream side of the flow-control valve would connect to a test manifold equipped with motor valves that open or close on signal from the computer control system. They would route the flow from a single well through a three-phase meter and then to either the production line or the testing circuit. Production routed through to the group line would go directly into the gas-gathering system. Production routed to the test circuit would be processed through the equipment outlined under "test system". Data from the three-phase meter would be processed through the computer control system.

Test System

The test system would incorporate a high-pressure (ANSI 600) three-phase separator, as well as a gas meter, hydrocarbon-liquid meter, water meter and back-pressure regulator. After metering, the streams would be recombined and routed into the group system for delivery to the gas plant. All meter data would be injected into the computer control system and displayed on hard copy at the operations centre.

Chemical Injection System

There might be need to meter corrosion-control chemicals and/or methanol into the well bore from time to time. In such case a control-metering pump installed in one of the cluster process modules would meter the chemicals through small-diameter tubing lines to each wellhead. Storage would be provided for corrosion inhibitor, methanol, and diesel fuel. All tankage would be enclosed in a dyke with an impervious liner to contain any spill.

Flare Facilities

All cluster process facilities downstream of the flow-control valve would be equipped with pressure-relief valves set to pass at 1440 PSIG. These valves would not pop to the atmosphere, but into a relief header that would route the discharge to a flare stack located off the cluster pad and about 300' from the cluster process facilities. The flare tip would be equipped with a pilot light.

Heating Systems

Cluster process facilities would be delivered to the location in the form of pre-assembled, skid-mounted modules. These modules would be completely housed and once connected on the cluster site, would form a completely housed process unit. Module design would provide for some form of heating, and we will be investigating the application of electric space heaters and hot glycol circulation to meet the various needs of the cluster process facilities, the emergency living accommodations, and the liquid storage tanks. All heating systems would be controlled and monitored through the computer control system.

Emergency Power Generation

Clusters would normally be supplied with electrical power from the gas plant, through a transmission line parallel to the gas-gathering line. With any disruption of plant-generated power, an emergency generator at the cluster would take over. This generator, driven by either a gas turbine or a diesel engine, would be rigged to start automatically when there was a power outage at the cluster, and would be sized to handle all critical process loads, as well as the cluster life-support facilities.

Emergency Shelter

Although the cluster facilities would normally operate unattended, they would include an emergency shelter to accommodate up to 8 men. This shelter would consist of a sleeping section with double bunks, and a kitchen stocked with enough food to sustain the crew for several days, should severe weather or an arctic "white out" prevent their getting back to the life-support centre at the gas plant.

Computer Control System

A remote terminal unit (RTU) at each cluster would communicate with a master terminal unit at the plant operations centre. The RTU would interface with the cluster process and devices, which in turn would provide four basic functions: alarm detection, status checking measurement and control. These four functions might be used at each site in any combination, and might vary in complexity depending on the specific application. Measurement, for example, might require simply the accumulation of the number of units measured by a positive displacement meter, or the calculation and integration of instantaneous flow rates by the RTU to obtain total volume.

The master terminal unit (MTU) at the control centre would be capable of analyzing data gathered by the RTU's, as well as performing complex functions for each cluster such as automatic well testing, pipeline leak detection, alarm message display and corrective action, trend analysis and operator override, and auditing. The MTU would also interrogate RTU's within the plant-process and life-support systems. The function of the latter-mentioned RTU's will be covered in the plant and life-support sections of this submission.

Compression Facilities

During the first 6-10 years of operation, the wells should sustain enough productivity against the plant inlet pressure to keep the plant loaded to design capacity, while at the same time providing some flexibility in operations at the clusters. Eventually, however, the wellhead flowing pressure would decline, and unless the wells were produced at a lower pressure level, plant throughput would not be maintained at the design level. The first few months of cluster operation would enable us to approximate the length of time that the wells would sustain plant design throughput without compression; however, the initial cluster design would allow for compression facilities to be added later. There is also a possibility that compressor installations would be deferred several years by the development of new reserves in the area, which in turn would precipitate additional clusters.

There would be no change in the mode of cluster operation when the compressor units were in service. The computer control system proposed for the Parson's Lake development would be capable of expansion to handle all the additional control and monitoring functions associated with compressor operation. The only difference we can see at this time would be more frequent visits by maintenance personnel.

Cluster Operations

Normal cluster operations would be unattended except for periodic visits by maintenance personnel. The entire operation would be monitored and controlled at the operations centre by the computer control system.

The RTU at the cluster would gather all operations information such as pressure, temperature, valve position and alarm conditions, etc., and relay this via the control systems communication link to the main terminal unit, where a condition display by CRT would be shown for each cluster. Also, the operator's consol at the operations centre would allow him to change the operating conditions at any cluster, conduct individual well tests, or shut in a cluster without having to wait for the self-activated safety devices at the clusters to automatically trigger a shut-down.

Although maintenance personnel would attend full time during start-up operations, or loss of any of the control system communications circuits, during normal operations they would visit each cluster as required. Personnel on the cluster site would be able to use either the fixed communications voice-channel system or their portable ultra high frequency (UHF) sets to communicate with the operations centre. Normal travel to and from the centre would be over the all-weather road system serving each cluster, but helicopters could also be used. Crews would normally return to the operations centre each day, but in bad weather the emergency shelter at the cluster could accommodate them for several days if necessary.

2.23 Gathering-System

Design

Although a structural design for the gas-gathering system has not yet been undertaken, some of the design parameters have been firmly established:

- The design would conform to CSA Standard Z184
- All pipelines connecting the clusters with the gas plant would be supported above ground on piling frozen into the permafrost.
- Gas-gathering lines would be insulated and heat-traced with a skin-effect current tracing system.
- Fuel-gas and/or hydrocarbon-liquid lines would be supported by the same frame that carried the gas-gathering line. They might be insulated but would not be heat-traced.
- An all-weather road system for maintenance would be constructed on the permafrost next to the pipeline construction and the permanent service road.
- A high-voltage power transmission line mounted on timber poles would be installed within the road/pipeline rights of way.

- All piping supports would be engineered to handle the static and dynamic loading, and to provide for expansion movement of the pipe.
- The computer control system would monitor pipeline operating conditions, and would constantly compare inlet and outlet volumes for discrepancies outside normal limits that might indicate a leak in the system.

Early in the development of a concept for producing the Parsons Lake reserves we examined several alternative gathering methods, including underground transmission of refrigerated dry gas, underground transmission of the warm three-phase well effluent, and methods of transferring the well effluent from cluster to plant in above-ground piping systems. These investigations indicated that an above-ground pipeline handling raw three-phase well effluent would require the least elaborate cluster process facility, produce much less waste, and have the least effect on the environment. The above-ground system does pose the problem, however, that the pipeline system should be brought up to operating temperatures before start-up to prevent the well effluent from freezing.

Heat-loss calculations on an insulated line indicate that, once the line is warmed above the hydrate temperature, the effluent itself can sustain the operating temperature above that level. We therefore had to devise a means of pre-heating the pipe before production would be into the line.

The most efficient method of pre-heating the line is to apply a skin-effect trace system. This system has a distinct advantage over other trace systems in that it can be energized over very long distances (10 miles or more) from each current-connection point. Skin-effect heat tracing has been used very successfully for heating water lines and bunker fuel lines, but so far as we know it has never been applied to a high-pressure gas line. We are currently evaluating various procedures for brazing or welding the skin-effect tracer tube to the carrier pipe. The results of this investigation will be the subject of a separate submission to DIAND.

There is a very good possibility that we would install a 3" fuel-return line from the gas plant to each cluster site. At first this line would carry sales gas back to the cluster, to operate instruments and supply fuel to the process heaters. Later, when compressors were installed, it may transfer diesel fuel from plant to cluster to feed the compressor drivers. At the same time, the process heaters at the cluster would be converted to operate on diesel fuel, and an instrument air system would be installed. The fuel line between plant and cluster would be run above ground on the same supports that carried the gas-gathering line. It is not yet certain whether this line would have to be insulated, but it would not be heat-traced.

A high line for transmitting power to the cluster would be installed in the pipeline right of way. It would supply electricity at the cluster to drive small circulating pumps, operate space heaters, provide building and yard lighting, and recharge the computer-control battery packs. The power poles could also be used to carry a communications cable out to each cluster, which would be examined by the consultant responsible for designing the communications system.

Operation

Start-up operations on the gas gathering system would require considerably more manpower and attention than its normal operation. Before start-up the pipeline would be pre-warmed by the skin-effect current-trace system to a temperature in the order of 80°F. One or two wells at each cluster would be turned on and their production routed through the cluster facilities to the flare stack for long enough to warm all the cluster piping. Several barrels of methanol would be injected into the gas-gathering system at the cluster, and the line would then be pressured by admitting sales gas at the plant end. When the pressure had reached approximately 1000 psig, the cluster production would be switched from flare to flow into the gas-gathering system. This operation would have to be closely monitored by the operator at the operations centre computer control consol to check line temperatures and pressures until operation was stable. Throughout this procedure, the start-up crew at the cluster would also be in constant communication with the operations centre.

During normal operation, the gathering-system operating conditions would be monitored by the computer control system and the data displayed at the operations centre. Maintenance crews on routine checks of the clusters would be travelling alongside the pipeline and could make visual checks of the support system on their way.

2.24 Processing Plant

Process Description

The plant would be required to process raw fluid from the producing wells to meet the following sales-gas specifications:

Delivery Pressure	1680 psig
Delivery Temperature	+25^{o}F
Hydrocarbon Dewpoint	+25^{o}F at 850 psig
	+20^{o}F at 900 psig
	+10^{o}F at 1000 psig
	0^{o}F at 1050 psig
	-10^{o}F at 1100 psig
Water Content	0.2 lbs per MMSCF

Raw fluid would enter the plant inlet separator where raw gas, liquid hydrocarbons and water would be separated. A refrigeration system and ethylene glycol or dry dessicant system would remove further condensable liquid carbons and water from the raw gas stream to achieve required sales gas hydrocarbon and water dewpoints. The sales gas would then be compressed and cooled by air exchange and propane refrigeration to meet pipeline pressure and temperature specifications.

Figure 2.1 shows the proposed process facilities for the plant. Table 2.1 shows the feed-gas analysis of the inlet raw fluid stream. Table 2.2 shows the anticipated material balance through the plant, it is based on the inlet analysis from Table 2.1. Balance will be revised through the pre-construction planning period based on further gas sample analysis and final gas volume definition.

During preconstruction engineering, a study will be carried out to determine the feasibility of removing carbon dioxide from the process stream to increase the BTU value of the sales gas.

Some of the liquid hydrocarbons removed from the raw fluid would be used for plant fuel, while the surplus liquids would be injected back to the producing formation. Phase 1 engineering will include an evaluation of the feasibility of a liquid topping plant designed to produce diesel fuel, naphtha and possibly aviation fuel from stabilized hydrocarbons.

Produced water removed from the raw fluid would be injected into a suitable underground formation.

Plant Fuel

Fuel during plant start-up would be diesel oil. After start-up, liquid hydrocarbons would be used wherever possible.

Flare System

The plant would be designed to minimize the need to flare. The design would consider the effect of radiation heat in the surrounding area and provide for smoke prevention. All liquids from the process would be recycled and not flared.

Process Equipment

Major equipment would include process vessels, heat exchangers, pumps, condensors, aerial coolers, gas compressors for gas and propane, turbine drivers for compressor and electrical power generation, and a closed-loop hot-oil system for process heat requirements.

2.25 Utilities

Auxiliary utility services for the process plant would include the following:

Power Generation and Distribution

Turbine-driven electric generators would be installed to provide the electrical energy for the project facilities. Part of this system would be a standby unit with supply capability for plant shutdown and maintenance of life-support systems. Primary process voltage would be 600 volts and three-phase 60 cycle; however, other higher voltages might be needed to handle distribution requirements. Rechargeable batteries would be used to activate the computer and all controls.. Depending on the conceptual studies, which would be carried out in pre-construction, a power-distribution system might be needed to serve clusters and well sites.

Water Supply and Treatment

Water would have to be treated for a potable water supply. The treatment facility would be designed for use in both construction and operating phases. Several possible water sources were surveyed and the resulting analyses can be found in Table 3.5.

It is anticipated that plant operations would require 2000 IGPD for domestic consumption and process demand. During peak construction the requirement would be 8000 IGPD. Aerial coolers would be used, thus eliminating the need for cooling towers that use water.

Process-Liquid Disposal

The process liquids would consist of water and liquid hydrocarbon. The waste water would be injected into a suitable subsurface disposal well. The liquid hydrocarbon would be injected back to the producing formation.

Waste Handling

A sewage-disposal system would be designed to handle all sewage from the living quarters, gas-plant washroom facilities, and temporary facilities in areas away from the plant. The sewage process unit would be located near the living complex (the largest contributor of sewage). It would have the treating capability to produce an effluent with BOD and suspended solids concentrations not exceeding 15 ppm, and meeting any other standard required by the Territorial Government regulations before discharge.

It is anticipated that sewage rates would be 8000 IGPD during peak construction and 2000 IGPD during operation.

Solid waste and sludge would be incinerated; the residue after incineration would be handled according to applicable regulations. During pre-construction engineering, the feasibility of combining partially treated sewage effluent with process waste water from the plant, then injecting the total into a suitable disposal well will be evaluated.

A sewage-handling system would also be installed at each well cluster and at the dock site, to deal with any wastes originating from these sources.

Air

Air-compression systems would be installed to provide service air for plant maintenance and instrument air for the process.

Heat

Building heat might be provided by an ethylene glycol heating system, while heat for the plant process would be furnished by direct heaters or a hot-oil system. The potential of electrical systems for building heat in nonhazardous areas would be evaluated in pre-construction activity. The possibility of recovering gas-turbine waste heat would also be evaluated.

Tankage

Tankage would be required for various liquids during construction; the kinds of liquids and the quantities of each would be determined during pre-construction activity.

Permanent tankage would be provided to store heating oil, glycol, diesel fuel, stabilized condensate, and gasoline. The plant might have additional storage facilities to handle propane and the by-products of the liquid topping plant. All liquid storage tanks would be enclosed by dykes with impermeable liners to contain any spills or leaks.

2.3 ACTIVITIES

2.31 Pre-Construction Activities

Pre-construction activities would involve route and location surveying and a short soil-sampling or geotechnical survey at the plant site, at the gravel source and along the proposed access-road locations. In addition, some sounding or determination of water depth, and soil samples, would be taken in the proposed dock area on Hans Bay. Pre-construction survey and sounding work would involve only a few personnel who would either commute to the job site from Gulf's Swimming Point camp, or of its drill-site camps, or have a small camp set up for them on the job site. The surveys would be made in both winter and summer, and would be supported by helicopter, boat, and ground vehicles.

A general geotechnical survey was carried out in the Parsons Lake area during the summer of 1975 to evaluate surface and subsurface conditions that would influence the location of the gas plant and its associated roads and airstrip. Three possible locations were considered (Areas A, B and C, Geotechnical Map)

Area A was selected for the following reasons:

1. It has adequate foundation conditions.
2. It offers a choice of favourable locations for jet and STOL airstrips.

3. It is closest to the area's granular resources.
4. It is closest to a suitable dock site.

Area B is sloping and hence poorly drained, moisture content of the active layer is high and ice wedging extensive.

Area C is acceptable from a geotechnical viewpoint and has good surface drainage, but is relatively remote from producing facilities, dock and staging area, and farther from the borrow areas than Area A.

The geotechnical survey report is now being finalized and will be forwarded when completed at a later date.

2.32 <u>Construction Activities</u>

<u>Borrow Source</u>

Preliminary conceptual designs indicate that an estimated one and one half million cubic yards of granular material would be needed for construction of the roads, staging area and STOL airstrip. The use of insulation to protect the permafrost would reduce this requirement considerably.

The main sources of granular material are deltaic and fluvial terraces formed along a small river south of Parsons Lake, which enters the Eskimo Lakes between Hans Bay and Bonnieville Point. The terraces contain interbedded gravel, sand and silt ranging in depth from a few feet to over sixty. The location of this gravel source is indicated on the 1:20,000, the 1:50,000 and the 1:250,000 maps attached. The deposits are accessible in winter by truck over winter roads across Hans Bay; for summer access a land road would be built.

The gravel deposits outlined in the four sources shown in detail on the 1:20,000 geotechnical map are not of the best quality for road construction and load-bearing foundations, but adequate for these requirements. The total volume of granular material available, although not yet clearly defined, is estimated to be about 1,800,000 cubic yards, from a detailed survey made by the Applicant during the summer of 1974. Additional geotechnical surveys will be undertaken during the winter of 1975-1976 to provide more detailed information on the quality and quantity of material in these deposits.

The Applicant would bring earth-moving and material-handling equipment into the area during the winter, and work the gravel source during the summer. The organic silt and peat overburden would be removed from any drainage courses. Development would proceed inland from the river bank, from east to west across the source. A berm or dyke and probably retaining ponds would be needed on the inactive flood plain between the stream and the southern boundary of the deposit.

The pit would probably be operated during the summer, although the source is large enough to permit operation for a longer period. The material might be stockpiled to allow it to thaw and drain before being placed in the field. Stockpiling would be in the form of large wide windows to expose the maximum surface area of the frozen material.

After the gravel had been removed the pit would be backfilled, graded and covered with the organic silt and peat removed in the initial stripping.

Roads

Construction and operation of the Applicant's gas plant and production facilities would require a network of access roads connecting the plant to the gravel source, dock, airstrip and cluster producing facilities.

The road to the dock and staging area would be a 35-foot top transporter road, designed to handle large modules weighing up to 1,500 tons. Maximum grades and alignment would be dictated by the class of vehicle and the dimensions and weight of the loads to be moved.

All the other access roads would be 20-25 feet wide, and designed to handle normal truck traffic both during construction and after the plant and cluster facilities were complete and operating.

Preliminary road routes are shown on the location maps. Roads would be located and graded to require a minimum of fill material and to interfere with normal surface drainage patterns as little as possible.

Pads

Gravel-pad foundations would be needed for the roads, airstrip, drilling and producing locations, dock and staging area, and plant site. Their preliminary locations are shown on the location maps. As all gravel pads would be placed on permafrost, pad design would be governed by several criteria such as minimum fill thickness. Insulation might be used within the pad to reduce the amount of granular material required and still protect the permafrost. This will be studied during pre-engineering work in early 1976.

Insulation may be used beneath cold tanks and the floors of most buildings. Heated tanks and other floors would probably be elevated above grade and ambient air circulated during winter. Conduits or culverts would provide adequate drainage around and away from the pads, to control subsidence and heaving due to interruption of the natural drainage pattern. Insulation could be installed beneath the culverts to control permafrost thaw.

The construction of pads for roads, plant, dock and airstrip would involve special procedures developed for arctic areas. Fill materials might be placed during either winter or summer. The granular material would be placed in several layers of a few inches thickness, compacted and levelled. Insulation, if required, would be placed in one or possibly two layers and covered with a thin lift of relatively fine gravel by a light scraper. Coarser gravel would then be added to bring the road or pad surface to the required grade and thickness. During winter construction on permafrost, conventional earth-moving machines would be used to place the material. During summer, end-dump trucks traversing the partly finished roadways and pads would be used, to restrict travel on the tundra. Culverts would be installed only during summer, in ditches located in the roadways during spring runoff. Culvert design would ensure water flow during spring break-up. Maintenance of pads, roads and side slopes would be annual for the first one or two years until the effect of heavy traffic and some permafrost thawing had been compensated, then minor maintenance and realignment would be carried out as needed.

A staging or holding area and a dock would be built on Hans Bay as indicated on location maps. The staging area would be pad construction utilizing gravel and insulation for permafrost protection. Sheet piling would be driven into Hans Bay, and filled with granular material behind it. The dock and staging area would be used during construction mainly to offload and store large modules that would be barged into Hans Bay through Eskimo Lakes. Construction of the dock and staging area would probably start during the summer of 1977 and should be completed by 1979.

Airstrip

An airfield would be built near the plant site approximately as shown on location maps. Conceptual studies are now being carried out to determine the feasibility of a STOL vs. a full jet strip. It would be a unlicensed, private facility. If a STOL airstrip was built, the over-all dimensions would be approximately 2,500 feet long by 200 feet wide, with a travelling surface of compacted, gravel 100 feet wide. If conceptual studies called for a full jet strip to handle aircraft up to the size of a Boeing 737, the airstrip would be about 6,500 feet long by 390 feet wide, with a travelling surface 150 feet wide. The airstrip would have offstrip parking for several aircraft, and limited access to the runway.

The airstrip would be connected to the road network to move men, freight and supplies into the working area. The strip would be built early, for use during the heavy plant and producing facilities construction period.

2.33 Development Drilling

The number of development wells required to drain the Parsons Lake reserves has not so far been established, mainly because of the extensive and complex faulting system in the area. Gulf intends to drill four wells capable of production during the 1975-76 drilling season. Their location are shown on the location maps. Results of these wells and of future seismic work in the northeast end of Parsons Lake will dictate the total number of development wells needed.

From current information we anticipate a need for at least 12 development wells. Further development drilling will probably begin in the 1978-79 winter season and continue for about three years. Enough wells would be drilled to provide spare capacity in case of problems.

A liquid-hydrocarbon disposal well would be drilled on a cluster or completed from an existing well. It would be used to dispose of surplus hydrocarbons if a liquid topping plant were built, or of all liquid hydrocarbons should liquid topping not be feasible. Hydrocarbon-disposal depths and anticipated injection pressures have not yet been established.

A water disposal well at the plant site is planned. It would be a shallow well drilled to unconsolidated sands at about 3,500 feet, into which waste waters from the plant process and treated effluent from the living accommodations would be injected.

As reservoir pressures declined, infill development wells would be needed to maintain deliverability. Two additional wells are expected to be placed on production in the 6th and 8th years after start-up.

Depending on the degree of success, as many as 6 clusters are anticipated, with from 2 to 4 wells drilled on each. One well in each group would be a straight vertical hole; the other would be directionally drilled to strategic parts of the reservoir. Maximum horizontal deviation of directional wells would be 1 mile.

Rig

On the basis of studies to date, it is planned to modify an existing mechanical or diesel-electric drilling rig or Parsons Lake development drilling. Total horsepower requirement would be about 2,500 continuous horsepower capable of a 550,000 lb. hook load.

The rig would be moved from well to well on the cluster by means of a skidding system. Both air-coaster and skidding-beam techniques are being considered, with the choice depending on the type of rig and the modifications required.

For optimum economy a development rig would include the following mobility parameters:

1. Ability to move from well to well in minimum time. A maximum of 4 days between release and spud is considered reasonable.
2. Minimum need of horsepower and special equipment for moving.
3. Minimum need to dismantle equipment between moves on a cluster pad.
4. Year-round mobility.

Operations

Present indications are that the complex faulting system in Parsons Lake will limit the number of wells that can be drilled from a single cluster location to 2 to 4. Wells would be drilled in a straight line at 100-foot intervals. This spacing provides the best compromise between pad-size economy and a safe working distance between wells. It would allow enough room for well access in case of future workover.

A mobile rat-hole unit would first auger a 60-foot rat hole, after which 20" refrigerated conductor pipe would be cemented to surface. A 17½" hole would then be drilled to about 4,000' where 13-3/8" casing would be run. An attempt would be made to cement this string to surface, if necessary, by using stage cementing. This depth has been chosen because it represents a competent formation for setting the string. The setting depth for each hole is based on seismic analysis. Below this depth, hole size would vary depending on whether the hole being drilled was straight or deviated. If straight, an 8½" hole would be drilled to the base of the Parsons Lake "C" sand or gas/water content at 9,503 feet subsea. Seven-inch casing would then be run by means of a hanger and tie-back assembly system, and a stage-cementer would be used to cement it through the producing formation and to the 13-3/8" string. This design is shown in Figure 2.2. For a deviated hole, an additional string of 9-5/8" casing would be set at about 8,500 feet, to prevent sloughing and key-seat problems. A deviated hole design is shown in Figure 2.3.

Considerable experience with water-base drilling fluids has been gained in the Mackenzie Delta. Development drilling in a deviated hole would demand more of a drilling fluid. There could be some risk of differential sticking, but it is felt that a water-base drilling fluid could handle the requirements adequately. While drilling the 17½" hole, water base, non-inhibited polymer mud would be used, with the refrigerated conductor pipe operating to keep the top hole frozen. While drilling the intermediate and/or main hole, drilling fluid toxicity would be kept to a minimum by using non-toxic additives whenever possible. Adequate solids-control equipment would be used, though some fluid would still have to be dumped to the drilling sump. Barites (barium sulfate) would be used to increase the density of the drilling fluid should hole conditions dictate.

A typical mud-system composition is as follows:

Component	Surface Hole	Intermediate and Main Hole (3500'+)
Bentonite	10-20 #/bbl.	6-10 #/bbl.
Potassium Chlorid (KCl)		10-16
Caustic Sods (pH control)		1/4-1/3
Polymer		1/4-1/2
Lignosulfonate		1 - 5
Barites	(As required to control formation pressure)	

Materials

During the first few years of development drilling, Swimming Point would be the primary staging site for drilling supplies and materials. A winter road from Lucas Point to Parsons Lake would provide the main means of moving goods to drilling locations.

As development progressed, more emphasis would be placed on moving drilling supplies directly into the Parsons Lake area. Cluster-pad development drilling would require construction of such facilities as a dock/staging area, pads for cluster drilling, and permanent roads to connect them. The dock site on the Eskimo Lakes would be about 10 miles from the furthest cluster and would also serve as a staging area for activities other than drilling, such as construction activities for gas-plant and gathering facilities.

A barging route around Tuktoyaktuk peninsula and entering the Eskimo Lakes chain via Liverpool Bay is generally ice-free for 70 days a year from July 15 to September 20. Running time from Hay River to Tuktoyaktuk with a 6-barge tow is about 6 days. From Tuktoyaktuk to Hans Bay with a 3-barge tow would require 3 or 4 days. Mud, cement, diesel and casing for 12 wells would require approximately 20 series 1500 barges loaded to a 5-foot depth.

Drilling-supply storage at Parsons Lake would be a combination of dock and cluster storage. A yearly major material requirement based on four wells is estimated to be:

- Mud materials - 1800 tons
- Cement - 650 tons
- Casing - 850 tons
- Diesel - 2400 tons

Cluster-pad storage would probably be limited to drilling-mud materials for 1½ wells, a two-weeks' supply of diesel fuel, or about 32,000 gallons, as based on rig consumption of 2300 gallon/day, about 10,500 linear feet of casing and about 1500 sacks of cement.

Drilling-Fluid Disposal

It has been the general practice of the drilling industry to dispose of fluids from land-based operations by open sump. The main purpose of the sump in the northern areas is to fully contain all fluids and materials placed in it during and after drilling of the well. In the Gulf operation in the Mackenzie Delta, drilling fluids and solids would be placed in an open sump, the size of which would vary depending on the depth of the hole and the method of fluid disposal. Generally the sump volume in cubic yards is based on 1.5 times the well depth.

When the drilling operation is completed before breakup, the fluids and solids are frozen as they enter the sump. Once drilling is completed, these materials are covered over with the material originally excavated from the sump. Normally a six-to eight-foot mound covers the general sump area, ensuring that the drilling fluids and solids remain frozen and thus contained. The risk of losing sump fluids in winter is negligible if the sump is built large enough.

A sump that remains open in summer needs special precautions to ensure containment of fluids. The high ice content in the general Parsons Lake area makes for a large degree of melt on the sump walls and the excavated material. Depending on the location, steps would be taken to ensure that all fluids would be contained. When the well had been completed, and sufficient freeboard maintained, the sump would be left to freeze, after which it would be filled in and mounded with the excavated material and gravel where required.

Where no more than two development wells were planned in a cluster, an open-sump drilling system would be used. Wells would be drilled in winter, with a separate sump for each.

If more than two wells were planned for a cluster, they would be drilled continuously during the year, with drilling fluids injected into a subsurface disposal well. The disposal well would be located on the cluster and might serve another cluster as well. Once the main solids had settled in the sump, the liquids would be essentially water with soluble drilling products plus some unsettled bentonite and barite particles. They would be pumped out of the sump during the summer and conveyed to the disposal well, by a temporary line if the well were on the cluster or by truck if it were on another cluster.

A disposal well for sump fluid would be less than 3,000' deep and would be used exclusively for that purpose. A casing string would be set in competent formation.

Contingency Plans

The application for each development well would include a detailed contingency plan covering, among other items, spill containment and the drilling of a relief well if required.

During normal operations the drilling crew would consist of about 35 persons, thoroughly trained in every area of contingency operations. For all drilling operations crews have and would be trained through continued, recognized technical institutes. Regular drills would also be held on blowout-prevention safety.

Completions

The same rig would be used for both development drilling and completion work. The latter would consist of running an insulated casing string or other suitable insulation such as gelled diesel, running production and safety valves, perforating, stimulating, and initial production testing.

Studies to date indicate that thermal insulation would probably be needed to limit the thermal disturbance around the wellbore and minimize the downdrag loads. One method is by using a 7" X 10-3/4" polyurethane-insulated string. Another method being considered is the use of gelled diesel between the tubing string and the 13-3/8" casing string. These insulating techniques would limit thaw ratios to an estimated 10 feet during the production life of the well.

It is estimated to take 15 days to complete a well once it has been drilled. Much less material is needed than for drilling: possibly 2,000' of insulated casing, 1200 barrels water, 3,000 barrels of diesel fuel, 10,000' of 4½" or 5" tubing, and up to 2000 gallons of cleanout acid.

Initial well testing and clean-up would consist of spent acid, formation water, and liquid and gaseous hydrocarbons. Test-separator equipment would separate and measure any liquids produced. It is estimated that about 300 MMCF of gas and 3,000 barrels of condensate would be produced during testing.

A contingency plan for completions and subsequent workover would be much the same as for drilling.

2.34 Accommodations and Support Facilities

This section will describe the facilities; more detailed description and specification will emerge from the design phase. Foundations, water supply, waste disposal and restoration are covered under sections 2.31 and 2.34.

The design phase will give prime consideration to all building codes and standards that apply to constructing and operating a gas plant in the Parsons Lake area. Some other considerations are listed below.

1. Size of work force
2. Labour demands
3. Optimization of services
   -- kitchen
   -- medical
   -- communications
   -- living quarters
   -- shops
   -- warehousing
4. Optimization of utilities
   -- fresh water supply
   -- heat
   -- power
   -- sewage disposal

5. Human elements
-- comfort
-- privacy
-- variety in entertainment and recreation
-- provision for co-habitation

The accommodations and support facilities are described below in three main categories.

2.35 Construction Camp

Gravel conditioning and site preparation would be one of the first scheduled activities. The accommodation for it would be a 20-30 man standard skid-type camp located at the gravel source, and would be dismantled when the main construction camp was completed at the plant site. Portions of it could be used as emergency shelters at more remote gravel sources or cluster sites.

The main construction camp would be one large complex, which makes for optimization and uniformity of services and utilities.

The services would include a well-equipped medical facility, staffed with qualified personnel, that would function on a 24-hour basis. The food service would be designed to mitigate the environmental hardships by providing the utmost in dining comfort and enjoyment.

The living quarters, in addition to the basic semiprivate rooms, would include space allocated for recreation and entertainment. Special consideration would be given to the problems inherent in accommodating a work force of both sexes.

The utilities would be designed as modules, so that they could be moved later to other sites. Power, heat, water- and sewage-treatment systems would be designed for use in both construction and operation phases. The power system would have an independent back-up that could supply power to all life-support facilities.

2.36 Warehousing and Shops

Both the warehousing facility and the maintenance shops building could be used for recreation in the operations stage. The shops building would house a full complement of maintenance tools and machinery, and would provide the space and organization needed for safe and efficient maintenance work.

2.37 Permanent Accommodation

To avoid noise and increase safety and working efficiency, the building would be removed from the plant and its design would integrate the following facilities:

1. Offices and Conference Room

Offices for supervision and administration staff, conference room, and storage space for engineering plans and supplies.

2. Operations Control Centre

The control centre would function as the core of the community. The central computer would be housed here and would perform a variety of tasks, including monitor and alarms for the life-support system (utilities, fire, intrusion, communications, etc.). The communications control centre would consist of ground-to-air communication, radio and television reception, outside telephone trunks for communication and data transmission, a camp intercom system, and standby for local radio communication.

3. Medical Facilities

The medical facilities, as in the construction phase, would be well equipped and have a qualified person on staff. The medical staff would work a standard shift and be on 24-hour call.

4. Living Quarters

The size of the permanent living quarters would provide for single occupancy or accommodation for couples. The rooms would range in size from 180 to 220 sq. ft. and their furnishings would include a bed, easy chair, desk, dresser, and night table. The washroom facility would consist of a shower, a toilet and a sink and mirror. Colour schemes in rooms and halls would provide variety and contrast in decor.

5. Kitchen and Dining Facilities

The kitchen would be designed for clean operation and would comply with all government regulations. The dining area would be separated from the cooking area and provide a comfortable atmosphere.

6. Recreation Facilities

Assorted recreation facilities planned for this complex could include radio, television, games rooms, library, gymnasium, theatre, and background music through the intercom system.

In short, the design parameters for accommodation and support facilities would comply with all government codes and regulations, and would aim at providing the safety and comform necessary for a satisfied and productive work force.

2.4 LOGISTICS

The major difference between building a gas plant in southern Canada and in the Mackenzie Delta is one of logistics. All the major components and equipment must come during the summer shipping season by river or ocean barges. This shipping season is restricted to from mid-June until mid-September, depending on whether it is by ocean or river barging. Some equipment may be flown in, but there are limitations on weight and size. To make the best use of the transportation systems available calls for careful preplanning, so that equipment can be delivered at its required destination before the end of the shipping season.

In a major project such as this, all modes of transportation would be utilized; that is, trucking and railroading in southern Canada to barges, fixed-wing aircraft, helicopters, tracked vehicles, low-pressure tired vehicles, and conventional trucks in the Delta.

Winter access to the local communities (Inuvik and Tuktoyaktuk) would be restricted from mid-January until the end of April. This is generally the period when the ice road on the Mackenzie River between Inuvik and Tuktoyaktuk is opened and maintained by the producers. Movement around the project site would continue the year round where permanent roads had been built, and from around the first week in November until the end of April on temporary roads.

2.41 Routes

The supplies, material, modules and equipment would have to be transported from the provinces to the plant location in the Mackenzie Delta. These items would be shipped by rail or truck to Hay River or some staging site along the Mackenzie River, then barged to a site in the Mackenzie Delta. Depending on the priority and the size of the item, it could be shipped to Gulf Canada's Swimming Point Base Camp, Lucas Point, an intermediate staging area on the east side of the Mackenzie River, or directly to the job-site staging area in Hans Bay.

If large modules should be used for our gas plant, some ocean barging might be required. These barges would leave from some point on the west coast, travel around Alaska through the Arctic Ocean and Beaufort Sea to the Mackenzie Delta, and then into the Eskimo Lakes.

The amount of ocean barging would depend on the degree of modularization, that is, the number and the sizes of modules to be used. These would depend on the results of studies to evaluate labour availability, plant-site capacity, on-site handling requirements, transportation restrictions, availability and scheduling of materials, and general logistics requirements.

Modules to be transported by ocean barging would be welded to the barge to ensure safe shipment on truss pedestals. These barges might need some lightering if they were navigated through the Eskimo Lakes.

A study undertaken on behalf of Gulf Oil Canada indicates that barges can navigate safely through the Eskimo Lakes to Hans Bay with no need for dredging provided barge and tug draft does not exceed 7.5 feet. As this is the maximum draft of the 1500 serires river barge, there should be no problems with the material received at Hay River. With the number of modules we anticipate for this project, steps would be taken to provide lightering facilities so that these modules could travel through the Eskimo Lakes without need for dredging. Environment studies planned for the Eskimo Lakes include further work to confirm the above findings.

Dock

Since water transportation is expected to be an integral part of this project, the loading and unloading facilities would be important to the success of the barging program.

In the southern area, existing docking facilities would be used wherever possible. Further facilities at Hay River or along the Mackenzie River would be developed and brought into service as required.

In the Mackenzie Delta, existing docking sites at Swimming Point and Lucas Point would continue to be utilized as the delivery schedules of certain items and the short shipping season (mid-July until mid-September) in the Eskimo Lakes might require.

A permanent docking facility for unloading supplies and the heavy modules would be established at Hans Bay in the Eskimo Lakes. The proposed location is shown on our site plan. The exact location and type of dock would depend on the type of modules built and the soil conditions at the site. A further geotechnical survey will be undertaken in the spring of 1976 to gain additional engineering data for the design of the docking facility.

It is anticipated that this dock would incorporate sheet-steel piling design, which should provide an excellent docking facility for the construction period and for resupply after the plant had been completed. The dock would probably be started in the summer or fall of 1977 and, during the next two years, brought up to a standard that would permit the unloading of modules. Some minor dredging might be needed around the docksite to allow barges to dock and unload.

In conjunction with our environmental program for the Eskimo Lakes, water-level meters will be established to determine the water fluctuations within Hans Bay. With the sheltered nature of Hans Bay, and from our past observations in the Eskimo Lakes, no problems are anticipated with ice on the dock. Base data on water quality around Hans Bay and in the Eskimo Lakes, obtained during the fall, would be expanded for the other seasons to provide a complete base line before any work was undertaken in the area.

Offloading Areas

The dock at Hans Bay would require a staging site to store drilling materials and to accommodate the modules until they could be transported to their designated sites. This area would be self-supporting and some temporary personnel shelter would be installed. Gravel would be placed to a depth that would prevent degradation of the permafrost and provide a solid working base.

In the program's initial stages fuel would be stored at Swimming Point and Lucas Point during the summer. Enough fuel would be stored at the various operation sites to ensure year-round performance. During the winter, when travel is permitted over the tundra, fuel would be transported from Swimming Point and Lucas Point.

The amount and type of hydrocarbon storage needed at the plant or the docking area would depend on whether Gulf elected to install a topping plant as part of the process facilities. All fluids stored during the life of the project would be surrounded by impervious dikes, at locations chosen to minimize the risk of polluting any water body.

Every facility built would conform to all the applicable governmental regulations.

2.42 Roads

For the Parsons Lake Gas Plant, a network of permanent roads would be required in the Parsons Lake area to connect the plant site with the clusters, the airstrip, the docksite and the gravel sources. These roads would be very important in ensuring year-round access to all the related gas-plant operations.

To minimize the disruption of drainage patterns, selection of the routes for the roads would be based on the results of our geotechnical surveys and an evaluation of the land forms in the general area. Special care would have to be taken to ensure that design gradients in the hilly Parsons Lake region would permit the safe and efficient operation of all classes of vehicles. The preliminary routes shown in the detailed site plan could change according to the final choice of sites and the conditions between the sites chosen.

Where routes did have to interrupt normal drainage patterns, culverts would be placed to minimize the effect. Where they encountered streams, special measures would be taken to ensure that fish migration would not be affected.

Road construction would start in the spring of 1977 and be completed that summer. These permanent roads would not link up with any existing land routes providing access to local communites. The Gulf network could be reached by boat or barge through the Eskimo Lakes, or by using the private Gulf airstrip.

A temporary winter road from Lucas Point to the permanent network would be needed during the early construction period until fuel storage and storage areas have been determined and completed. This road would allow for the stockpiling of supplies required from Swimming Point and Lucas Point, and provide a link with communities offering necessary services. It would be built with snow and water, in conformance with the standard now approved by the Land Use Authorities. Gulf has had considerable experience in building these roads in the Mackenzie Delta as a result of its drilling operations.

2.43 Air Transport

Aircraft provide one of the most important means of transport both during and after the construction period. Both large and small fixed-wing craft would be used, as well as helicopter support. They would be used to move personnel, to replenish supplies and, in some cases, to deliver articles received too late for barging.

During the project's initial phases, as use of the temporary jet strip (Rat Strip) at Swimming Point decreased, a full jet strip would be made on the ice in Hans Bay or Parsons Lake. Personnel would then be transported to the jobsite by STOL aircraft or over the winter road. STOL strips could be made in winter on any of the small lakes close to the jobsite. With this method of operation, the supply of materials and personnel that must come from the south would be maintained much more efficiently. In the summer the strip at Inuvik would be used, where personnel and supplies would be transported to the jobsite by helicopter or float plane.

Gulf is now investigating the type and location of airstrip required for its operations. To ensure accessibility to the plant, the strip would be a permanent one. Its exact location would depend on whether it was to be a jet or a STOL strip. A study is also being undertaken in conjunction with a pipeline company (CAGPL) to determine if a jet strip could be built where it would serve both parties.

In determining the location and type of the airstrip, the following factors would be considered:

- Obstructions at ends or sides of strip
- Weather conditions i) incidence of fog
  ii) direction of prevailing winds
- Ground conditions i) drainage patterns
  ii) landforms
- Airstrip gradient - volume of material required
- Distance from operating centre

The airstrip would be completed as a private facility with full navigational aids. It would be equipped with all proper lighting facilities to ensure 24-hour operation. The installation would include refueling facilities as well as some support buildings for personnel and equipment.

Landing pads for helicopters would be provided at both the airstrip and the plant site.

2.44 Personnel Movement

The movement of construction personnel in and out of the site during peak construction will be frequent. In as much as the construction of the airstrip will be undertaken early in the development stage, it will be utilized to full capacity. Personnel, particularly during winter construction, will be transported directly to and from the development site and Inuvik will be utilized at a minimum. Except for occasional weather delays, construction personnel will have little or no contact with adjacent communities.

Work schedules have not been developed at this point of time for operating personnel, however, it is expected that regardless of their domicile, they will be transported directly to the plant site.

2.5 ENVIRONMENTAL PROTECTION MEASURES

2.51 Waste and Toxic Materials

Construction and operation of the Parsons Lake plant would introduce some quantity of gaseous, aqueous and solid wastes to the environment. This section identifies and describes the pollutants expected and control methods employed during all phases of the project. For most of them, quantified estimates will not be available until completion of pre-construction engineering.

Atmospheric Emissions

During the project's construction phase, most emissions to the atmosphere would come from the tank farm, camp heaters and generators, construction equipment and, intermittently, the incinerator. They would consist of particulates, carbon monoxide, hydrocarbons, nitrogen oxides and water vapour; the exact quantities of each will not be known until pre-construction engineering is completed.

There would be some localized exhaust emissions from barges, boats, aircraft and helicopters, but concentrations would be low and would cause little noticeable change in the physical and chemical parameters of the air and ground facilities. Any effects should be of short duration.

Exhaust gas from turbines and fired heaters, and flare pilot gases would be emitted continuously by the process plant. Emissions from emergency flare relief, incinerator combustion of solid waste, vehicle and aircraft movement, and other minor point sources would be only intermittent.

Ice fogs could be expected to form in winter, because of the significant amount of water vapour emitted as a result of fuel consumption. They should be confined to plant site, however, and only certain transportation activities might be sporadically affected.

Aqueous Wastes

The small amounts of aqueous wastes would be treated and injected through a disposal well to a suitable underground formation.

During construction and operating stages, liquid wastes from washrooms, laundries and kitchen facilities would be treated to provide water acceptable for discharge to nearby receiving waters. An appropriate sewage-treatment system would be designed in pre-engineering and the quality of discharged effluents would be monitored regularly.

Solid Wastes

An incineration system would be used to burn refuse from the camp and waste sludge produced by the sewage-treatment plant. The resulting ashes would then be buried in a designated landfill site, along with waste materials that cannot be incinerated.

Other Emissions

Dust

The main source of dust would be the movement of gravel or other granular materials for the pads, dykes, roads, etc. Emissions would be greatest in the construction phase with the frequent movement of heavy equipment. As they would be restricted to the short summer season, however, environmental hazards should be minimal, with no long-term effects.

Odours

As the raw well effluent is sweet, odours will be negligible.

Noise

Sound-suppression devices would be installed on all equipment that did not meet noise-emission standards. Noise at the plant boundaries would not exceed the standard of 65 dBA.

Toxic Materials

The Parsons Lake gas plant operation would involve very little toxic material as the Parsons raw gas contains no sulphur. Possible sources of toxic materials include:

1. Inhibitors injected into the raw gas stream at the clusters and carried through the gathering system into the plant.
2. Amines used in the carbon-dioxide removal system (if one is installed) and glycols used in the glycol absorption system.

As process systems would be enclosed, toxic materials would not come in contact with the environment, however discreet selection of these treating agents will be base on persistent toxic limits.

Other possible sources of toxic materials include the water- and sewage-treatment plants. The chlorine residue and heavy-metal concentration from the water-treatment plant are not expected to present any problem. A quantified estimate of these effluents and their toxicity would be available on completion of pre-construction engineering.

2.52 Contingency Plans

Contingency plans for the project would be based on two parameters.

1. The source strength of the contaminant.
2. The sensitivity of the environment in the area.

In all cases, the concern would be with small volumes of refined products such as diesel oil, gasoline, process chemicals and drilling fluids. As detailed plans are required in any drilling application, they have been prepared for all wellsites and hence for all potential cluster sites.

Cluster drilling would mean a well-established, fixed base, operated by trained crews experienced in emergency procedures and the use of emergency equipment.

The gathering systems would be subject to close scrutiny by both Gulf Canada Limited personnel, and public officials who would appreciate the sensitivity of the terrain. When considering receptor sensitivity, it is important to remember that the plantsite and all clusters would be built on gravel pads so that any spill would be confined to the general area. By diking tankage areas and elevating tanks, any escaping fluids would be trapped in the dyked area, where they would be detected and subsequently recovered. An integrated production facility would permit close surveillance of all facilities so that early leak detection would be assured. The addition of sensors within pipe insulation would provide early warning and detection of leaks. This technique would be particularly applicable in the case of the water-disposal line, in that it would significantly reduce the maximum potential undetected loss.

During the design phase of the project, detailed specific site contingency plans would be developed for the area. The plans would detail responsibilities and actions in the event of an emergency, and would outline a communications network and reporting system to be used.

The "Arctic Oil Contingency Plan for Gulf Oil Canada - Ecological Evaluation" provides a basis for developing detailed contingency plans for supply camps, well sites, gas field production, and plant construction and processing, for both winter and summer conditions, over the complete range of biological regimes encountered in the Parsons Lake area.

In any emergency, such as a chemical spill, equipment can now be procured from the Delta Environmental Protection Unit, which has storage facilities at Tuktoyaktuk and Tununuk Point. Equipment includes booms, watercraft, skimmers, pumps, sorbents, oil-proof clothing, protable power plants, hand tools and emergency rations. During construction of the project, a facility in the Hans Bay area would be similarly equipped, and personnel instructed in its proper use. This would ensure that any spill in the Hans Bay area would receive immediate mitigation.

2.53 Restoration

During the Parsons Lake project, some disruption of the terrain, aquatic life and fauna of the area would be inevitable. Gulf Canada Limited will develop sound environmental guidelines and use revegetation and restoration techniques that will ensure the degree of disruption during and after the construction phase would be kept to a minimum. The aim throughout would be to have the gas plant and support facilities exist in harmony with the ecosystem in the area, and to avoid any impacts that could alter the delicate balance of nature.

One way of maintaining the natural balance in the area is by developing and implementating a revegetation program for all disturbed areas.

Preliminary construction would involve the mining of approximately 1.5 million cubic yards of gravel in an area southwest of the plant site. The landform in the area consists of deltaic and fluvial terraces formed along a small river which enters the Eskimo Lakes between Hans Bay and Bonnieville Point. The vegetation varies from mainly alder bushes and medium willows with some black spruce trees near the river, to a shrub-heath vegetation dominated by small shrubs on the terraces.

As gravel removal would destroy the vegetation along the terraces, as soon as it was completed a revegetation programme for the area would begin. Results of an aerial seeding programme conducted on similar terrain in 1973 and 1974 (Northern Engineering Service Company Ltd.) using a 2:2:2:1:1 mix of Nugget Kentucky Bluegrass, Boreal Creeping Red Fescue, Climax Timothy, Frontier Reed Canary Grass and Spring Rye at 50 pounds per acre, proved successful in revegetating rig sites and winter roads. At the end of one season, mean cover was 11 per cent. Pilots of Arctared Creeping Red Fescue and Nugget Kentucky Blugrass proved the most successful, with and 56 per cent cover respectively. The programme established that a mix of Arctared Red Fescue and Nugget Kentucky Bluegrass would be most suitable for revegetation in the area. This study will continue until an optimum mix has been established and confirmed by field results.

During initial design studies for the project, further programmes would be carried out to assess the covering and insulating capabilities of other plant species for ensuring immediate and long-term erosion control.

At the end of operations in the project area, the following terrain restoration and abandonment procedures would be carried out: All production wells would be plugged to surface, tubular goods be cut off and the well be capped. Gravel from the roads and pads may be salvaged. All pipelines and transmission lines would be removed. Pipeline supports and power poles would be cut off at ground level and the right-of-way revegetated if necessary. As the gas plant, cluster equipment and support facilities would be in modular form, they would be dismantled and removed from the site for salvage.

3.0 ENVIRONMENTAL CONCERNS

This section discusses the ecosystem of the Parsons Lake area and the interactions which exist there. Potential impacts of development in the area are discussed in relation to the environmental quality.

Background data for this section come largely from studies carried out by F. F. Slaney and Company Limited in the period 1972-75. These data are referenced to the Slaney reports listed below:

- Volume 1 - Meteorology and Climate
- Volume 2 - Hydrology
- Volume 3 - Landform and Vegetation
- Volume 4 - Birds
- Volume 5 - Mammals
- Volume 6 - Aquatic Resources
- Volume 7 - Environmental Quality
- Winter Study Supplement
- Impact Assessment

3.1 CLIMATE

Most of the northern Mackenzie Delta lies within the Marine Tundra Climatic Zone, characterized by long cold winters and short cool summers. Since historical climatological records have been restricted largely to locations of human habitation, none were available for the Parsons Lake area. The closest Environment Canada weather stations are at Inuvik Airport, Tuktoyaktuk, Aklavik and Shingle Point.

The most comprehensive description of the climate of the Mackenzie Valley was presented by Burns in 1973. His study gave a broad overview of climatic factors pertinent to the Mackenzie Valley - Beaufort Sea and has been used extensively in this report.

In 1973, battery-operated chart systems to record wind direction, wind speed and air temperature at a height of eight feet were installed at Parsons Lake and Swimming Point.

Averaged monthly temperature and precipitation summaries for each station are shown in Appendix A. The annual temperature variation is high for all stations. Maximum mean monthly temperatures of 13°C are reached in July and minimum, near -29°C, in January.

The precipitation regime is variable across the Delta with all stations showing less than 30 cm. per year. Historical records show that average yearly precipitation is highest at Inuvik (28.3 cm.) and lowest at Tuktoyaktuk (13.5 cm.).

The Parsons Lake area, with an elevation close to that of Inuvik, would probably show a similar precipitation regime.

Fogs are common occurrences across the Mackenzie Delta. They take the form of radiation fog, advection fog or ice fog, with radiation being the most prevalent type in the Parsons Lake area.

Parsons Lake showed a higher monthly mean wind speed than Swimming Point, with the prevailing wind from the northwest.

In early 1976, Gulf Canada Limited will install at Parsons Lake a weather station capable of recording wind speed, wind direction and temperature at three heights (3m, 10m, 30m). Precipitation and snowfall will be recorded at ground level.

The wind speed and wind direction will be sampled by three Dominion Instruments 540^{O} Windflo indicators. Temperature will be sampled by means of aspirated temperature bulbs, and precipitation and snowfall will be recorded by a Fisher-Porter rain and snow gauge. The strip-chart data will be reduced to a readable format, and it is hoped that by these means better data will be obtained for the study area.

3.11 Temperature

Temperature controls the growth and development of plants, depth of permafrost, rate of organic decay, and duration and amount of snow and ice cover.

Mean monthly temperature in the Mackenzie Delta varies greatly during the year. Values range from -29°C in January to 13°C in July. Table 3-1 (Appendix) shows the averaged monthly temperature regime for selected stations.

Since Swimming Point is located inland away from the modifying influence of the Beaufort Sea, it experienced less cold air advection, less fog and higher air temperatures than coastal stations. Summer temperatures at Swimming Point were generally higher than at Parsons Lake, because the lower elevation resulted in compression effects and offered more shelter from wind. Mean temperatures at coastal stations are warmer in winter and colder in summer because of the modifying effects of sea water.

In 1973, Parsons Lake and Swimming Point reached their maximum temperatures on July 26 with readings of 27.8°C and 26.7°C respectively. The minimum temperature of 1974 was -40°C for both, in January.

3.12 Inversions

Perhaps the most conspicuous element in arctic meteorology is the inversions. Their increased temperature with height is caused by negative radiation balance from the snow/ice-covered surface, intensified by subsidence creating warmer air aloft, and by the shallow solar angle. Only in the few months of summer is there enough solar energy to override inversions: the higher ground surface temperatures produce convective plumes and local instabilities that break up lower inversion layers. Early summer mornings can still show signs of ground-based inversions. Inuvik Airport reports that 61 per cent of its surface-based inversions occur at 0400 M.S.T. daily from June to August.

Associated with inversions are numerous types of visibility obstructions such as fogs, ice fogs and stratus clouds. Inversions can also act as lids or barriers to prevent vertical distribution of pollutants.

3.13 Winds

Wind distribution across the Mackenzie Delta, though affected to some extent by local topography, tends to have a predominant northerly component in summer-fall and an easterly component in winter-spring.

Westerly winds over the Richardson Mountains cause subsidence, turbulence, lee waves and chinooks across the western Delta, especially near Aklavik (Burns, 1973). In winter chinooks bring warmth and relief from the bitter cold.

Easterly winds in the area of Reindeer Hills cause low-level turbulence and down-draft along the western slope, which can pose problems to small aircraft.

Parsons Lake showed both higher monthly mean wind speed and higher monthly peaks than Swimming Point (Table 3-2, Appendix) from July, 1973 to May, 1974, due primarily to its higher elevation and greater exposure to upper winds.

Figure 3-1, (Appendix) shows the monthly wind roses for Parsons Lake and Swimming Point for the period July 1973 - May 1974. As can be seen, the roses are similar, with the prevailing winds northwesterly in summer and easterly in winter.

The vertical gradient of mean wind speed, or wind shear, is important in describing the amount of vertical mixing and longitudinal spread of aerial debris. The amount of gradient is determined by the roughness of the surface and the atmospheric stability. Under neutral conditions the vertical velocity profile is usually logarithmic.

Wind measurements from the 30m tower at Parsons Lake will enable Gulf Canada to analyze wind shear in the area by mid-1976.

3.14 Precipitation

Precipitation across the Mackenzie Delta is light and rainfall is generally confined to the period from June to September, with July and August the wettest months. Most rain is associated with frontal or cyclonic activity and falls as showers. Periodic downpours of an inch or more have been reported at some arctic stations (Environment Canada, 1945-1974).

Snow does not cover the Mackenzie Delta until late September, and the heaviest falls come in October. Although the snowfall may be nearly uniform across sections of the Delta, it soon becomes redistributed and compacted by wind. Freshly fallen snow has a characteristically low density because of its numerous crystalline shapes.

In some areas, the vegetation canopy can limit the amount of snow reaching the ground. Snow will therefore be deeper where vegetation is deciduous and the reduced wind speed allows light, fluffy flakes to sift through. In open areas, the stronger winds rapidly break the freshly fallen snow into smaller particles, causing increased density and compaction.

Although the annual precipitation is light over all, it varies significantly across the Mackenzie Delta, as can be seen by comparing the records of various points (Table 3-3, Appendix).

Annual totals vary from 5 to 12 inches, but summer thawing of the upper soil layer causes vast tracts of wetlands across the Delta.

Environment Canada records show that Inuvik receives an average precipitation of 29.2 cm. a year, compared with Tuktoyaktuk's 13.5 cm. The difference is due primarily to the difference in their elevations (61 m ASL at Inuvik, 18 m ASL at Tuktoyaktuk).

It seems likely that precipitation in the Parsons Lake area would be much the same as at Inuvik. The 1976 data from the Parsons Lake weather station should effectively decide the matter.

3.15 Atmospheric Phenomena

Fogs are common occurrences across the Mackenzie Delta. They take the form of radiation fog. advection fog, or ice fog.

Radiation fog develops in a layer of air near the ground when the temperature and dew point are equal or nearly so. The most favourable meteorological conditions for its formation are calm clear nights, when long wave radiation from the ground is lost to the atmosphere and the surface is cooled. A ground-based inversion results, making for a very stable fog layer. Where air drainage is possible, the fog may flow downslope like a misty river (Mackay, 1963).

Advection fog is fog from another region that has been carried to the Delta by prevailing winds. Over the Beaufort Sea, thick fog banks form in cold air overlying warmer surface waters, and are periodically carried inland by prevailing onshore winds. Prolonged winds may bring fog as far south as Aklavik, Inuvik and Eskimo Lakes.

Ice fog is best described by Benson (1965). He says,

"Ice fog is a special case for two reasons: (1) it is man made and (2) it forms a result of injecting water vapour at temperatures generally exceeding 100 degrees Centigrade into a precooled (-35^{o}C. or below) water saturated air mass. The injected water vapour cools at rates five to six orders of magnitude greater than the most rapid cooling rates observed in the free atmosphere; this results in small crystals which fall very slowly. The abundant nuclei also resulting from combustion processes insure that the supercooled droplets freeze at temperatures above the spontaneous freezing point for small droplets ie., -40 $\pm$ 1.5^{o}C. Ice fog is a form of air pollution which appears at temperatures below -25^{o}C. in populated regions where topography, combined with strong inversions, causes air to stagnate."

Fogs of the above types may prevail in the general study region for several days, but would usually dissipate each day around noon with increased solar input.

The incidence of fogs is highest in May-June and September-October, the periods of general break-up and freeze-up across the Delta, when there is much interaction between cold arctic air and either surface water or moistened surfaces.

Ice fog is occasionally observed at Inuvik in winter, especially during cold spells (air temperatures less than -30^{o}F). The source is usually combustion products from automobiles or the town power plant.

Elevated inland areas, such as the region around Parsons Lake, would experience less advection fog but perhaps more radiation fog.

In the Mackenzie Delta the angle of incidence of the sun's rays is small compared with that in lower latitudes. Hence, at any one time the ground receives smaller amounts of incoming solar radiation per unit surface area. In summer this dearth is compensated by longer hours of available solar energy. At latitudes of 69^{O}N, the sun is completely above the horizon from May 24 to July 19 (Burns, 1973), resulting in a solar energy input equal to that of temperate latitudes.

In winter, however, the sun is completely below the horizon from December 2 to January 10 (Burns, 1973). The ground receives no solar radiation directly and only small amounts from arctic twilight. The result is a depletion from back radiation at the surface, and hence colder air temperatures.

Cloud cover is the most important solar reflector and prevents a large percentage of the short-wave radiation from reaching the earth's surface (Burns, 1973). Much the same is true for fog. As a result, the amounts of annual incoming radiation in coastal areas is more susceptible to cloud, and areas further inland, often show measurable differences.

The albedo of the ground surface (ie., the fraction of incoming solar radiation it reflects back into the atmosphere) is also important. Snow and ice have a high albedo and reflect a large percentage of incoming radiation, whereas water has a low albedo (depending on solar angle).

These differences are very important in late spring, when snow and ice begin to melt, exposing water surfaces and bare ground.

The predominant air mass encountered in the Mackenzie Delta is continental arctic (ca). However, it is subject to several modifications. In order of decreasing occurrence but increasing temperature and moisture content, they are:

1. cold maritime arctic (cma)
2. maritime arctic (ma)
3. maritime polar (mp)

In winter ca dominates the Mackenzie Valley Region. Occasionally cma and rarely ma air enter, associated with the infrequent penetration of frontal lows. A cold dome of air usually forms a block to the migrating frontal lows, but there are exceptions. The Aleution low may send secondary centres into the Beaufort Sea and Delta area, causing blizzards in January, March and occasionally other winter months (Burns, 1973).

In spring, with additional solar energy input and resultant melting of ice and snow, portions of the Mackenzie Valley become modified to cma air. Penetrations of frontal lows by ma and mp air become more frequent.

In summer the polar ice pack becomes broken and covered with pools of melt water, causing the air mass to become more maritime (cma) than continental in character. Coastal regions, where open water between pack and shore can prevail, show low cloudiness and a stable lapse rate. Upper-level short-wave troughs from around a major vortex in the Russian sector develop frontal lows in Siberia and the Bering Sea. These lows move east or southeast across the area under investigation and, together with cyclones of Pacific origin, are the primary sources of summer precipitation in the Yukon, Beaufort Sea and Mackenzie Valley.

In fall, dropping air temperatures and freeze-up start a reversal of the spring transition. Gradually cma air replaces ma air. During freeze-up the air temperature becomes much colder than the water in lakes, rivers and the ocean. The "steaming" that results can add large amounts of moisture to the air, to produce extensive fog, clouds and snow flurries.

3.16 Air Quality

Concentrations of seven air-quality parameters (suspended particulate matter, dustfall, sulphur dioxide, hydrogen sulphide, ozone, nitrogen dioxide and hydrocarbons) were collected at seven sites during 1972 and 1973.

Suspended particulates were measured at a concentration of six micrograms per cubic metre.

Dustfall yields from the study region were in the magnitude of 0.046 to 4.34 tons per square mile per month. Inuvik values were somewhat higher and ranged to 29 tons.

The SO_2 concentrations estimated from sulphation plates were less than 0.0026 ppm and had mean values of .00032 ppm in 1972 and .00026 ppm in 1973.

Hydrogen sulphide concentrations up to 0.036 ppm were recorded on the basis of an instantaneous sample.

Ozone concentrations at three stations in the Delta did not exceed .017 ppm over six hours.

Measurable concentrations of nitrogen dioxide were found in only 25 per cent of the samples taken in the Delta, and values ranged from 0.006 to 0.0002 ppm.

Concentrations of hydrocarbons in the study region ranged from 0.3 ppm to 2.4 ppm, with a high of 4.1 ppm in Inuvik.

3.17 Potential Impacts

The direct effects of all-weather road construction and use in the Parsons Lake area would be localized and of short duration.

An estimated total of 30 miles of roads would be built near Parsons Lake gas plant.

Dust loading and hydrocarbon-exhaust emission from construction machinery, routine traffic and support facilities would affect local air quality to some extent. Most machinery would be mobile, however, and would not operate long in any one place, so that effects should be noncumulative and widely dispersed.

Each operating engine would act as a mobile point source of heat, carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, sulphur trioxide, water vapour and unburned hydrocarbons. Any long-term increases of SO_2 levels adjacent to the roads should be so small as to be negligible.

During calm, cold sessions when temperatures are less that $-35^{o}C$, some localized ice fog would prevail along roads, especially near the largest sources of heated water-vapour emissions. It should be no more obvious, however, than what now occurs during winter gravel hauls for exploration drilling pads and islands, or what occurs near urban centres.

Dust and other suspended particulate would be introduced into the atmosphere by movement of vehicles along roads, or by scouring during high winds, but the levels would be lower than along many nonsurfaced highways and secondary roads elsewhere. Dustfall during calm conditions would be restricted to within about ¼ mile of either side of the road. Particulate and other debris uplifted by heavy winds would be redeposited several miles downstream from roads, but in small quantities because of the wide dispersion. Particulate redeposition from roads on the surrounding snow cover would lower surface albedo and thus increase the rate of spring snow melt. As a consequence, vegetation nearer roads would be exposed sooner than elsewhere. Along roadsides the over-all effect would be offset by snow piling and drifts, but beyond the piles it would be noticeable. The "dirty-appearing" road drifts of snow might be sustained right up to break-up and spring flooding or beyond.

Similar localized and short-term effects would occur around staging sites, gravel extraction areas, airstrips and pads.

Only small amounts of hydrocarbon exhausts would be vented from barges and boats. Any effects on air quality would be too brief and localized to be measurable by standard techniques.

Full use of container transport would keep wind scouring of particulate materials off barges to a minimum.

Fuel exhausts and disturbance of looser surface particulate by moving aircraft would cause small changes in the physical and chemical parameters of airstrips. Warm water vapour from exhausts would cause localized ice fog during calm conditions when air temperatures on the strip are below -35^{o}C, especially during take-off and landing procedures, when maximum thrust or reverse thrust are utilized.

A combination of uplifted snow and ice particles from the ground surface plus the ice-fog production would restrict visibility, but would constitute a problem only if there was sustained heavy traffic during the very cold periods. Restricing vehicular traffic and other water-vapour emission sources in areas near airstrips when air temperatures are less than -35^{o}C would reduce the cumulative effects. The jets and larger craft that would be utilizing Parsons strip would give it the highest potential for reduced visibility, but the higher mean winds that prevail at Parsons Lake would help to counteract this effect.

At heliports there would be some disturbance of loose surface material and reduction of visibility during take-offs and landings, as well as some additional, well-dispersed hydrocarbon exhausts. Both effects would be minimal and of very short duration. Sound levels about the heliports would also increase during take-offs and landings.

The presence of plant facilities would alter the surface roughness, the surface albedo, the heat-storage capacity of the ground, and the convective nature of the atmosphere in the immediate vicinity.

The surface roughness effect would cause more turbulence around the plant and also in areas downstream. Emission stacks would have to be designed high enough to avoid downdrafts in the module wakes so that exhaust plumes would not be carried quickly to ground levels.

These effects would have little significance except in terms of dispersal of gaseous emissions, and then only if harmful levels of emittants were produced during some extension of the current project.

Change of heat capacity and albedo of the plant site would create an urban "heat island" effect. During calm, summy conditions, temperatures on the pad might rise several degrees higher than those of adjoining areas.

The extra heat would be produced primarily by the large areas of gravel and module structures, which absorb and store heat better than vegetation or soil, and impede transpiration cooling. In summer, the combined effect of heat supplied from the pad and plant combustion exhausts could enable a strong convective plume to reach the lifting condensation level and trigger a small cumulus cloud either above or slightly downstream from the plant. However, as the normal occurrence of local cumulus cloud at these times is high, the effect would in most instances go unnoticed.

Water vapour emissions from hydrocarbon burning at Parsons would cause additional hoar frost, slight rises in relative humidity, additional fogging, some reduction of net radiation to the ground, high potential for local ice fog and increased deposition of ice crystals around the plants. The following paragraphs discuss these possibilities.

Hoar frosts occur when air with a dew point below freezing is brought to saturation by cooling. The usual form occurs when calm, damp air sublimates and forms interlocking ice crystals on exposed surfaces, especially

The frost that would build up from water vapour emissions and atmospheric conditions around Parsons Plant would be this light, fluffy hoar frost. It would be most prevalent during calm conditions in April, May, September and October. Deposition of ice crystals on the ground surface would add some additional snow and ice-crystal cover around the plants, and would require a longer thaw period to clear the area of snow if thaw were completely dependent on isolation. However, associated deposition of dust and particulate on the snow from plant activities would decrease albedo and increase snow melt because of increased absorption. The higher winds around Parsons Plant would help to reduce the accumulation if ice crystals from frost occurrences there because of wide dispersal.

The net effect of frost build-up on thaw rates in the vicinity of the plant will be slight.

Relative Humidity (R. H.) seldom drops below 85 per cent. During stable atmospheric conditions, when moisture from the gas plants would have an opportunity to accumulate, the R. H. could approach 100 per cent, with fog occurrences common. Results of additional moisture from the plant would be some local increases in the incidence and density of fogs, and hence some reduction in net radiation to the ground during stable conditions in the immediate vicinity.

During highly stable conditions in winter, when air temperatures are below -35°C ice fogs would build up near the Parsons Plant. As the plant lies on flat high ground with low lands to the east, the ice-fog cloud would probably spill out over the highland into adjoining lowland areas.

Plant noise would produce no atmospheric effect except to raise the ambient noise level in the atmosphere about each operation. Individual plant equipment would meet a noise-emission standard of 85 dBA at a distance of three feet for the working levels.

The gas plant would be designed to meet a noise level of 65 dBA at the plant lease boundary, which is assumed 500 feet outside the plant dyke. The living quarters for the plant personnel would meet a noise level of 50 dBA.

No liquid hydrocarbons would be flared at any time. If the liquid hydrocarbon disposal system would be inoperative for any reason, the plant would be shut down once surface storage had been filled. Gaseous hydrocarbons flared from time to time to prevent overpressuring a piece of equipment, or during plant start-up operations, would be scrubbed of liquid hydrocarbons. The flaring would be carried out in a tall stack to maximize dispersal of combustion products. Noise levels would be high but within the same range as testing at exploration drill sites. No hydrocarbons would be vented.

There would be some additional exhausts from rig engines and heaters at well clusters, but not enough to affect the local climate.

Compressors would be established at clusters. Their turbines, however, would burn condensate or gas with little or no sulphur content, so that the exhaust emissions should be very clean by present standards in other Canadian gas fields. The main components of the emissions would be nitrogen, oxygen, carbon dioxide, nitrogen dioxide, water vapour and heat.

Solid refuse from all operations would be incinerated along with the sewage-treatment residual and the ash and remaining noncombustible solids would be buried in an approved land-fill site. Some ash and unburnt hydrocarbons would be dispersed from each incinerator during fire-up, but only in its immediate vicinity. Gaseous and heat emissions at each cluster should be readily dispersed by local atmospheric conditions.

active layer. They may continue to grow as organic matter is produced and permafrost develops in the older peat. Permafrost is generally within six inches of the surface.

3.22 Surficial Geology

The geologic history of the Parsons and Eskimo Lakes area is dominated by two major events. The first is the formation of a structural trough originating deep below the Mackenzie valley, which allowed a very thick sequence of sedimentary rock to accumulate. The subsequent formation of the Richardson Mountains, 60 to 100 million years ago, was accompanied by folding and faulting of the bedrock in the Parsons and Eskimo Lakes region that allowed the migration and entrapment of hydrocarbons originating in the sedimentary rocks. It is these hydrocarbons that this gas-plant development project would exploit.

The second significant geologic event influencing the site was the Pleistocene glaciation and deglaciation. The last glaciation in this area ended only 12,000 years ago. Before that time the area had been part of the preglacial Mackenzie delta, and prodelta i.e., silts and clays were deposited in the study area (Mackay, 1963). Above these beds are prodelta i.e., and shallow fluvial sands and silts showing some cross-bedding. These sands grade upward into outwash sand and gravel, some of which may have been deposited in a proglacial lake which formed between ice lobes near Liverpool Bay and the Mackenzie Valley, or end moraines between Parsons Lake and the Eskimo Lakes. Glacial-lacustrine beach ridges at an altitude of 190 to 210 feet are recorded around the Eskimo Lakes (Mackay, 1963).

The plant-site location lies on the border of two physiographic subdivisions of the Pleistocene Coastland Region, the Morainic Hills and Pitted Outwash Plains, as defined by Mackay (1963). The Caribou Hills Physiographic Region lies to the immediate south and west of the study area.

Morainic Hills

The Morainic Hills are characterized by higher and rougher topography than the areas of Pleistocene sediments but are lower than the Caribou Hills. Pre-Pleistocene Mackenzie delta sediments are believed to underlie the area. The highest hills are over 250 feet in elevation but most are between 100 and 200 feet. The hills are frequently capped with kame-like sand and gravel deposits that have been exploited for some local borrow.

The morainic topography is believed to reflect terminal ice conditions along an irregular belt 5 to

10 miles wide through Parsons Lake and north of the Eskimo Lakes. The amount of glacial drift is believed to be small.

Pitted Outwash Plains

The pitted outwash plains were formed when outwash was deposited into a large proglacial lake that formed in the Eskimo Lakes - Sitidgi Lake lowland. The outwash deposits are reddish-brown sands and gravels, not much over 5 to 10 feet thick. "The area is composed of many flat-topped mesa-like areas interspersed among numerous large and small irregularly shaped highly indented lakes" (Mackay, 1963). Generally the elevation in the study area is below 150 feet. Dead ice and morainic terrain are interspersed with patches of outwash, kettle holes and glacial-fluvial deposits. The strand lines from many lake elevations can be seen in the form of wavecut terraces and shallow beaches.

3.23 Potential Impacts

The preservation of stable slopes, control of erosion and avoidance of thermokarst are all concerns of both the environmentalist and the engineer. The proposed development plan reflects this joint concern and has been contrived to prevent the initiation of soil movement. Some provisions have been made to circumvent potentially troublesome landscapes, and a later phase of design should carry this further. Provision has also been made to survey development sites to detect and prevent disturbance of unstable terrain. As far as can be determined at present, although minor problems might occur, the development would not initiate serious erosion, slope instability or thermokarst.

Proposed all-weather roads in the Parsons Lake area would travers areas that have a high potential for slumping. Due precautions would have to be taken to prevent terrain degradation.

Sections of the proposed road system passing through lowlands, i.e., meadows and high-centred polygons, would intercept broad diffuse drainage patterns. Engineering and construction methods as proposed should minimize drainage disruption. However, any impounding of surface water by the road might lead to a shift in species composition of the vegetation.

Impondment of surface water would change the thermal regime of the soil surface. If there was massive ground ice under the airstrip, thermokarst could become a problem along its edges. This impact could be avoided by providing adequate drainage.

Slope modification or extensive removal of vegetation within the field gathering-system right-of-way of the Parsons Lake area could result in slope erosion. If massive ground ice should be encountered, thermokarst and slump could certainly ensue.

Winter operation of heavy vehicles on tundra has been associated with exploratory drilling in the Parsons Lake area. Some sites of intensive use can be seen easily from aircraft but many cannot. Ground inspection reveals substantial regeneration (20 to 30 per cent ground cover) and no evidence of surface subsidence.

After perennial use by large machinery, gravel structures would become highly compacted. If the gravel were not removed from the site, the surface would very likely remain bare for many years.

If the gravel were removed in summer, the heavy equipment used would operate over adjacent terrain, compacting the soil and destroying the vegetation. Permafrost that would have developed well into the gravel would be exposed. Furthermore, the weight of the gravel over the ground would have compressed the soil so that the surface would probably remain bare for many years.

Grading abandoned development sites could result in the destruction of adjacent vegetation, with the possible consequence of initiating thermal erosion. Restoration of development sites should be accomplished with minimum use of heavy equipment and no large-scale movement of earth materials. Landfills and sumps should be filled with material from borrow areas if feasible, rather than by grading adjacent earth.

3.3 HYDROLOGY

3.31 Physical Features

Delta lakes are usually shallow, few of them being deeper than ten feet at low water. Depths at high water are much greater, and can be estimated by noting the high-water marks on lakeshore willows.

Mackay (1963) classified the delta lakes into five general groups:

1. Abandoned Channel Lakes, which are old channel basins.
2. Arcuate (Point Bar) Lakes, which form when migrating channels leave a swell-and swale ribbed pattern marking flood deposition on convex point bars.
3. Floodplain Lakes, which form 90 per cent of all delta lakes and occupy depressions rimmed by the higher land along the channels.
4. Thermokarst Lakes, or cave-in lakes, which occupy depressions resulting from subsidence caused by thawing of ground ice.
5. Dammed Lakes, which are formed along the lateral land boundary of the delta, where streams entering may be partially dammed to impound lakes.

Those lakes that flood yearly are either connected with channels or have low closures and receive yearly additions of silty flood water from the Mackenzie and Peel Rivers. Some seaward inundation from storm surges occurs along the dital edge of the Delta. In early summer, following break-up, lakes that have been flooded are easily recognized by their muddy waters, which contrast with the clear waters of unflooded lakes whose suspended sediment has had at least one winter in which to settle out.

Upland lakes are located on sand and gravel formations and are characterized by gravel shorelines and the high topographical relief of the surrounding terrain. They are subdivided into three types: shallow lakes (isolated from channels and less than ten feet deep), deep lakes (clear water with transparency greater than 200 cm. and usually deeper than 20 feet), and channel lakes (two basins, one with upland lake and the other with floodplain lake characteristics). Floodplain lakes are located on clay-silt deposits and are subject to seasonal and storm-surge flooding. The three types are: shallow lakes (isolated from channels and less than ten feet deep), salt lakes (occasionally flooded by the Beaufort Sea), and channel lakes (usually linked by rivers to channels, and with turbid water).

The streams in the region are usually shallow (six feet deep or less) and narrow (less than 50 feet across). As a result most freeze solid in late winter. They usually contain clear flowing water, and are bounded on one end by river channels or other streams, and on the other by sources other than channels, e.g., lakes, other streams. Streams also differ from channels in that stream flow is normally one way, and is not usually affected by summer storm-surges or high tides.

Lakes, in the forested upper Delta, become ice-free a week or two after channels clear. Those linked to ice-free channels clear first.

Lakes in the lower outer fringes of the Delta are usually last to clear. Air temperatures near the coast are cooler and there is more fog and low cloud. Some do not clear until the end of June or mid-July.

In 1973 ice cover on lakes in the Delta area ranged between 0 and 60 per cent at channel break-up. Melt was greatest on lakes that were accessible to warm river water. Thawing in the upland lakes varied: some had narrow moats with water on top of ice, others had moats 30 feet wide or wider. Areas of widest moat formation corresponded with lower and flatter areas on the lake edge.

3.32 Potential Impacts

Some roads in the proposed all-weather system would have to cross slopes and could thus disturb drainage patterns and slope stability. Bridging or re-routing would be necessary to prevent any silting of lakes through slope failure.

Sections of road that would pass through lowlands and intercept broad, diffuse drainage patterns might impede the drainage temporarily.

Some additional siltation of streams and adjoining lakes by permanent roads in the Parsons Lake area would be unavoidable. Appropriate location, design and construction would keep it to a minimum.

Airstrip construction could cause impondment of surface water, which changes the thermal regime of the soil and hence could lead to slope instability. Similarly, massive ground ice under the airstrip could result in thermokarst. Adequate drainage away from the airstrip and sufficient insulation should remove these risks.

Some slope erosion would be unavoidable. Despite efforts to minimize road and stream-bank erosion, during run-off periods the sediment loads in all streams crossed would be increased. Streams designated as important to fish would have to be bridged to minimize silting effects on spawning beds. Culverts should provide more than enough clearance for peak flood conditions and areas around them should be reinforced to minimize erosion. Accumulated debris at crossings should be removed to prevent its obstructing culverts later.

Gravel excavations could cause some siltation of the watershed from snow melt or precipitation run-off. It could be minimized by diverting such run-off to settling areas.

Estimates of liquid waste from construction camps (peak amounts) are as follows: washrooms, laundries and kitchens in the camp facility would normally discharge 1,995 gal/day. Process-plant waters at 50 to 100°F would amount to about 3,600 gal/day.

Assuming equilibrium conditions at 0°C and 30°C water discharge, a total of approximately 8 m^3/day of ice could be melted if all the supplied heat overcame latent heat of ice fusion. Actually, however, some heat would be lost to the colder atmosphere and in warming surrounding ice to 0°C so that less heat would be available for ice melting, and the volumes of ice melted would be much less than 8 m^3/day. Eventually an equilibrium would be reached where heat supplied to the ice would equal heat lost to the atmosphere, and no further ice would melt. A periodic open area of water, and some fog, could occur at the point of discharge on the lake. Sewage facilities would process all wastes from living accommodation, and sewage waste from the plant.

The emission of low-biological oxygen demand (B.O.D.) effluent with reduced nutrient concentrations should not cause excessive eutrophication or reduce oxygen concentrations if ejected into larger lakes. Excess heat from the discharge would cause localized instabilities in ice cover associated with areas of ice melt.

3.4 FLORA

Arctic plants are adapted to their environment because their life histories, physiologies and growth forms enable them to take advantage of favourable conditions and avoid damage during adverse times. The major stresses on plants in these latitudes are drought and the short growing season. Mineral nutrition may also restrict plant development. This section discusses plant biology as it relates to plant responses in an arctic environment.

Reproduction in arctic plants is primarily asexual by means of rhizomes, runners, etc. (Bliss, 1971). In many arctic environments seedlings are rare because of the low seed production (Mosquin, 1966), stringent environmental controls of seed germination (Amen, 1966) and high seedling mortality (Bonde, 1968). In the study region seedlings of sedges and grasses were common, but seedlings of woody plants were rare.

The growing season (daily mean temperature at least 45°F) in most of the study region is ten to twelve weeks (Vol. 1, Meteorology and Climate). During this period, arctic vegetation produces between 40 and 130 grams of plant material per square metre (0.01 to 0.03 pounds per square foot) (Bliss, 1962). Generally plants have attained their maximum growth (height, number of leaves, flowers, etc.) within four weeks of snow melt (Johnson, 1969).

Alders, willows and birch may live as long as 50 to 100 years, although in the study region they never exceed 1½ inches in basal diameter. Ericaceous shrubs have an average life span of 10 to 20 years and grow in the order of two cm. per year (Bliss, 1966). In most evergreen shrubs the leaves are photosynthetic for two to four years, after which they become storage organs (Hadley and Bliss, 1964). Most of the heaths in the study region are evergreen.

The growing portion (meristem) of sedges and grasses is at the base of the leaf. The amount of green tissue on a leaf is the result of the meristematic activity minus the rate of die-back. Both processes occur simultaneously during most of the year (Bell, 1974). New leaves are formed at the centre of the plant and live from one to three years.

Arctic lichens live for 30 to 50 years (Hale, 1967) and grow very slowly. Reindeer lichens grow in the order of 3.5 mm. (distance between branching axils) per year (Pegau, 1968; Scotter, 1963). While lichens are tolerant of most environmental stresses, they are sensitive to atmospheric contaminants because they absorb materials from the air very readily. Atmospheric impurities therefore tend to accumulate in lichen thalli.

In the study region, plant growth is greatly influenced by soil temperature. Cold soils make a root system less efficient at taking up water and minerals, and retard the plant's ability to incorporate the minerals into protoplasm (Dadykin, 1955). Permafrost impedes drainage and reduces the volume of soil available for root systems to exploit.

Leaf temperature directs the balance between the two opposing metabolic functions, photosynthesis and respiration. Photosynthesis is the process by which plants store energy as carbohydrate (sugar and starch). Respiration utilizes this energy in growth, reproduction, tissue repair, etc. At lower temperatures, photosynthesis is more rapid than respiration and carbohydrates will accumulate. At higher temperature the stored energy can be used for plant growth. The vigour of a plant in any given year is determined to a large degree by the amount of carbohydrate stored from the previous season (Fonda and Bliss, 1966, Hadley and Bliss, 1964). In arctic plants the optimum leaf temperature for maximum net photosynthesis is between 8° and $10^{\circ}C$ (Mayo et al., 1973; Ahmadjian, 1970; Lange, 1965).

In plants that have little resistance to transpiration (e.g., sedges) leaf temperature remains near-ambient, but in some plants it may exceed air temperature by more than $10^{o}C$ (Courtin, 1968).

Light compensation point - that is, the light intensity (langleys per minute) necessary for net photosynthesis - is low for arctic plants; e.g., lichens - 0.06 (Bliss and Hadley, 1964), willows - 0.024 (Tieszen, 1971), sedges - 0.013 (Tieszen, 1971) and avens - 0.010 (Mayo et al., 1973). Daytime light levels seldom fall below these values during the summer (Vol. 1, Meteorology and Climate).

Cold injures plants by desiccation and by mechanical damage when ice crystals form in the tissues as temperatures fluctuate across the freezing point. Even a thin layer of snow can effectively moderate these stresses. Consequently the height of woody vegetation in the study region often corresponds to the depth of winter snow accumulation.

Plants are exposed to dry conditions in the study region even though most of the soils are imperfectly drained. Part of the reason is the inability of roots to take up water in cold soils. Water stress becomes most acute in spring, when leaf temperatures are high but the soil is still frozen. Snow cover alleviates this stress, and certain evergreens (e.g., Cassiope Tetragona) can grow only where snow cover persists well into summer (Lambert, 1972). On sites that are blown free of snow for much of the winter, and where water is limited in summer, plants often have a compact growth form (cushion plants) which generally increases resistance to water loss.

In most arctic soils nitrogen is the nutrient most limiting to plant growth (Babb, 1972; Haag, 1972). Although the atmosphere is 80 per cent nitrogen, only a relatively few specialized organisms can utilize (fix) atmospheric nitrogen and make it available to other plants. Nitrogen-fixation in arctic ecosystems is carried out by lichens, primarily Peltigera Aphthosa (Alexander and Schell, 1973), soil algae (Alexander and Schell, 1973) and soil bacteria (Stutz, 1973). There are several legumes in the study region that presumably fix nitrogen, although root nodules were not observed in this study. Alder has been shown to fix nitrogen (Zavitkovski and Newton, 1968) as well as species of Dryas (Lawrence et al., 1967).

Nitrogen may accumulate in soils. A measure of the nitrogen regime of soil is the ratio between organic carbon and nitrogen (C/N). In the study region the ratio is generally wide (greater than 50), indicating nitrogen-poor soils. In some soils, however, it is well below ten.

Native plants exposed to nitrogen stresses have developed diverse strategies for hoarding nitrogen. Most arctic plants are perennial, so that they retain nutrients year after year. Nitrogenous compounds are translocated from senescent leaves and stems to the plant's bud and growing tips. Tussock and cushion growth forms permit decomposition while the dead plant parts are still attached, allowing the nutrients released by decomposition to be re-used immediately by the plant. (Svoboda, 1972).

Heavy applications of nitrogen fertilizers increased the growth of several introduced grasses (Younkin, 1972) but predisposed natural vegetation to fungal injections (Savile, 1964).

3.41 Plant Succession

Before the last ice advance about 44,000 years ago, when the entire study region became covered with ice, the vegetation was similar to that of the present day (Terasmae, 1959). During the ice retreat the land was vegetated from two refugia: the Richardson Mountains and the Northern tip of Tuktoyaktuk Peninsula (Mackay, 1963). Up to about 6,000 years ago the study region was vegetated by a closed-canopy spruce forest (Ritchie and Hare, 1971). Since then the tree line has retreated until closed-canopy forest does not occur north of about 68°N latitude.

The development of vegetation on a denuded area is accompanied by the progressive development of soil. The forces directing the rate and direction of succession can be physical (allogenic) or biological (autogenic), but more commonly involve a combination of the two. On the active Delta, allogenic forces; e.g., seasonal variations in water level, siltation, ice scour, etc., exert such an influence on vegetation that autogenic factors are nil. Plant succession, primarily allogenic, occurs in the study region when a lake recedes because of changes in drainage. In this case distinct vegetation zones develop with Carex aquatilis dominant around open water, Eriophorum vaginatum on drained lake sediments, and ericaceous shrubs along the former lake shore.

Autogenic succession is more evident on stagnant ponds. Undecomposed plant materials accumulate and the organic soil encroaches on the aquatic habitat. An extreme case in the study region was a meadow, several acres in extent, which had developed on a floating peat soil. The roots of Carex aquatilis extended below the peat into four inches of water. The major allogenic processes in these sites are dependent on temperature. Ground ice may develop as vegetation and soil insulate the surface and the active layer becomes shallower.

Differential freezing and thawing, thermokarst, polygon development and pingos may result. Microtopographical variations, in turn, affect drainage and influence the distribution of vegetation.

Opportunistic plant species such as several grasses, fireweed, cloudberry and sedges invade following the destruction of vegetation (Hernandez, 1972). Native grass species (Calamogrostis spp., Arctagrostis latifolia and Poa spp.), although not present in large numbers in dwarf shrub-heath vegetation, occur commonly around animal burrows and on exposed peatland.

3.42 Revegetation

Much information has been gathered on natural revegetation of disturbed sites in the tundra. The degree to which a site has been disturbed largely determines which species invade and the rate at which revegetation occurs. When disturbance is restricted to the above-ground level, revegetation occurs fairly rapidly from roots and rhizomes. When rooting systems are destroyed and revegetation cannot occur through them, plants are able to colonize the bare ground by means of seeds.

Kerfoot (1972), studying seismic lines one to nine years old between Parsons Lake and Noell Lake that had mostly reverted to a continuous vegetative cover, found they contained much higher percentages of grass and sedge.

In general, the wet sites (meadow, sedge-herb, willow-sedge, willow-herb and low-centred polygons) regenerate relatively quickly when disturbed. Drier sited (dwarf shrub-heath, Eriophorum tussock, medium willow, alder and high-centred polygons) need more years to revegetate after the same amount of disturbance.

Hernandez (1972) recorded that after six years, plant cover along a seismic line was only 30 to 50 per cent where the lines passed through dwarf shrub-heath vegetation, as compared with 100 per cent in undisturbed areas. He observed that initial recolonization of disturbed areas is by uncommon species, and that these species invade primarily by means of vegetative reproduction rather than seed.

Hanson (1950) also observed that invasion of plants on bare areas was more rapid by vegetative means than by seeds.

Bellamy et al. (1971) recorded that drier areas had not reverted to a natural state after 20 years, although disturbed wet areas (floodplain vegetation) may recover within 5 years.

Any major disturbance that destroys plant rooting systems over a large area inhibits natural recovery by vegetative means. In the tundra, when seeds are needed to establish colonizing species, the recovery rate is slow. Well-planned seeding programs can very likely enhance the rate of recovery and, to date, seeding trials have shown some success. The use of _Calamagrostis canadensis_ and _Arctogrostis latifolia_ has had some success in reclamation programs on the Tuktoyaktuk Peninsula (Younkin, 1972). Bliss and Wein (1972) seeded 16 species of grass in mineral and peaty soils at Inuvik, Tununuk Point and Tuktoyaktuk. Seeds established themselves more rapidly on peaty soils but sustained growth was better on mineral soils. It was recommended that seeds be sown in either very early spring or late fall.

Native species can be encouraged to revegetate by simply adding fertilizer to the disturbed site, but this is effective only where there is an adequate seed supply or rooting stock. Fertilization with nitrogen and phosphorus together resulted in better growth than treatment with nitrogen alone (Bliss and Wein, 1972). Because of low natural seed production, any site treated with fertilizer only must be small enough to permit revegetation asexually; e.g., a seismic line or road.

Plant regeneration in northern regions is generally slow because of low soil nutrition, and temperatures, and short growing seasons. The rate at which vegetation recovers depends on the type and extent of the disturbance and the type of vegetation originally on the site. Most sites that have not been excessively disturbed will be revegetated within a few years without assistance (Hernandez, 1972). In areas where mineral soil has been exposed, where thermokarst erosion has been initiated, or where slope stability is threatened, natural revegetation may be too slow to prevent accelerating damage. In these instances, artificial revegetation techniques may be important.

3.43 Vegetation Mapping Units

Mapping units delineate the vegetation of the study region in terms of vegetation structure, species composition and landform.

The distribution of vegetation in the study region is dominated by drainage. Drainage is determined zonally by the texture of surficial material and locally by topography. Microtopography becomes important in areas with impeded drainage. Hence, vegetation on the rims of polygons can differ vastly from vegetation on the centres, although the difference in relief is only a few inches.

Sedge-Herb (Sh)

Areas covered with shallow water throughout the summer are vegetated primarily with sedges (*Carex aquatilis* and *Eriophorum* spp.) and horsetail (*Equisetum arvense*). Depending on water depth, the relative abundance of these species varies from one area to another. The distinction between aquatic and terrestrial habitats becomes conjectural. This mapping unit is restricted to Recent river deposits

Soils under sedge-herb vegetation are Gleyed Regosols and Cryic Fibrisols. Neither Regosols nor Fibrisols have soil horizons characterized by zones of eluviation (A horizon) and deposition (B horizon). The soil types differ in that one is mineral and the other organic. Seasonal deposition of silt has made sedge-herb soils relatively fertile.

The organic matter in this soil has increased the cation exchange capacity and narrowed the C/N ratio to six. Active-layer depths ranged from 10 to 24 inches. Soil reaction is slightly acid (pH 6.5) to neutral. Often associated with sedge-herb soils are a distinctive "swampy" odour, a reddish precipitate on the surface, and a thin oil-like film on the water. These are presumably products of soil microbial activity.

Willow-Sedge (Ws)

This mapping unit is restricted to Recent alluvial deposits that are subject to frequent flooding but where siltation is not excessive. The mapping unit is dominated by dwarf willow (under two feet) and sedges. Mosses, found mostly in stagnant ponds or as a thin ground cover, are of secondary importance.

The soils under this unit are mainly Gleyed Regosols with distinctive silt layers representing successive deposition of river sediments, and thin bands of organic matter representing organic surface horizons that have been buried. The active layer is 12 to 15 inches thick. In silt layers the cation-exchange capacity is low (20 meg per 100 grams) while in organic layers it is somewhat higher. An extremely high C/N ratio in these soils, however, suggests they are nitrogen-poor. Willow-sedge soils are generally mildly alkaline (pH 7.5).

Depending on the intensity of flooding and siltation the soil texture may range from a silt loam to a fine clay. Often over clay deposits there is a fibric organic layer underlain by a humic layer and a layer of gleyed find clay (rego-Humic Gleysol) (Figure 3-1).

Willow-Herb (Wh)

The willow-herb mapping unit is restricted to the tops of levees where maximum siltation occurs. Willows attain heights of six to ten feet in these areas but few other species can cope with the siltation rate. This mapping unit is not extensive in the areas studied.

The soils in this unit are mainly Gleyed Regosols with distinctive layering due to successive deposition of river sediment. They are of medium (silt loam) texture. In areas of minimum annual flooding, the soils may develop a fibric organic surface horizon, underlain by an organic-mineral and a gleyed mineral horizon (Rego Humic Gleysol). The low cation-exchange capacity (20 to 25 meg per 100 g) and wide C/N ratio (more than 100) makes these soils relatively infertile.

Willow-herb soils are mildly alkaline (pH 7.5). The active layer is extremely thick (greater than three feet). Indeed, permafrost may be absent under many of these sites.

Meadow (Mw)

This mapping unit defines poorly drained areas on lacustrine deposits. It is not extensive in the study areas. Meadow vegetation is diverse, consisting primarily of sedges, heaths and mosses. On the wettest sites the vegetation resembles sedge-herb. In areas with moderate drainage, it may include species common to Eriophorum tussock and dwarf shrub-heath mapping units.

Meadow soils are Fleyed Regosols and Cryic Fibrisols. Although the organic matter affords a high cation-exchange capacity, the system is only 20 per cent saturated. The C/N ratio is very wide. These data suggest low fertility in meadow soils. The pH ranges from 7.5 (mildly alkaline) to 6.5 (very slightly acid). The active layer ranges from 6 inches in Fibrisols to 12 inches in Regosols.

Eriophorum Tussock (Et)

Cottongrass (Eriophorum vaginatum) is associated with imperfectly drained landscapes and is therefore common on lacustrine deposits. The Eriophorum tussock mapping unit is an important component at the southern end of the Parsons corridor. Although the vegetation is dominated by cottongrass, the floristic composition may resemble meadows in wetter sites or dwarf shrub-heath in drier sites.

Soils in Eriophorum tussock mapping units are Cryic Humic Gleysols. They are relatively infertile because of the low base saturation (20 per cent) and wide C/N ratio (25). The pH tends to be very strongly acid (pH 4.6). The active layer is 9 to 12 inches thick.

Alder (A)

The diagnostic shrub of the alder mapping unit requires moist conditions in an aerated soil and is therefore usually found on more gentle slopes that receive moisture from late melting snow. This moisture regime is reflected by luxuriant heath growth and high moss cover with occasional *Sphagnum* clumps. The understory may vary from *Eriophorum* tussock - type vegetation in wet areas to a dwarf shrub-heath type on well-drained sites.

Soils under alder range from Humic Gleysols to Dystric Brunisols. Soil analyses suggest the latter are among the more fertile in the study region. The active layer is 6 to 12 inches deep. Soil reaction is from extremely acid (pH 4.5) to neutral.

Medium Willow (W)

This mapping unit is used to define two specific habitats in which shrub vegetation is exceptionally lush; viz., steep slopes and stream beds.

Growing conditions are favourable here because the vegetation is protected from desiccating winds, soil moisture is available and soil aeration is adequate. Woody vegetation may form a dense stand and attain heights of over five feet.

On steep slopes, generally slump scars on lake banks, woody vegetation is dominated by Salix Lanata, birch and alder. Ericaceous shrubs, mosses and lichens are important understory components. Soils in these areas are relatively fertile, well-developed Cryic Dystric Brunisols. The active layer is 6 to 18 inches deep. Soil reaction is neutral.

In depressions Salix glauca dominates the canopy and sedges dominate the understory. The soils are generally Gleyed Regosols and Fibrisols. The active layer is 10 to 12 inches deep. Soil reaction is very slightly acid to neutral.

Black Spruce (Bs)

Since most of the study region is considerably north of the tree line, this mapping unit is rare. It occurs in only two locales south of Parsons Lake. The spruce are stunted and confined to large stream beds or south-facing hillsides. The understory is mostly heaths and sedges.

Dwarf Shrub-Heath (Ds)

The dwarf shrub-heath is an indiscriminate mapping unit that includes most of the upland tundra. It dominates morainal and glaciofluvial landforms, grades into *Eriophorum* tussocks on lacustrine deposits, and characterizes most of the Pleistocene marine deposits.

Dwarf shrub-heath vegetation can be divided into two major groups according to the degree of drainage. Where drainage is rapid; e.g., on glaciofluvial deposits, heaths and fruticose lichens (*Cetraria* and Cladonia) are dominant. Dwarf shrub-heath in the Parsons group is largely of this type.

Dwarf shrub-heath soils are a mosaic of different soil types ranging from Dystric Brunisols to Cryic Fibrisols. The distribution of these types is related to the complex microrelief characteristics of the areas. Hummocks from 6 to 24 inches in height and 12 to 36 inches in diameter may be of mineral soil with an organic surface layer (Dystric Brunisol) or entirely organic material (Fibrisol). Soils in interhummock areas are generally organic and are underlain by ice wedges. Organic soils are generally mesic, but in better-drained areas may be fibric. Under hummocks the active layer is 12 to 18 inches while under depressions it is 6 to 12 inches. Soils in dwarf shrub-heath mapping units are generally fertile. Organic horizons accumulate phosphorus and nitrogen, while the mineral horizons appear to have a supply of mineral nutrients.

Reactions of organic soils varies from extremely acid (pH 4.5) in humic soils to neutral (pH 7.0) in fibric soils. Mineral soils are generally slightly acid to neutral.

Xeric Gravel (Xg)

Several locales in the study region are extremely dry, as a result of rapid drainage of coarse soils and exposure to high solar angles and desiccating winds. The crests and southern exposures of gravel eskers and kames are typical of the xeric gravel mapping unit. Vegetation is sparse (less than 50 per cent ground cover) and includes species restricted in the study region to the xeric gravel mapping unit. Some of them are:

Carex Nardina	Draba hirta
Kobresia myosuroides	Saxifraga caespitosa
Zygadenus elegans	Saxifraga oppositofolia
Salix arctica	Saxifraga tricuspidata
Selaginella densa	Anemone patens
Arenario capillaris	Potentilla Vahiliana
Cerastium beeringianum	Polemonium pulcherrum
Dianthus repens	Antennario monocephala
Melandrium affine	Artemesia frigida

Many of the species listed above are common in alpine and high arctic sites. The others are common elsewhere.

Well-drained soils are warmer than wet soils. Frost was not encountered in xeric gravel soils in the first three feet. The surface is often covered by a pebbly pavement beneath which a thin organic or juvenile organic-enriched mineral layer occurs. The soil is an Alpine Dystric Brunisol. Soil fertility is relatively low in these soils due to low cation-exchange capacity and wide C/N ratio. Field pH is mildly alkaline (pH 7.5).

Patterned Ground

Low-centered polygons (Lc) are common in areas with poor drainage (photo 3-3). Sedges (*Carex aquatilis* and *Eriophorum Scheuchzeri*) may form pure stands, and brown mosses (*Drepanocladus* spp.) are often abundant.

The soil in the centre is Regosolic, but on the raised rims is organic on the surface and mineral at depth (eight inches). The active layer is about 12 inches on the rims and 10 inches in the centre.

The low-centred polygons with peat mounds (1 cpm) mapping unit is similar to the low-centred polygon unit except for comparable well-drained mounds. Vegetation and soils on the mounds are similar to those on the polygons.

High-centred polygons (Hc) are common on lacustrine sediments. Drainage on high-centred polygons is improved with standing water only in the peripheral fissures created by ice-wedge development. In the fissures the soil and vegetation are similar to those of the meadow unit. Near the centre, they become like those of dwarf shrub-heath.

Aquatic Vegetation

Approximately 30 per cent of the surface of the study region is represented by channels, lakes or streams.

Floodplain-channel lakes support very little submergent or emergent vegetation. Shoreline vegetation is dominated by *Carex aquatilis* with *Eriophorum angustifolium*, *Caltha palustris* and *Equisetum* spp. playing important roles.

Floodplain lakes support a varied and often a lush aquatic vegetation. Submergent vegetation includes at least six species of pondweed, *Ceratophyllum* sp., *Callitriche* sp., and *Myriophyllum* sp. Emergent vegetation includes primarily *Hippuris vulgaris* and *Menyanthes trifoliata*.

Several species may be considered emergent during periods of high water levels and terrestrial at low water. They are *Potentialla palustris*, *Equisetum arvense* and *Carex aquatilis*.

Upland lakes do not support as dense a submergent vegetation as floodplain lakes, possibly because they have lower concentrations of mineral nutrients and/or ice scouring. Potomogeton perfoliatus and Chara sp. were collected only in water deeper than about seven feet. Other species of Potomogeton were represented in shallower water. Emergent vegetation is not as common in upland lakes as in floodplain lakes.

Streams are generally clear and shallow with a fairly strong current. Few vascular plants grow from the bottom. Stream banks are vegetated with either hydrophilic sedges or with medium-height (five feet) shrubs. Selaginella selaginoides was restricted to stream banks, and several other vascular plants; e.g. Parnassia spp., Pinguicula spp. and Spirea Beauverdiana were common in this habitat.

3.44 Flora of the Parsons Lake Area

The Parsons corridor is topographically irregular, consisting of many hills and water-filled depressions. The hills rise as much as 150 feet above the bodies of water, which range in size from small ponds to large lakes, the largest being Parsons Lake on the west side of the corridor.

The southern end of the corridor lies on the eastern slope of the Caribou Hills.

Most of the corridor, and especially that to the north and east, is typical kame-and-kettle topography dominated by glaciofluvial outwash of sands and gravels. The depressions (kettles) are formed in glacial tills, the bottoms being infilled with lacustrine silts and clays.

Ground ice occurs in varying concentrations throughout the area. In low-lying areas it occurs as massive ice lenses and ice wedges. The ground-ice content of sand and gravel on the topographic highs is generally low.

The deposits of sand and gravel are generally stable, as are also undisturbed lacustrine deposits. Instability was observed in the steep glacial-till slopes that border the many lakes.

The tops of the hills are vegetated with xeric gravel plant species. Most of the slopes are vegetated with dwarf shrub-heath, whose floral composition depends on drainage. On well-drained slopes lichens dominate while on moister slopes birch is abundant. Alders were found associated with drier sites. The understory is of heaths and lichens rather than sedges.

3.45 Potential Impacts

Since vegetation is dependent upon the terrain it covers, the impacts which affect the terrain of the region (Section 3.23) will affect the vegetation of the region. Revegetation and proper conservation techniques will keep long-term environmental impacts to vegetation to a minimum.

3.5 FAUNA

The fauna of the Parsons Lake area was studied by F. F. Slaney and Company in 1972-73. Field investigations were made to assess the type and density of species of mammals, birds and aquatic life.

A summary of the findings is found in the following sections (3.51, 3.52. 3.53).

3.51 Mammals

In 1973-74 detailed studies were undertaken in the Parsons Lake area. Field work was aimed at determining indices of mammal abundance and the identification and description of habitats important to mammals near areas of possible natural gas development in the area. Emphasis was placed on species of high commercial, recreational or subsistence value and on rare and endangered species.

Large, wide-ranging mammals such as grizzly bears, reindeer, and white whales were observed from the air and the ground or from a boat. Grizzly bear and fox dens were located by thoroughly searching all the circles and corridors from a helicopter. An index of ground-squirrel use of the various vegetation mapping units was obtained by locating active burrows on sample plots and along transects. September aerial surveys were flown over most suitable habitats in search of beaver caches and lodges. Aerial muskrat push-up counts were conducted in late May, 1973. In addition, data describing depth, substrate, clarity, shoreline and aquatic vegetation were obtained for selected lakes which contained muskrats. Small mammals were surveyed by snap-trapping in various vegetation mapping units.

Additional information was gathered by talking with local trappers, RCMP officers, government and other scientists working in the region.

Five mammalian orders are present within the study area:

Insectivora
Lagomorpha
Rodentia
Carnivora
Artiodactyla.

These five orders were represented by a total of 17 species that occur regularly. A number of other species occur less regularly. The main components of the mammalian fauna are typical of the arctic tundra. Nearly all the regularly occuring species are found in tundra habitats of both Eurasia and North America.

Because of the nearness of the tree line, the lynx, moose and other boreal species occasionally find their way into the study region.

Reindeer and Caribou

Numbers of caribou inhabited the study region in the early part of this century, only to disappear and be replaced by reindeer herds from Alaska.

Following extermination of the caribou in 1935 semidomestic reindeer, the Eurasian variety of caribou, were introduced to the region in an effort to provide a reliable substitute for native use.

Few reindeer remain in the Parsons Lake area in summer, probably because wind does not disperse the insect pests as it does on the coast. A maximum of 14 reindeer were seen in this region in summer, 1973. In past years, Parsons Lake has been on the route followed by the managed reindeer herd on its semiannual trek between summer range on the Tuktoyaktuk Peninsula and winter range to the south. It is considered spring-autumn range by Scotter (1970), but was used as a wintering area during 1973-74.

Grizzly Bears

After conducting biological investigations in the Mackenzie Delta region in 1927-28 and 1931-35, A. E. Porsild (1945) wrote that, "Brown or grizzly bears were common in the Mackenzie Delta region during my residence, particularly in the mountains west of the Delta and in the Eskimo Lakes basin." He also reported that in spring grizzly bears also came into the forested portion of the Delta to utilize the abundant plant and animal food associated with break-up.

By 1943, the decline in the number of grizzly bear sightings in the Delta prompted the first legal protection - a closed season from June 1 through August 31. C.H.D. Clarke (1944) reported that:

> "Grizzlies are found locally in the Mackenzie Delta, Richardson Mountains, Reindeer Reserve and eastward... in many parts of this range their numbers are possibly as great as they ever were. However, this cannot be said of the Delta and its fringes, where conditions peculiarly suitable for them are found and where they were once more numerous, than elsewhere. The innumerable cutbanks of the Delta offer ideal hibernacula for bears, and the hills to the east and west are excellent summer range for them. The Eskimo name 'aklavik' applies to the lower Delta and means Bear Country"

In 1949 the closure was extended to all year, and " . . . in the 1950's the frequency of sightings increased considerably. Also, the animal was encountered occasionally beyond its range, a finding variously interpreted as true range extension or a re-occupation of country from which the bears had recently been exterminated" (Macpherson, 1965).

Bears appeared to make use of different habitats during different parts of the year. In June and July, they were seen in areas of interspersed fluvial lowlands, meadows, and uplands, which would be expected to provide an abundance of sedges, herbs and moulting or nesting waterfowl.

Foxes

Porsild (1945) considered the coloured fox to be very common in the Delta, second only to the muskrat in importance as a furbearer. The white fox was plentiful along the coast during 1927-28, but rare inland. He reported that the white fox was attracted to the reindeer herd, where it fed on carrion and weak fawns, McEwan in 1954 trapped white fox pups on Kendall Island and deltaic islands to the south (McEwan, 1955). He considered them to be the most abundant denning species in that area.

Coloured foxes were seen commonly year-round in upland habitat throughout most of the study region. Winter surveys indicated that they were associated with shrubby areas inhabited by ptarmigan. Arctic foxes were most common during winter near the coast, on floodplain habitats and on barrier islands. In summer they were seen mainly in upland areas near the coast as well as the nearby islands.

With two possible exceptions, all dens located in 1973 probably belonged to coloured foxes. Coloured foxes were seen at all but three of the dens judged to be active, and one of those dens had coloured-fox hair on adjacent bushes. White hair was found near the remaining two dens, although the entrances were the size expected for coloured foxes.

Arctic Ground Squirrels

Active burrows of arctic ground squirrels were most abundant in areas of sandy or gravelly soil covered with xeric-gravel or short dwarf shrub-heath vegetation. In addition, ground squirrels sometimes dug burrows in pingos and in the banks of thermokarst lakes, where sandy deposits are covered by only a thin mantle of moraine. They were not found in floodplain habitats.

In the Parsons Lake region ground squirrels were restricted to the dry tops of hills where vegetation is sparse. They were most common in the Parsons Group, where the soil is derived from moderately well-sorted Pleistocene deposits. In that part of the Parsons Corridor south of the Parsons Group, landscape relief is less and the soil is composed of poorly sorted materials. As a result there are fewer dry areas and smaller numbers of ground squirrels. Surveys of the southwestern portion of the Parsons Corridor revealed no ground squirrels.

Muskrats

Several authors have reported muskrats to be less abundant in the northern, treeless portion of the Delta than in the forested part (Porsild, 1945; Clark, 1944; McEwan, 1955). Stevens (1953) and Hawley (1968) have published accounts of muskrat biology within the treed portion of the Delta, where good range is more or less contiguous and trapping effort therefore more productive.

In the first years of this century, muskrats were found to be abundant (Preble, 1908). However, dramatic changes in abundance approximately every four years characterize the muskrat population in the north. By examining fur-trading records from 1821 to 1927, Elton and Nicholson (1942) clearly established this cyclic pattern for Mackenzie Delta muskrats. More recently, Hawley (1968) has documented a Delta population decline and subsequent increase. In 1963, numbers had dropped to about 10 per cent of those of 1962; by 1967 the population had recovered to near the 1962 level.

Results of current surveys showed that muskrat push-up densities in the study region ranged from nil to moderate in both 1972 and 1973.

Not all lakes in the study region support muskrats, and distribution is intermittent. Lakes with muskrats were most frequently observed in southern parts of the region. Similarly, densities were generally higher in floodplain lakes closest to the tree line.

Upland and floodplain lakes at least seven feet deep and with banks suitable for burrow construction had the highest push-up densities. Floodplain-channel, upland-channel and salt lakes had few or no push-ups.

Lake size appeared to be important. Lakes smaller than 100 acres had densities less than one-third those of larger lakes.

Voles and Lemmings

As compared with other tundra areas, current small mammal densities in the study region are low. Krebs (1964) reported trap indices as high as 27 and 14 for brown and collared lemmings respectively, in the tundra near Baker Lake, N.W.T. Highest trap indices for brown and collared lemmings in this study were 0.09 and 0.23 in 1973 and 0.78 and 0.66 in 1972.

Numbers of small rodents may be reduced to approximately the same low level each winter by the severity of the environment, regardless of fall populations. However, maximum numbers in the summer can vary. Martell found 1973 summer populations of red-backed voles in the Delta to be roughly twice those of 1971 and 1972 (Martell, pers. comm.).

Red-backed voles appear to be the most numerous small mammal in the uplands of the study region, particularly the alder mapping unit.

Beaver

Hawley provides a summary of recent beaver fluctuations in the treed portion of the Delta. "The nutshell history of the delta beaver is one of being almost entirely exterminated in the 1920's. The beaver were given complete protection in the 1940's with establishment of the delta beaver sanctuary. By 1958, natural recovery from a population pool in the southeast corner of the delta was such that a harvest of one beaver per lodge was allowed on the sanctuary. The delta trappers harvested about 100 beaver annually under that system.". (Hawley, 1968)

Porsild (1945) reported that by the time of his residence (1927-1935) beavers had almost entirely disappeared from the country east of the delta proper, and that only one colony "survived on Nils Holme's Creek." Hawley (1968) estimated 1,600 beaver colonies on the entire delta, and an annual harvest of 4,000 beavers was allowed by the N.W.T. Game Management Service. However, only 1,100 beavers had been harvested in each of his last two years of study.

Few beavers exist in the Parsons Lake region. During autumn surveys in 1973, five active and one inactive lodge were located, all between the East Channel and the Eskimo Lakes. Dennington et al. (1973) rate the Parsons Lake area as Class 4, "insignificant beaver habitat," while riparian areas along Holmes Creek are rated as Class 3, "poor beaver habitat".

Moose

Several moose were recorded in the study region during the investigations. On May 28, 1973, an adult antlerless moose was observed standing in several feet of water on an island 7 miles northwest of Tununuk Point, and a large bull was observed 10 miles west of Parsons N-10. Winter moose pellets and evidence of moose browsing on willow were found south of Parsons N-10. A Canadian Wildlife Service habitat survey (Prescott et al., 1973) lists most of the study region as Class 4 moose habitat, "insignificant or nil moose wintering habitat - may be used in summer." A small area on both sides of the East Channel near Swimming Point, Holmes Creek and Pete Creek were listed as Class 3, "poor wintering habitat."

Wolves

Wolves, formerly scarce, were attracted to the east side of the Delta with the introduction of reindeer in 1935 (Porsild, 1945).

In 1973, only two sets of tracks were seen, both south of Parsons Lake (Collage). According to Jacobsen, constant vigilance by the herders and local residents has reduced the number of wolves in the reindeer area.

During an eight-year study of tundra wolves in the Northwest Territories, Kuyt (1972) found that wolves migrate up to 200 miles in association with the barren-ground caribou. He found the wolves' diet consisted mainly of caribou, but also included muskoxen, wolverine, ermine, wolf, arctic fox, red fox, arctic hare, arctic ground squirrel, small rodents, geese, ptarmigan, small birds, eggs, fish, carrion and insects.

Weasels

Both the least weasel and the ermine (short-tailed weasel) occur in the study region, although the former is quite rare. Porsild (1945) reported ermine to be common in the delta, particularly at Reindeer Station.

He further stated that the least weasel was much less common, with only a few pelts taken each year.

Wolverines

Wolverines occur throughout most of the taiga and tundra although their numbers are nowhere great. Kucera (1973) observed a wolverine southeast of Parsons Lake (67° 35'N., 132° 25'W.). None were observed during this study. Porsild (1945) reported that wolverines "appear to migrate to the delta region from the barren grounds to the east." Wolverines have been reported on the barren grounds east of the study area by Preble (1908), Harper (1932) and Aleksuik (1964); on the North Slope of Alaska by Sage (1970) and Bee and Hall (1956); and on the north slope of the Yukon Territories by Ruttan (pers. comm.).

Hares

Both snowshoe and arctic hares range into the study region, the latter less frequently. Porsild (1945) reported that the arctic hare " . . . occurs sparingly in the Caribou Hills and in the higher parts of the Eskimo Lakes country." He collected one near Kittigazuit on the East Branch of the Mackenzie River. Hall and Kelson (1959) give their range as extending to the East

Channel. However, no signs of arctic hares were seen during this study, and Martell has not seen or heard of arctic hares closer than Cape Bathurst.

Snowshoe hares are common in the forested portion of the Delta, and Porsild (1945) reported that, "During the years of greatest abundance - snowshoe hares - were plentiful practically everywhere in the Delta, even in the treeless but hill-covered northern part . . . and in the treeless Eskimo Lake basin they were occasionally seen in willow and alder thickets along lake shores and creeks."

In the summer of 1972, no sign of snowshoe hares was seen at Parsons Lake. Martell found them very abundant in the winter of 1971-1972, but very few in the winter of 1972-1973. He felt that the snowshoe hare population had crashed throughout the Delta region and a scarcity of hares in the spring of 1972 was confirmed by a trapper from Aklavik. Snowshoe-hare populations are well known to fluctuate dramatically in approximately ten-year cycles.

Other Mammals

No evidence of coyotes, black bears, lynx, mink, martens, otters, fishers or shrews was found during the 1972-73 study period in the Parsons Lake area.

Mammal Occurences in the Parsons Lake Area

In recent years, this area has been on the route followed by the reindeer herd in its movements between summer range on the Tuktoyaktuk Peninsula and winter range to the south. During the winter of 1973-1974, field personnel several times observed the main herd in the vicinity. A female that had probably wandered from the main herd was seen in the summer of 1973.

Grizzlies use this area in late autumn when they are foraging for berries and ground squirrels. No den sites were located.

Ground squirrels regularly occur on the xeric tops of most of the hills in the N-10 area.

Medium-sized high lakes in the area provide moderately good muskrat habitat.

Red-backed voles are found in the dwarf shrub heath and high-centred polygon mapping units.

In the area foxes (mostly coloured) hunt in upland areas during summer. In winter, foxes of both species hunt ptarmigan in dwarf-shrub heath and willow habitats. Suitable denning sites are scarce. One arctic fox was seen in 1973 and a cross fox was observed at the well-site. Workers reported having seen only coloured foxes during the winter of 1972-1973.

The K-09 area is considered spring-autumn reindeer range and is on the route followed by the reindeer herd in its movements between the summer and winter ranges. A female and a male were seen here in the summer of 1973, probably stragglers from the main herd.

Grizzlies use this area in late summer. No den sites were located.

Ground squirrels regularly occur on the xeric tops of most of the hills in the K-09 circle.

Medium-sized high lakes in K-09 provide moderately good muskrat habitat.

Voles and foxes are found in the same mapping units as in N-10.

The Parsons Corridor is considered spring-autumn range and is also on the migration route followed by the reindeer herd over the last few years. In the summer of 1973, an adult male reindeer was seen in the north end of the corridor, and another just south of the bend.

Grizzlies feed in spring in the lowland areas south of Parsons Lake, where sedges and moulting waterfowl are abundant. In late summer, bears may forage for berries in upland areas. There are a few ground squirrels in the northern part of the corridor. In 1973 a sow with two cubs was seen in the south end of the corridor, and tracks of a lone adult were measured in the same vicinity. Tracks of a smaller lone adult were measured near the centre of the corridor.

Ground squirrels are very scarce in that part of the Parsons Corridor just south of K-09 area. They appear to be absent in that part of the corridor oriented to the southwest.

Medium-sized high lakes in the northern part of the Parsons Corridor provide moderately good habitat for muskrats. The lakes in this portion oriented to the southwest are less productive.

Red-backed voles were often trapped in dwarf shrub-heath and alder mapping units in the Parsons Corridor. Meadow voles were locally abundant in sedge-containing mapping units.

In the Parsons Corridor coloured foxes are found both summer and winter. Suitable denning sites are scarce and only one den was located. Two coloured foxes were seen in 1973 - one in the southwest end of the corridor and one in the north end.

Potential Impacts

All-weather roads would affect mammals by taking a small amount of land out of production, presenting an obstacle to movement, and disturbing more wary species through traffic and equipment noise.

Experience in Scandinavia and Alaska suggests that where roads are raised above the surrounding terrain, reindeer and caribou usually either move along and try to circumvent them or adopt them as travel routes. Reindeer should have little difficult crossing roads in the development area, as they are herded by local residents.

Road systems near Parsons Lake would parallel gathering-system pipelines except for the haul roads from the dock to plant site.

Reindeer would probably habituate to vehicular traffic, as they are accustomed to snowmobiles coming close during herding. In February 1974 they showed no alarm at winter road traffic a half-mile away or a Bombardier that came within about 200 ft. Scandinavian experience also indicates that traffic should pose no threat other than the risk of an animal's being hit in the dark.

Grizzly bears can be expected to feed within about 1000 ft. of a traveled road during poor light. Although they avoid being seen by people, they may sometimes cross moderately travelled highways; for example, a radio-tagged female and cub frequently crossed the Alaskan Highway in the southern Yukon.

It is assumed that grizzly bears will not use land within 1000 ft. of a travelled roadway. On this basis, 3200 acres in the Parsons Lake area would not be available for general use by the species.

Where the road covered dry hilltops, a small amount of ground-squirrel habitat would be destroyed.

All-weather roads would make a small amount of land unavailable to voles and lemmings, which would probably be reluctant to cross them, especially in winter. This effect, however, should be no greater than on winter roads and seismic trails.

Drainage changes and minor silting in the Parsons area could change the aquatic plant regime in ponds inhabited by small numbers of muskrats. However, any changes would probably be minor and might not noticeably affect the muskrat populations.

Construction of airstrips would remove a small amount of land from production. Noise of construction machinery would have about the same effect as road traffic.

The main effect on reindeer would be to present an obstacle to movement. Any deflection of movement would be of no significance at any rate, since it would be masked by the effect of facilities and pipelines. The airstrip in the Parsons Lake area would be a minor obstacle that the reindeer would circumvent without consequence.

Other mammals would probably be affected only be the removal of a small amount of land from production.

In the Parsons Lake area, where both large and small aircraft may operate, grazing land would be affected. Reindeer have used the Parsons Lake region in their semi-annual migration between summer and winter ranges; any disturbance would be limited to this period. Movement of the herd around the zone of disturbance is quite feasible.

The Parsons Lake area was used as a wintering area during 1973-74 and it will be a number of years before it can be safely used again. Winter disturbance around the airstrip would therefore occur only two or three times during the life of the project.

Grizzly bears probably would not be affected much by aircraft.

Other mammals are unlikely to be affected by aircraft landings on strips. It is unlikely that helicopters would have any serious disturbing effect at altitudes above approximately 500 ft.

Boats might occasionally encounter reindeer or grizzlies swimming in inland waters, and might come close to them near waterways. Such encounters would be infrequent, and no adverse effect would be expected if the boats approached no closer than 500 ft.

The main effect of plant, staging, dock and cluster-site construction and use on most mammals would be to remove small amounts of land from production.

Facilities might be obstacles to travel for reindeer but would not halt either herded or unherded movement.

No fox dens have been located in the areas proposed for site construction.

Reindeer probably would not be seriously affected by noise from compressors or equipment: it has been reported that in Scandinavia they come so close to tree-felling operations, despite the noise of chain saws and other machinery, that many are killed by falling trees. Caribou, on the other hand, avoided coming closer than about 1/8 mile to any machinery as noisy as a gas compressor, and they may have used areas within 1/2 mile less extensively.

Bears can be expected to remain more than 1,000 feet from gas compressors. Ground squirrels are little affected by noise; for example, they were living near the runway at the base camp at Swimming Point. Other mammals probably would not be seriously affected by the sound of gas compressors or the presence of man. Foxes will congregate at camps if food is made available.

Foxes displaced from dens could suffer a higher mortality rate. Denning sites appear to be limiting to some fox populations, but not over most of the development region, and the Parsons Lake area has an adequate number.

Ground squirrels are abundant in areas where the substrate is gravel. They would probably not be able to use the areas from which gravel was taken for several years. The loss of ground squirrels through gravel excavating operations would be about 2.8 dens per acre.

Clearing activities near Parsons Lake would remove higher shrubs such as willows and alders, but might also require slope modification that could cause some thermal erosion and slumping. Should significant silting result, increased water capacity might decrease the growth of muskrat food plants, causing decreases in muskrat population over a long term. Few animals would be affected, however, and trappers might not notice any fall-off.

For several years, reindeer have passed between Parsons and Eskimo Lakes on their migrations between summer and winter ranges. As the pipeline lies to the west of this area and roughly parallels the migratory route, serious effect on the reindeer is unlikely.

Trucks and aircraft would be used on all-weather roads. Where there are no permanent roads, aircraft would be used in summer, and ground transportation on winter roads in winter.

Reindeer would be in the Parsons Lake area, however, only when moving between summer and winter ranges, and on the few occasions when they wintered there, there would be few helicopter or fixed-wing inspection flights to disturb them because the line is paralleled by an all-weather road.

As no dens were located in the Parsons Lake area, it seems unlikely any bears would be encountered during the spring "sensitive" period. Bears use the region in summer, and could probably be affected by helicopter and truck traffic within 1,000 feet.

3.52 Birds

Compared with other vertebrate populations of the area, the bird fauna is rich, a direct result of the seasonal influx of migratory species (Table 3.4).

Spring Migration

The distribution and abundance of birds within the region of interest during spring migration is variable in time. Loons arrived later than other large migrants. Arctic loons were first observed on May 28, 1972, and May 27, 1973. Red-throated loons appeared at the same time or shortly after. Breeding birds were established on nesting lakes by June 7 in both years.

Whistling swans arrived before all other kinds of large waterfowl (May 22, 1972 and May 8, 1973). Most birds took up nesting territories immediately.

Geese present in substantial numbers in the study region during spring migration included black brant, snow geese and white-fronted geese. No Canada geese were recorded. Goose migration began with the arrival of white-fronts in both 1972 and 1973 (May 21 and May 18 respectively).

Snow geese and brant were observed in large flocks but white-fronts were in small groups or in pairs.

Important duck species in the study region included both dabblers (pintails, mallard, American wigeon) and divers (greater scaup, oldsquaw, white-winged scooter). Both groups arrived at approximately the same time as geese. No areas of particular concentration were noted but ducks were characteristically present around flood or melt waters.

As melt water collected in shallow pools in terrestrial habitats, shorebirds arrived to feed and rest. Shorebird migration began in the last week of May and appeared complete by the end of the first week of June in both years.

Sandhill cranes arrived on May 21 in both years. They immediately dispersed over the nesting area and established territorial rights.

Passerine birds arrived at various dates depending on species, ranging from before April 30, when redpolls were already present in 1973, until the first week in June.

Nesting and Rearing

Loons started their clutches about two weeks after they arrived. Since they came late in comparison with other birds, they were one of the last groups to begin nesting. Average clutch-size in both species was found to be 1.5.

Incubation is by both sexes and takes about 29 days. Most loon eggs had hatched by the third week of July. Young loons are precocial but are fed by their parents throughout the brood rearing process. They were given both fish and arthropod foods. Most young loons were flying by early September.

Whistling swans occupied territory of approximately one square mile, and began egg-laying before the end of May. Incubation by the female takes between 35 to 40 days. Most cygnets hatched during the first two weeks of July. With the onset of brood rearing there was a marked change in habitat use, involving a greater use of lakes.

Black brant were found breeding in coastal areas and on offshore islands, but one colony was located several miles inland. Nesting started before the end of May. Black brant are colonial nesters, and lay four or five eggs. Evidence indicated that goslings hatched in early July and birds from each colony quickly congregated into large flocks composed of goslings and attending adults. Brant goslings were reared in or close to marine environments.

White-fronted geese are noncolonial and secretive nesters. The first geese to arrive in the study region, they were already paired and nested early, probably beginning before the end of May. Nesting in this species was fairly synchronous. Hatching took place during the first ten days of July in 1973.

Dabbling ducks nested along floodplain-upland interfaces. Clutches were started by the first week in June but some were still being completed by June 20, 1973. Clutch size varied from six to nine. Incubation takes 23 days.

Greater scaup did not begin nesting until the middle of June and clutch initiation extended into early July. In 1973 the hatch period extended from mid-July to the early days of August. Brood size was 7.3 eggs.

Oldsquaw began nesting before other diving ducks, with first clutches initiated June 7, and more until the third week in June. Clutch size averaged 8.7. In 1973, the first broods appeared during the second week of July.

In both 1972 and 1973 white-winged scooters initiated clutches from the middle to the end of June. These birds are solitary nesters. Hatching took place in the last half of July.

The willow ptarmigan is a permanent resident in the study region. Winter flocks started to break up in April and by May male ptarmigan were on territory. By late May nesting had started, primarily in dwarf shrub-heath and alder habitats. Average observed clutch size was 8.5. Youngsters were first observed at the start of July. They were able to fly when less than half their adult weight. Broods foraged in upland habitats and, as brood rearing progressed, congregated into larger groups. By late August, few family groups were present and most birds were in flocks numbering up to 60 individuals.

Sandhill cranes started egg-laying in early June and reached a peak during the second week. Nests were found on ridges in low-centred polygons, or on sedge-herb flats adjacent to lakes. Hatching took place the second week of July.

Pectoral sandpipers arrived in late May and most clutches were initiated by mid-June. Clutch size is four. Newly hatched chicks were observed from the end of June until the second week of July.

The semipalmated sandpiper was one of the most common of the study area's shorebirds. Arriving in late May, it nested in both uplands and flooplains, initiated clutches during the second and third weeks of June. The clutch size is four. Hatching took place in early July.

Northern phalaropes are one of the last species to arrive each spring. Eggs were laid during the second and third weeks of June and young appeared in early July.

Both parasitic and long-tailed jaegers nested in the study region during the first half of June.

The glaucous gull was found throughout the area. The species use a wide variety of habitats but have specific nesting requirements. Nesting began in early June and chicks appeared in early July. The clutch size was almost always three and the eggs were incubated by both parents for 27 or 28 days. Brood rearing or at least parental attentiveness persisted for some time after the young had learned to fly.

Arctic terns were the only breeding terns of the study region. They came in late May and started nesting in mid-June. Tern chicks hatched during the second week of July.

The gray-cheeked thrush frequented the shrubbiest parts of the study region. Neither clutches nor brooks of this species were observed, but territorial display suggested breeding activity.

The yellow warbler was the most common inhabitant of shrubby habitats. Incubating birds were found during the second week of June, 1973. Four or five eggs make up a normal clutch. Incubation takes 11 days.

Redpolls are found throughout the study region. Most breeding activity, including fledgling, was completed by the first week of July.

Savannah sparrows were the most numerous birds in the area, being found in all terrestrial habitats. Nesting began in early June. In 1973, the first chicks had hatched by June 23.

The tree sparrow appeared as numerous as the savannah sparrow in upland habitats. In 1973, nesting began during the first week of June.

Fox sparrows were seen regularly near Parsons Lake. Nesting in the study region had begun by mid-June.

Lapland longspurs were the common passerine where shrubs were short or virtually absent. They began nesting in early June, and most hatching occurred during the fourth week of June.

Moulting

All birds moult at least once each year. Waterfowl lose all their flight feathers at once and for a time cannot fly. The timing of moult in waterfowl is closely related to reproductive activities, with nonbreeding birds tending to moult much earlier. In the study area pintail drakes were first observed moulting in both 1972 and 1973 by the first week of July. Other dabbling species were moulted shortly afterward, while diving ducks, geese and swans were still ably to fly several weeks beyond the first of July. By the third week of August most geese and male diving ducks were again flying, but some female diving ducks did not finish moulting until early September.

Dabbling ducks were not observed in large concentrations during moult, and diving duck species were found almost entirely on upland lakes.

Fall Migration

The term "staging" is used to describe the unusually large concentrations of birds just before migration. Within the study area the most spectacular are those of snow geese.

Arctic loons did not depart in any significant numbers until the second week of September. From then until the end of September the departure appeared to be rather gradual. Most arctic loons from the Mackenzie Delta migrate west along the Alaskan coast, passing south through the Bering Strait to wintering grounds along the west coast of North America.

No premigratory concentrations of whistling swans were observed in the study region. Most birds appeared to leave breeding and moulting areas in small groups.

From the Mackenzie Delta some whistling swans travel southeast to spend the winter in the Chesapeake Bay area.

White-fronted geese started to congregate in late August and reached their peak numbers during the first week of September.

Most ducks departed between September 9 and September 18. Premigratory flocks were small.

Although a few sandhill cranes were recorded as late as mid-September in 1973, the peak of departure was earlier. Sandhill cranes from the Mackenzie Delta fly up to the Mackenzie Valley and along the Alberta-Saskatchewan boundary.

Staging of shorebirds spanned a long period: late June to early September. The early staging flocks left the north and formed the vanguard of the southward migration, arriving on the plains in July. The major exodus was not until August. Where departing Mackenzie Delta shorebirds ultimately winter is not known.

Glaucous gulls do not show any increased tendency to form flocks during the fall. In 1973 the early departure of glaucous gulls was gradual, but after

September 18 there was a definite exodus from nesting areas. It is likely that most Mackenzie Delta glaucous gulls winter on the Pacific side of North America.

Arctic terns do not congregate into conspicuous staging flocks before departure. The last time arctic terns were obvious in the study region was during the last week of August; the main departure took place during the third week. Arctic terns from the Mackenzie Delta migrate to the southern hemisphere via the Pacific Ocean.

The most conspicuous premigratory flocks of passerines were redpolls and Lapland longspurs. Flocking was less noticeable in tree and savannah sparrows. The savannah sparrow appeared to be the first to depart. Peek departures of Lapland longspurs and tree sparrows appeared to be during the fourth week of August.

Willow ptarmigan, rock ptarmigan and the common raven are permanent residents, and snowy owls and snow buntings spend most of the winter in the study region.

Birds of the Parsons Lake Area

The Parsons Lake Area is characterized by shrub-dominated plant communities and numerous lakes but was remote from Mackenzie River channels. Lake surface made up over 35 per cent of its total area. Terrestrial sections were dominated by shrub communities (mostly dwarf shrub-heath). Well-developed drainage systems were present, draining into both Parsons Lake and the nearby Eskimo Lakes.

The birds of the Parsons Lake group reflected both the high proportion of aquatic habitats and the shrubby nature of the upland habitats. The area has high indices for loons (particularly arctic) and three species of diving duck: greater scaup, oldsquaw, and white-winged scooter.

Owing partly to differences in climate and vegetation, several species occurring at Parsons Lake were uncommon or absent elsewhere: they included common loon, lesser yellowlegs, gray-cheeked thrush and northern waterthrush.

Spring Migration

Like other areas of upland habitat, the Parsons Lake group was not used extensively by birds during spring migration.

Breeding Period

High breeding densities of loons and diving ducks characterized the Parsons group. At least one tern colony was present, but there was no evidence that glaucous gulls bred in the area. No geese were observed there during June, although nearby areas supported moderate numbers of white-fronts. Gray-cheeked thrush, yellow warbler, northern waterthrush, Harris' sparrow, white-crowned sparrow and fox sparrow were common breeding species.

Brood Rearing and Moult

The Parsons Lake group had the highest indices for young birds observed during aerial surveys, especially for whistling swan and oldsquaw. During ground surveys high densities of young were also recorded for arctic loon, greater scaup, white-winged scooter and willow ptarmigan.

Most male diving ducks had disappeared from the breeding lakes by mid-July and it was assumed that they moulted elsewhere.

Fall Migration

No staging concentrations were observed in the area but snow geese, white-fronts and swans flew past in a southerly direction.

Summary

The birds of the Parsons group are characteristic of an area with a high proportion of aquatic and shrubby terrestrial habitats. Above-average numbers of breeding loons and diving ducks were present in June and reproductive success in loons, swans and diving ducks was high. No migratory concentrations were observed.

The Parsons Corridor extends southwest from the Parsons group for a distance of about 20 miles. The area slopes gradually downward from either end to a midpoint roughly adjacent to Bonneville Point on the Eskimo Lakes. This central lowland is fairly extensive, includes many lakes and tends to be poorly drained. The major vegetation type in this lowland is *Eriophorum* tussock. Toward either end of the corridor the vegetation becomes largely dwarf shrub-heath.

Potential Impacts

Construction of all-weather roads near the proposed gas-plant site and associated wellsite clusters would directly remove some bird habitats.

Approximately thirty miles of permanent roadway are planned in the Parsons Lake area. These roads would remove an area of cover made up mainly of dwarf shrub-heath, high centred polygon and sedge-herb (meadow). Limited areas of low-centred polygon, medium willow and alder would also be included.

No high concentrations of any bird species were observed in the area proposed for development near Parsons Lake. Diving duck indices were high, but since these birds spend nearly all their time on medium to large lakes and were observed to be relatively undisturbed by nearby exploration drilling, no adverse effect would be likely from road construction.

Regular use of roads by men and equipment would tend to maintain the effects of their construction, but probably to a lesser degree, as most birds using areas near roads adjust to the presence of men and equipment. Many species would use the roads as a source of digestive gravel, at the expense of a few losses from road deaths.

Construction and use of winter roads might have a very slight effect on ptarmigan winter habitat. Most willow ptarmigan winter in areas characterized by willow thickets, but a small fraction of the population remains in upland areas, where similar habitats are available. Some winter roads would cross upland willow stands and temporarily modify a small fraction of these habitats.

Boat traffic would have little or no effect on birds, as few use main channels during the ice-free season. Restricting boat traffic on small lakes would reduce disturbance to moulting waterfowl using those areas. Regulations against travel to or through concentration areas would be a further safeguard.

Barges, because of their size, are restricted to Eskimo Lake, which is used by very few birds.

The airstrip associated with the Parsons Lake Gas Plant would cover resting grounds. When in use besides the direct and indirect effects outlined under Airstrip Construction, there would be a further indirect effect at either end of the runway because of low-level approaches and take-offs. Maintaining the fastest rates of descent and climb that can be carried out safely would keep any disturbance with a limited area.

At landing sites, the helicopter's ability to make a steep descent should eliminate approach area effects. Even under adverse conditions, effects should be well within the boundaries of secondary effects already outlined for plants, clusters and other facilities where landing pads would be located.

As observations in the study area in 1972 and 1973 showed little difference in bird reaction to helicopters and to fixed-wing craft, no distinction has been made between them when estimating impact.

The construction and use of staging sites would cause and maintain much the same indirect disturbance as in the case of all-weather roads. On abandonment, a site would remain bare until vegetation could be re-established. Some species - sandpipers, gulls, terns and perhaps geese - might nest on abandoned gravel staging sites. Many species might use the grit as a digestive aid and the abandoned pads as loafing spots.

Gravel excavation in the Parsons Lake area for roads, pads and airstrips would have some direct and indirect effects on birds, but as source sites are not yet chosen these cannot be accurately estimated. As in the Ya Ya Lake area, gravel pits near Parsons would have a slow rate of recovery and birds could not use them for some time after abandonment.

Four to six cluster facilities are planned for the Parsons Lake gas plant. As pre-construction activities and pad construction would be carried out primarily in winter, they would not disturb migratory birds.

Development drilling activities and establishment of permanent facilities at each cluster site would proceed continuously until completion. After that, normal operations might lessen the effects on birds, but there would still be work-over drilling, probably for the life of the cluster.

Production wells would be drilled regularly at cluster and gas-plant locations for two years after initiation, and intermittently after that. The effects would be similar in kind and degree to those described for cluster construction, but would continue for longer.

Work along the pipeline right of way would require some clearing and destruction of avian habitat, particularly willow stands which are easily damaged by winter equipment. Such damage would affect only small areas, and while ptarmigan and shrub-dwelling passerines might have to abandon them, other species adapted to open or ecotonal habitats could be expected to move in.

Pipelines would be inspected regularly from the air and every spring and fall from the ground. Low-level aerial inspection would disturb some birds near the right of way. Some nests of loons, ducks and geese might be lost because of eggs being broken or seized by predators when incubating birds were disturbed. Reducing the number of inspection flights during the breeding season (May 20 to July 20) could lessen this risk.

Construction of gas-plant facilities would affect birds in much the same way as construction of permanent roads: directly by destroying habitats and indirectly by the presence of men and equipment. An area of 30 acres has been assumed for the gas-plant site.

Noise levels during gas-plant operation are not expected to be greater than 65 dBA at a distance of 500 feet outside the plant lease boundary, and would be generally constant except for flaring. Their effect on birds would not be greater than the estimated disturbance from other sources. Most bird species were observed to adjust to constant noise levels from drilling operations.

Observations elsewhere, near airports and similar gas plants, indicate that many birds can adjust to the noise from large jet landings and take-offs, and from plant operations. An estimated 5,000 lesser snow geese enroute to the north were observed on several occasions by F. F. Slaney & Co. personnel to continue feeding, without flight response by any individual, as large jet aircraft landed at the Vancouver International Airport, April, 1974. The birds fed in foreshore marshes with the jets less than 500 feet overhead.

A pair of mallards was observed using a surface run-off pond less than 200 feet from the perimeter of the gas plant at Cochrane, Alberta and about 500 yards from the compressors. They were apparently nesting nearby. Again, several pairs of pond ducks apparently on nesting territory were seen in the vicinity of the Alberta Gas Trunk Line plant near Princess, Alberta, in May of 1973. Mallards, pintails, widgeon and bluewinged teal were in ditches, dug-outs and sloughs within ½ mile of the plant. The closest pair were mallards, approximately 200 yards from the compressors. Several small water bodies close to the plant contained no birds.

Nesting geese and migrating geese in the north have not been observed to adjust fully to high noise levels. There is in fact some evidence that they may be unable to do so. Migrating snow geese exposed to gas-compressor simulators on the Yukon North slope were significantly disturbed in their movements and activities, at first as much as three miles from the sound source, but after continued exposure only within 1.5 miles. Geese when migrating react to disturbance very readily, perhaps more than at other times, which may partly account for these extreme ranges.

The results of the North Slope gas-simulator experiment suggest that some migrant birds might be deflected by sound emissions. No large flights of fall migrants have been observed or would be expected near the Parsons Plant.

Migration concentrations in spring were smaller than in the fall. The ones observed were along the coast and out of range of any anticipated noise disturbance.

Increased levels of sound are anticipated during "flaring", which would take place at irregular intervals depending upon operational difficulties. The amount of increase is not known but the effect should be similar to that of the testing process of exploration wells. High-intensity sound emitted over short periods at irregular intervals could disturb nesting geese near the plant, with the same effects as described under pipeline inspections. Studies of the effects of gas-compressor noise on other terrestrial nesting birds suggest that it has little effect on nesting success.

Personnel activities would have little effect on birds as a policy of no guns in camps will be strictly enforced. Photographing or observing wildlife near campsites might cause destruction of a few nests, but the difficulty of the terrain would restrict these activities to small areas. On the whole, such interest might have a net positive effect in that it both encourages environmental awareness and provides a recreational outlet. High-density waterfowl and colonial nesting sites would be avoided in season, however, and undue harassment prevented by regulation if necessary.

Removal of development facilities and pad materials would have the effects described for their placement.

Plans include reseeding with native plsnts and if necessary using fertilizers to speed re-growth on affected areas. This treatment should eventually return affected areas to a condition close to their original form and carrying capacity.

Total numbers of nesting birds expected to be displaced by a normally operating system of production wells, gas plants and associated activities are small when compared with the numbers of birds estimated for the study region.

3.53 Aquatic Life

The fishes inhabiting the Delta must be able to cope with wide fluctuations in the aquatic environment. Not surprisingly, the number of species in the Mackenzie Delta is limited in comparison with more southerly delta-estuarine ecosystems.

Eighteen species of freshwater fish are known from the Delta, and of these, eight are used for commercial or domestic purposes, including human consumption and dog food. The most important species is the broad whitefish. Four marine fish species were also taken in the offshore surveys, but none are utilized in a domestic fishery.

The fish fauna of the lower Mackenzie Basin has been described on numerous occasions since the 19th century (Macoun, 1888; Gilbert, 1895; Preble, 1908; Bethune, 1937; McAllister, 1962; McPhail & Lindsey, 1970). Hatfield et al. (1972) sampled fishes in the middle and lower reaches of the Mackenzie drainage system as part of a systematic inventory carried on by Stein et al. (1973). They gathered baseline data on species composition, age, growth, feeding habits, movement, length-weight relationships and spawning characteristics. No fish were collected in the outer Delta region, however.

Within the last four years, similar work has been carried out along the proposed route of the Alaska - Mackenzie Valley pipeline by several consulting firms. To date, the most encompassing studies of this type have been described in the interim reports of the Environmental Protection Board (Shotton, 1971, 1973) and in the Arctic Gas Biological Report Series (P. J. McCart, ed., 1974). The latter not only deals with baseline data, but also includes studies on the effects of pipeline construction and methanol toxicity on northern fishes.

Published information on the aquatic invertebrates and plankton of the Mackenzie Delta is limited. Hatfield et al. (1972) recorded invertebrate groups taken from fish stomachs, and Walker (1943 and 1951) described the Odonata of the Mackenzie Delta region. McCart (1974) also recorded fish-stomach contents and reported on a field study of how stream-crossing construction affected the benthic fauna of several small streams near Norman Wells, N.W.T.

Streams

Streams drain local topography or lakes; they are generally shallow (less than 6 feet) and narrow (less than 50 feet), and freeze solid during winter. Streams also differ from channels in that they normally flow in one direction, and their banks are well vegetated. Most streams in the area freeze solid in winter, which limits their use as fish habitat to the open-water period. Then, streams serve as feeding, spawning or rearing areas for some species of fish, and migration routes for others. Most of the streams in the area of Parsons Lake contain large amounts of gravel and rubble. Streams in the Parsons Lake area were characterized by reaches of gravel and rubble with little or no silt.

A further characteristic of streams near Parsons was the occurrence of shallow channel cross-sections in areas of fast water. Most featured shallow, fast-flowing riffles with rubble and gravel substrates.

The life histories, migration routes and timing of movements of many fish species are not well understood and can vary markedly from region to region. There is no published information available on the seasonal use of streams within the study region by resident species, or of the use of streams as migration routes by others. To provide data on possible fish movement before freeze-up a trapping program was conducted in September and October.

Two-way fish traps were installed on September 13 - September 15, when the water temperature was 7.5°C., and removed October 7 because of icing conditions (water temp = 0.25°C). Water temperatures were taken regularly throughout the trapping period. The outflowing stream of Lake 49 (Parsons Lake) was trapped to determine: 1) if any movement of humpback whitefish or least cisco between Parsons and the Eskimo Lakes, and 2) the occurrence and direction of any movement of grayling.

One lake trout and two pike were taken in the Parsons Lake trap over a five day period in late September when water temperatures ranged from 3.5-6.5°C. All three fish were moving upstream. This appeared to be a casual movement out of summer habitat and not part of a major migration. No coregonids or grayling were taken in the trap, and stream seining during the trapping period produced no fish. McCart et al. (1972) and Reed (1964) found that summer-resident grayling populations moved out of the streams in late summer or early autumn. Adult and juvenile grayling were taken from the outlet of Parsons Lake during the summer. Apparently these fish moved out of that stream before the trap was installed. It is not known if they overwinter in Parsons or in the Eskimo Lakes.

Most of the stomachs of the fish species taken in streams were empty. Notable exceptions were those of the grayling, many of which contained stickleback and trichopteran larvae. Bottom samples showed that streams produce considerable amounts of bottom fauna during the summer months, primarily dipteran larvae, trichopteran larvae, and ephemeropteran nymphs.

Juvenile arctic grayling use Streams D, H and L as rearing areas. The presence of suitable spawning sites suggests they may also spawn there. Spawning would occur shortly after break-up.

Ninespine stickleback, also known to be stream spawners, utilize aquatic vegetation (McPhail and Lindsey, 1970) and probably spawn in the quiet backwaters of streams on Richards Island and in the Parsons Lake area. Stream mouths and lower reaches of streams are probably used as rearing areas by other species. While some fish species may not spawn in the streams, they undoubtedly use them as migration routes to spawning areas. Fish of this group include: broad whitefish, anadromous least cisco, inconnu and northern pike. The latter species migrates from lakes to marshy areas inundated by spring flooding (Robertson, 1969). Several streams with large spawning runs of inconnu and broad whitefish occur on the Tuktoyaktuk Peninsula.

Lakes

Lakes consist of standing water, although some channel lakes may have a slow directional current. In the Mackenzie Delta, lake basins and lakes were formed through thermokarst or abandoned river channels and flooded valleys. Consequently, there is considerable variation in physical and chemical features.

The lakes in the Parsons Lake area are located on upland sand and gravel formations and are characterized by gravel shoreline and the high topographical relief of the surrounding terrain. Generally, upland lakes have transparency ratings exceeding 200 cm. and often contain populations of lake trout. Lakes of this type are isolated from the Delta channel system and are not subjected to annual flooding or storm surges.

For the survey, upland lakes were divided into two categories: 1) Upland-deep lakes - those with a maximum depth exceeding three metres. 2) Upland-shallow lakes - those with a maximum depth of three metres or less, and thus probably subject to annual winter kill.

During 1972, a total of 185 stomachs were found to contain food items. Most of the fish that were weighed, sexed and measured during the 1973 field program were also subjected to stomach-content analysis. Of 1,008 stomachs examined, a total of 573 contained recognizable food items.

The least cisco, a pelagic-feeding species, feeds primarily on zooplankton and the larger, free-swimming crustaceans, frequently supplementing this fare with ninespine stickleback. The two bottom-feeding species examined, broad whitefish and humpback whitefish, feed to a large extent on mollusks and amphipods. However, the humpback whitefish uses a wide spectrum of prey groups. Isopods and dipteran larvae occurred frequently in stomach samples.

Of the three predatory species listed, lake trout appear to have been the least-selective feeders, utilizing all the prey organism groups. Nevertheless, fish were the items most often observed. Pike in the study region were also fish-consumers, but used fewer auxiliary food sources.

Inconnu appeared to be casual users of most of the available prey groups, but chiefly the larger crustaceans. Mysids, isopods and amphipods occured in 76 per cent of the inconnu stomachs, with fish represented in only one-third of the total. Most of the fish netted in the lakes program are known to use lakes for spawning; these include humpback whitefish, least cisco, lake trout, northern pike, longnose sucker and burbot. Broad whitefish, boreal smelt and inconnu were also netted in lakes in the study region. However, these species are generally anadromous and prefer streams for spawning. Only one inconnu netted in lakes appeared to be in spawning condition.

Suitable spawning sites for coregonids and lake trout exist in all of the upland lakes that were examined.

Aquatic Life in the Parsons Lake Area

The N-10 covers a small portion of Parsons Lake (Lake 49), Lake 53, a number of small upland-high and upland-shallow lakes and several miles of small lake-connecting creeks.

Parsons Lake has a calculated area of 22.49 square miles or 14,394 acres and a calculated volume of 149,846 acre feet. The mean depth is 10.4 feet and the maximum depth 27 feet. The outflowing stream would appear to allow fish passage between Parsons and the Eskimo Lakes. The predominant substrate type is muck and mud with deposits of sand and fine gravel in some areas.

Aquatic Vegetation

Potomogeton sp., *Myriophyllum* sp., *Ceratophyllum* sp. and *Chara* sp. were found over much of the lake. The first three were present at depths of 12 feet or less, and the last at depths up to 22 feet.

Bottom Fauna Collected

	Date = 120773
Oligochaeta	99
Amphipoda	5
Chironomidae	48
Pelecypoda	174
Gastropoda	25

Avg. depth sampled (ft.)	11.5
No. of dredgings taken	13
No. of productive dredgings	13
Avg. no. organisms/dredge	27.0

Fish Fauna

The numbers and species of fish taken are listed below:

	No.	c/ue
Least cisco	104	0.45
Humpback whitefish	74	0.32
Lake trout	50	0.22
Northern pike	67	0.29
Burbot	8	0.035
	303	1.32

c/ue - No. of fish per hour per standard gang net of 250 feet.

All these species are probably lake residents the year round. It is not known if any grayling overwinter in the lake.

Lake 53

Lake 53 is a small upland-deep lake containing arctic grayling, burbot and ninespine stickleback.

Other Lakes

The other small upland-deep and shallow lakes in the radius may contain grayling, pike, humpback whitefish and least cisco.

Streams

The streams in the N-10 area vary 1 to 5 feet in width and from 0.2 to 2 feet in depth. Two grayling were observed in Stream 13, a typical small stream, but it is not known if they utilize other small streams. Concentrations of fish occur in Parsons Lake in spring around the mouths of tributary streams. Pike utilize the lower reaches of these tributaries throughout the summer.

K-09 Area

A two mile radius around the K-09 site covers a portion of Parsons Lake (Lake 49), Lake 53, a number of small upland-deep and shallow lakes, four miles of Stream D, 1.25 miles of Stream L and several miles of small lake-connecting creeks. Stream D is located on the outer fringe of the site radius and will be described in the Parsons corridor section.

Streams

Stream L

Physical Characteristics

The first 100 feet of Stream L is unlike the rest of it. This uppermost portion of the stream is 18 to 30 inches wide, one to four inches deep and has a current of 1.25 feet/second. The substrate is composed of several inches of walnut-sized gravel underlain by sand. Further downstream the stream enters a swampy area, becoming a series of deep pools with restricted access between.

Aquatic Vegetation

No aquatic vegetation was observed in the stream.

Fish Fauna

It is likely that the upper portion of the stream is a spawning area for grayling from the lake. Five grayling fingerlings and an immature grayling were collected in that part. It is not known if the stream is a grayling Migration route between Lake 53 and Stream D.

Other Streams

Other streams in the K-09 area vary from 1 to 5 feet in width, and from 0.2 to 2 feet deep. It is not known if grayling utilize these streams. Concentrations of fish occur in Parsons Lake in spring around the mouths of tributary streams. Pike utilize the lower reaches of these tributaries throughout the summer.

Parsons Corridor

The Parsons Corridor covers a large number of upland-deep and shallow lakes, including Lakes 49, 53, 54, 57, 58, 59 and 60 and portions or all of Streams D, H, I, and J.

Stream D

Physical Characteristics

Stream D flows from Parsons Lake into Eskimo Lakes, a distance of approximately 14 stream miles, 5.5 miles of which is within the Parsons corridor. The stream is a series of pools and riffles. It is 15 to 30 feet wide and 2 to 6 feet deep. The current varies from 3.5 feet/second in riffles to 1 foot/second in pools. Riffle substrate is rubble and gravel and pool substrate is silt and gravel. The water is clear.

Aquatic Vegetation

Small amounts of Potomogeton sp. occur in slow riffles and pools.

Bottom Fauna Collected

Four 1-cubic-foot basket samples and a Surber sample were taken in July and August, 1973. The following organisms were collected:

Chironomidae	136
Tipulidae	1
Tabanidae	4
Simulidae	19
Ephemeroptera	77
Trichoptera	64
Oligochaeta	3
Pelecypoda	1
Gastropoda	1

Fish Fauna

Adult and juvenile grayling were collected from the stream. It would appear that a large population of grayling uses it for spawning and rearing and as summer habitat. The stream is also used as summer habitat by northern pike. Small numbers of other fish such as humpback whitefish and lake trout probably use the creek on a casual basis. The grayling probably move into the creek after spring break-up and stay throughout the summer.

Stream H

Physical Characteristics

Stream H originates in the hills southeast of Parsons Lake and flows approximately 40 miles into the Eskimo Lakes. About 1.5 miles of it is within the Parsons corridor. The stream is 15 to 40 feet wide and 3 to 5 feet deep. Some pools were 5 to 6 feet deep. The stream current was 1 to 3 feet per second. The substrate type was rubble and gravel. Sand and gravel bars occurred along the stream, suggesting considerable fluctuation in water levels. The water was clear.

Aquatic Vegetation

No aquatic vegetation was observed in this stream.

Bottom Fauna Collected

Three Surber samples and two 1-cubic-foot basket samples were taken in August, 1973. The following organisms were collected:

Chironomidae	138
Tipulidae	15
Simulidae	4
Ephemeroptera	68
Trichoptera	19
Oligochaeta	8

Fish Fauna

Large schools of grayling fingerlings (48-59 mm) were observed and collected in the pools. In addition, two mature grayling were observed but not collected. The stream appears to be utilized by grayling as spawning, rearing and summer habitat. It is not known if these fish overwinter in lakes connected to the stream or in the Eskimo Lakes.

Stream I

Physical Characteristics

Approximately three miles of Stream I are within the Parsons Corridor. The stream is 20 to 40 feet wide and 2 to 3 feet deep. The current is less than 0.25 feet/second. The substrate type is muck and mud and the water is moderately silty.

Fish Fauna

No fish were taken in seine hauls and the stream does not appear to be utilized by fish.

Stream J

Stream J connects Lakes 57, 58 and 59 to Parsons Lake. The lower reaches contained pike. Movement of fish between Parsons Lake and Lakes 57 to 59 is uncertain, as no fish were taken in test nets set in the latter lakes.

Other Streams

The tributary streams of Lake 60 do not appear to be utilized by fish.

Lakes

Lakes 49 and 53

Lakes 49 and 53 are given in the N-10 site description.

Lake 54

Lake 54 is a small upland-deep lake containing humpback whitefish and northern pike.

Lakes 57, 58 and 59

Lakes 57 to 59 are upland-shallow lakes connected to Parsons Lake. They do not appear to support fish populations.

Lake 60

Lake 60 is a turbid, upland-shallow lake that very likely does not contain fish.

Other Lakes

The lakes south of Parsons Lake are generally upland-shallow lakes that probably do not contain fish. The lakes east of Parsons Lake are generally small upland-deep and shallow lakes.

Water Sampling Program

In October, 1975 water samples were taken at seven sites in the Parsons Lake area. The samples were analyzed and the results are given in Table 3.5.

Potential Impacts

Construction of roads will result in some soil erosion even though care is taken. Amounts of soil available for water transport will depend upon site locations, road design, and construction methods, including erosion control measures. None of these steps are finalized in the project description. In order to facilitate impact assessment, certain tentative assumptions have been made in these areas. Final project planning will take into account the matter of siltation and, as a result, the tentative siting of roads may change.

Gravel will be moved to the road right-of-way during the winter months and most of the road construction will be undertaken at that time. By limiting construction traffic to the roads, the disturbance of the surrounding vegetation would be limited to the specific area around the road-way and it follows that the total impact would be minimal.

Through proper design and utilization of the roads built during the construction phase of the project the amount of runoff produced along the road network should be minimized and erosion and consequent siltation greatly reduced. During spring and summer months, small amounts of silt would be washed out of the roadbed gravel into some of the adjacent lakes.

Present plans call for approximately thirty miles of permanent roads at Parsons Lake. The volume of silt introduced into the watershed should be very small. It is possible that even small amounts of silt could produce changes in the aquatic ecosystems of the area affected. All possible care should therefore be taken to prevent slumpage and erosion along the permanent road routes in this area. Presumably, some silt would be washed out of the roadbed during spring and summer, but the amount should be negligible. Normal use of all-weather roads at Parsons Lake should not affect the aquatic ecosystems in those areas.

Snow roads and any stream and channel crossings would be built by using snow and water, and traffic limited to the period of freeze-up, to prevent disturbance of the active layer. Properly maintained and used snow roads should have no adverse effects on the aquatic biota.

The major effect of stream-crossing construction for permanent roads would be increased stream siltation. Adequate culverts would be needed to avoid obstruction of fish movements. The effect of silting would depend on the volume of silt released, how long siltation lasted, the character and length of the stream involved, and the aquatic biota in the receiving waters. The use of bridges or improved (instead of standard) culverts for streams utilized by populations of migratory fish would allow the fish unrestricted movement.

At Parsons Lake, there would be some siltation of streams and receiving lakes, but the precautions planned impact on biota would be minor. Construction in winter means that most silt would flush with the spring runoff, when natural loads are highest. Soils should be stabilized by mechanical means to reduce persistent siltation, which could otherwise affect grayling eggs in spawning gravels or invertebrates in rubble substrates.

Stream D supports populations of summer-resident arctic grayling and northern pike. The grayling utilize the stream for spawning and rearing of young. The riffle areas were found to support high-density populations of invertebrates such as mayflies and caddisflies, which are important grayling food items. Schools of grayling fry and fingerlings were found or observed in pools and backwater areas. All activities would involve access to unexploited or almost unexploited fish populations. During construction this access would be of short duration and any impacts would be minimal.

3.6 LAND AND RESOURCE USE

The native population of the Mackenzie Delta is composed of people of Indian and Eskimo origin. The indigenous Eskimo population, descendants of the Thule tribe, was decimated by disease brought by whalers during the late 1800's. Since then, other Eskimos have immigrated from Alaska. Delta Indians are mostly of Loucheux Athabasca origin, centred to the south. The northern boundary of their territory historically extended to the point where the Peel River enters the Mackenzie Delta, but more recently they have moved as far north as Tuktoyaktuk.

The Delta was first explored in the late eighteenth century. However, trading establishments were not developed until the fur trade initiated them in 1840. Expansion of the fur trade drew Eskimo and Indian trappers closer to the trading posts. This in turn produced a need for community activities and provided a basis for an urban economy and a settlement life-style.

The native populations of the major Delta communities can be divided into three segments: 1) people who live on the land, 2) people who live in the communities but do not have continuous wage employment. People who live on the land require certain staples that the community supplies, but rely on the resources of the land for their livelihood. The number of natives living by the traditional methods is declining. Smith reported that in 1965 the intermediate group (i.e. those with occassional wage employment) was the largest. These people rely on fishing and hunting for some of their income and as a supplement to a diet of purchased food. A small group of natives have adopted a completely urban life-style; they may occasionally hunt and fish, but for recreation rather than subsistence.

The same three categories apply today but the proportions have changed. The number of people relying solely on country resources has probably declined further.

Today, the Delta region including Tuktoyaktuk contains over 5,000 people and represents one of the most densely populated areas in the Northwest Territories outside Yellowknife. There are no permanent residents in the study region, but there are oil and gas industry base staging camps that are used the year round.

From Inuvik north, there are 4,500 permanent inhabitants, of which about 3,000 are natives. There are also hundreds of transient personnel associated with the oil and gas industry.

At the last census the three major communities of Aklavik, Inuvik and Tuktoyaktuk accounted for 11 per cent of the population of the Northwest Territories. Continued development of the area can be expected to increase the populations of those communities further still.

Inuvik

Inuvik is the largest population centre in the Delta. It was established in 1957 to replace Aklavik as the centre of administration for the region. Its population for 1974, according to Forth, was 3,029. In 1971 it was 2,546. Most of Aklavik's native population did not move to the new townsite, so that Inuvik is a predominant white community. About 30 per cent of its inhabitants are natives.

Aklavik

Aklavik was established in 1912 as a fur-trading post by Northern Traders, a fur company. It was the original government centre for the region. However, by the 1950's the government facilities had expanded to such a degree that the townsite was strained to its capacity.

A new townsite was decided on and Inuvik was established. Aklavik's population in 1974 was 759, with over 70 per cent of Indian and Eskimo origin.

Tuktoyaktuk

Tuktoyaktuk was established in 1934 by the Hudson Bay Company as a focal point for barging supplies and goods down the Mackenzie River. It was originally named Fort Brabant. Most of its population is of Eskimo origin. In 1974 there were 669 persons.

The Distant Early Warning (D.E.W.) line provides permanent employment for some of the residents of Tuktoyaktuk. Many also work in the oil industry.

Reindeer Station

Reindeer Station was a small community originally established for the families of the reindeer herders and for the administration of the Reindeer Grazing Preserve. Its recorded population in 1966 was 76. However, in 1971 only one family lived there. There were none in 1973.

Kittigazuit

Kittigasuit was a major Eskimo settlement and had an estimated population of 1,000 when Dr. John Richardson visited there in the year 1826. The Hudson Bay Company established a trading post at Kittigasuit in 1912. There are no permanent residents now, but the site is used as a fishing and whaling camp by Inuvik and other Delta residents.

East Whitefish Station

East Whitefish Station does not have a permanent population but Aklavik residents use it seasonally as a fishing and whaling camp.

3.61 Resource Allocation

The region of interest lacks a large-scale resource-based industry or substantial commerce, and its population is largely dependent on exploitation of the land's resources. Some activities covered by permit or lease are identified in the following sections.

Land and Soils

The study region is encompassed by Land Management Zone 2 and as such is subject to the Territorial Land Act. Under these and other federal statutes, exploratory permits for hydrocarbons have been granted to several companies. Land-use permits have also been extended for quarrying gravel. Quarrying sites currently in use are at Ya-Ya Lake and east of Parsons Lake. A survey of possible gravel sites has been undertaken recently. Seismic surveys are also being carried out in conjunction with hydrocarbon exploration in the study region.

Water Resources

The Mackenzie River is the major water source for most Delta settlements. There is some available groundwater in the study region but it is not used domestically. Heavy silting of the Mackenzie causes its water to remain turbid and undrinkable in summer unless treated. However, in winter the Mackenzie provides an adequate source of drinking water in most reaches: Inuvik supplements a lake reservoir with water pumped from the river in winter.

Native Trapping Areas

Group trapping areas are negotiated every five years at a meeting of the Mackenzie Delta Trappers Association. Parsons Lake is a group area trapped by Tuktoyaktuk people. Trappers do not regularly harvest it because furbearer populations are not attractive enough and access is difficult.

No official records are available of the number or origin of trappers that used the study region in 1972-1974. However, trapping effort was at a very low level in both years. Some casual trapping of foxes is done by people travelling through the area. In 1972 and 1973, small numbers of foxes were taken around mainland camps and rig sites by travelling Tuktoyaktuk people.

3.62 Utilization of Birds

The study region is a nesting ground for large numbers of migratory and resident species. Geese, ducks and ptarmigan are most commonly hunted.

Sale of migratory game birds is prohibited. Bird hunting is a traditional source of food for natives and a recreational activity to both natives and others.

Ptarmigan

Natives hunt during the course of other activites from September to early May. The birds provide an alternative food to fish and whale meat.

Since birds are shot opportunistically for food at all times of the year, records of the total number harvested are estimates that suggest relative quantities rather than actual returns.

Ptarmigan are harvested in greater numbers than geese or ducks, probably because of their relative abundance and year-round availability.

Geese

Geese are hunted in spring when they first congregate in areas of open water, and in late August and September during the fall migration. Snow geese make up the largest percentage of the Delta harvest, while whitefronts are taken less frequently. Though some down feathers are saved for clothing, ducks and geese are valued primarily as a source of food.

Ducks

Ducks are taken when available. There are now known duck-hunting areas in the study region at which native hunters gather. Hunting returns group all duck species. Little is known of the kinds of ducks killed.

Aesthetical and Recreational Uses of Birds

Geese and ducks are hunted in a limited fashion within the study region by non-native residents. Despite large numbers of birds, outsiders are not attracted to the Delta to hunt waterfowl. The same flocks, however, are hunted extensively by sportsmen during their migration south. Naturalists and bird watchers also depend on the southerly migration for recreational purposes. At present migratory birds that nest in the study region are of greater recreational significance in southern areas than in the Delta.

3.63 Commercial Utilization of Mammals

Many natives rely on trapping for part of their income. Hunting in the region of interest is primarily opportunistic. The reindeer herd is a source of income for only a few residents of Tuktoyaktuk. However, it is important as a local source of fresh meat.

Reindeer

The reindeer herd is currently managed by one Eskimo. In winter he hires three or four herders, but at the summer roundup many more are hired and may be paid in cash or meat.

Management problems and other difficulties saw the herd reduced beyond harvestable levels by 1968. The Canadian Wildlife Service took over its management until it was sold in 1973. There are currently several thousand animals under management.

The herd is summered on the Tuktoyaktuk Peninsula. Currently they are wintered near Parsons Lake, but cannot be sustained there every winter because of range limitations.

Caribou have in the past associated with the main herd, producing generally unidentifiable offspring. Caribou-reindeer mixed herds may exist in the taiga southeast of Eskimo Lakes.

Trapping

Most trappers earn relatively little from their lines, but a few, especially in recent years of higher fur prices, do well by northern native standards. Trapping is generally used to supplement income from other sources.

Muskrats are abundant on the upper Delta and account for almost half the income of Inuvik trappers and two-thirds the income of Aklavik trappers. Trapping usually does not begin until air temperatures are high enough so that traps set in pushups will not freeze in solidly.

Arctic foxes provide two-thirds of the income of Tuktoyaktuk-based trappers, but are only of minor importance to Inuvik and Aklavik trappers. Although sales of white fox skins yield the highest percentage income, cross foxes currently bring the same price per pelt. Tuktoyaktuk trappers normally concentrate their fox-trapping efforts along the coast and occasionally the barrier islands.

Hunting

Caribou are an important source of meat and income for Delta hunters. They are hunted by people from all communities during the summer in the Richardson Mountains, and by Tuktoyaktuk people in the Anderson River area in winter. Since caribou hunting is restricted in the Reindeer Preserve, few animals are taken in the study region. In 1971-72 approximately 1,160 caribou of the Porcupine Herd were taken by people from Inuvik, Aklavik and Tuktoyaktuk. In the same year 440 caribou were sold for about $25,000 in the Inuvik region.

Domestic

Few natives depend entirely on the land for their domestic needs but many supplement their diets with wild game. The whale hunt is an important cultural activity that still yields large harvests. The 1973 harvest was approximately 177 animals. Whaling camps are run from late June to early August. Aklavik hunters camp to the west of Shallow Bay at West Whitefish Station, Bird Point or Shingle Point. Inuvik residents hunt in Kittigazuit and Kugmallit Bays from camps based at Kittigazuit, Indian Camp and Whitefish Station, or in Mackenzie Bay from a Kendall Island camp. Hunters from Tuktoyaktuk and Inuvik took the largest percentage of whale harvest in 1973.

The whale meat is processed by the wives and children of the hunters. The government has begun a program of transporting women to camps to accelerate processing and therefore increase the harvests, which are limited by the amount that can be processed. Muktuk and dry meat are the major products.

Recreational Use of Mammals

Sport hunting of mammals is virtually nonexistent within the boundary of the study region. Sport hunting of caribou and reindeer is prohibited in the Reindeer Grazing Presêrve. The barren-ground grizzly bear is considered a threatened population and may be shot only by General Hunting Licence holders.

Occasionally native hunters will charge tourists who wish to accompany them whaling. However, whales are primarily a domestic resource.

3.64 Utilization of Aquatic Resources

A commercial fishery for broad whitefish has been financed by the federal government. Processing is done at the mouth of Holmes Creek. Fish are netted in the creek and in adjacent sections of East Channel. The fish are gutted, frozen and sold locally in Inuvik.

Domestic Use

Fish form a high percentage of northern diets and are eaten raw, dried, and frozen as well as cooked. They are also a major source of dog food. Therefore, domestic fisheries play an important role in the Delta. Fish species most frequently netted in the 1973 season included broad whitefish, inconnu and humpback whitefish.

Fish camps are often combined with whaling camps and the close of the whaling season also ends the summer fishing. Kittigazuit and East Whitefish station are used as summer fishing camps by Inuvik residents. Gillnets are used to catch whitefish and inconnu. The fish are split and either smoked or dried. An average season's catch was reported to yield about five bales per family (one bale consists of sixty dried fish).

Aklavik residents fish along the coast between Herschel Island and Shingle Point. They occasionally net Arctic Char but their catch and methods are similar to those described above. They also extensively fish the Mackenzie near the settlement and in nearby tributaries. In the late fall, loche and pike are jigged through the ice. These catches are frozen and used in the winter for dog food.

Tuktoyaktuk residents catch their fish locally, mainly for human consumption and secondarily for dog food. Some domestic fishing is done in winter on the Eskimo (Husky) Lakes.

Inuvik fishermen also set nets locally in the Mackenzie River.

Few fish are caught for any purpose in the area to be directly affected by the hydrocarbon development project.

3.7 SCIENTIFIC USE, AESTHETICS & ARCHAEOLOGICAL SITES

Traditional use of the study region's renewable resources for the above purposes gives them a special kind of work that is difficult to measure or evaluate.

Scientific Use

Since the Delta visits by Posild (1943) and Cowan (1947), the upper and middle Delta have been the scene of an increasing number of faunal inventories and research studies of varying kinds. Muskrat, beaver and reindeer have been the topics of detailed population habitat and range studies by Canadian Wildlife Service and university personnel. In recent years, Dr. D. Gill of the University of Alberta and R. Hill of the Inuvik Research Station have conducted or coordinated ecological studies. Most recently, pipeline-oriented studies by private firms and government agencies have covered the Mackenzie River to Tununuk Point and sometimes beyond.

Until the last two years, the outer Delta and barrier islands had been essentially overlooked by scientists. The most notable exception is Dr. R. Mackay whose geographic monograph of 1963 ranks as a definitive work. Dr. Mackay has continued his studies primarily on Garry Island. Dr. T. W. Barry of the Canadian Wildlife

Service and others have monitored waterfowl populations for up to 15 years. A. Martell has studied small mammals. Various university specialists such as Dr. Denis Kerfoot, Dr. J. D. H. Lambert and Dr. L. C. Bliss have studied surficial processes and vegetation under the suspices of the Arctic Land Use Research Program and the Arctic Petroleum Operators Association. In the last two years F. F. Slaney & Company Ltd. have completed several baseline and disturbance studies for oil and gas companies and for Environment Canada. Private company research has been conducted into engineering problems.

Aesthetics

To many people, the character of the Delta is one of remoteness and vast distance where faraway objects loom near and sounds travel farther than expected.

During the very short period in June that days are long, the diverse bird population is made conspicuous by territorial defence, and the biting insects have not yet appeared in their customary abundance. Unfortunately it is one of the two seasons of fog and low cloud.

The climate can only be termed relatively inhospitable except for short periods in summer.

The area is wild but not wilderness, in that the presence of man is evident at all seasons and has been in varying degrees for many years. Drilling rigs, aircrafts, boats and trucks are often seen; and staging areas and camps occur along channels.

The use of aesthetic resources by nonresidents has been minimal.

Archaeological Sites

In August of 1975 the Parsons Lake area was inspected by Dr. Roscoe Wilmeth, Chairman, Salvage Program Archaeological Survey of Canada. His report states:

> "Two areas were examined east of Parsons Lake. The first was a patrol of Hans Creek down to Hans Bay, and slightly north to a possible compressor station site. This area had previously been traversed by on-the-ground survey in July, on inspection of two proposed borrow areas along the Inuvik to Tuktoyaktuk section of the Mackenzie Highway. No evidence of human occupation was found here, including the shore of Hans Bay. A possible station site near Zed Creek was examined. This again is low-lying tundra unsuitable for human occupation, and no evidence of use was noted.
>
> Conclusions: There appears to be no danger of disturbance to archaeological sites at any of the proposed compressor station sites, since all are located in muskeg

areas unsuitable for camping, and at some distance from navigable water ways. Travel across these areas would have been feasible only in winter, and no evidence would remain of such hypothetical journeys, particularly in view of the shallow depth of permafrost."

3.8 RECREATIONAL USE

During construction of the Parsons Lake gas producing and processing facilities, recreational use of the land in the project area will be limited by regulations imposed by Gulf Oil Canada Limited and governmental bodies.

The use of firearms will be strictly prohibited to avoid harassment of the wildlife in the area. Seminars will be given regarding the unique environment of the area, and it is hoped that Gulf Canada Limited and governmental personnel will co-operate in implementing a programme of environmental awareness which might include short-sessions in nature study and photography encouraging people working on the project to achieve an awareness of the Northern environment. Such a programme would help to discourage unnecessary contacts between man and the environment in the area which could alter the balance of nature.

The use of recreational equipment such as snowmobiles and all-terrain vehicles would be strictly prohibited so as to minimize any possible damage to vegetation or wildlife occuring through carelessness.

Recreational fishing in the area would be governed by the Canadian Wildlife Service, though a ban on fishing would be imposed if there would be any danger of depleting the fish stock of the area.

3.9 PUBLIC PARTICIPATION

The Gulf Oil Canada Limited application for the proposed gas development at Parsons Lake is but one part of the total potential gas development in the Mackenzie Delta region of the Northwest Territories. At an early stage in the development planning, therefore, the three companies with indicated gas reserves in the Mackenzie Delta; namely, Gulf Oil Canada Limited, Imperial Oil Limited and Shell Canada Limited, recognized the advantages of co-operative approach to environmental and socio-economic assessments. This approach included a combined comprehensive environmental-impact assessment of the total envisaged facilities and activities referred to collectively as the Mackenzie Delta Gas Development System. The nine-volume report detailing the environmental program was informally presented to various government agencies in the Northwest Territories, native groups, news media and the general public in the Mackenzie Delta communities, at meetings held during the weeks of January 13 and January 20, 1975. These meetings were held in Yellowknife, Inuvik, Aklavik, Tuktoyaktuk and Fort McPherson, with presentations by producer-company representatives speaking on behalf of the Mackenzie Delta Gas Development System proponents.

The format of the meetings included a 20-30 minute talk by an industry official, supplemented by slides illustrating some design concepts of the proposed development as well as some key environmental assessments. This was followed by a government representative explaining the review procedure the government had set up for the producer application. Scale models of well clusters, plant sites and a typical gas plant were set up for each meeting. Following the formal presentations, all meetings were opened for general questions.

Attendance at the meetings was as follows:

Yellowknife, January 15, 1975

Three Sessions:

(1) D.I.A.N.D. Group (15 persons)

(2) Local news media and press conference

(3) Territorial Council and staff members of Territorial Government (Approximately 35 persons)

Inuvik, January 16, 1975

Three Sessions:

(1) Committee of Original Peoples' Entitlement (COPE) and Canadian Arctic Resources Committee (CARC) (Approximately 15 persons)

(2) Inuvik Town Council (Approximately 10 persons)

(3) Public meeting (Approximately 85 persons)

<u>Tuktoyaktuk, January 20, 1975</u>

Two Sessions:

(1) Tuktoyaktuk Council (9 attendees)

(2) Public meeting (Approximately 100 persons)

<u>Aklavik, January 21, 1975</u>

Two Sessions:

(1) Aklavik Town Council

(2) Public meeting (Approximately 60 persons)

<u>Ft. McPherson, January 22, 1975</u>

(1) Public meeting

4.0 ENVIRONMENTAL IMPACTS

Section 3.0 outlined and discussed the anticipated effects of gas production on physical and biotic aspects of the environment, and on the ways in which people use the natural resources of the study region.

The following sections review the probable effects of development in other terms and shed light on their significance.

- The adverse consequences of unavoidable drainage modification would be slight. There might be some erosion in hilly areas which, if uncontrolled, could lead to silting of streams.
- Some soil erosion, slope instability, and perhaps thermokarst would be inevitable in the Parsons Lake region - a result of terrain modification during construction. Care in the siting of roads and facilities, as well as use of gravel and other insulating materials, and solicitous construction and follow-up procedures would minimize their occurrence and impact.
- The adverse nature of these physical effects would be largely absorbed in the area's natural tendency toward terrain instability.

Slumps and erosion along stream banks are historic features of the terrain around Parsons Lake. Thermokarst without fluvial action would result in surface disturbance.

The major adverse effect on vegetation that is anticipated would be the expropriation of upland vegetation types for road and facility development. The impact would be largely short-term (duration of the project) in that restoration would induce new vegetative growth, but the new communities would be different from those originally in place.

Xeric gravel vegetation would be lost through gravel exploitation near Parsons Lake.

Bird and mammal habitat over a large area would be altered. Restoration at the end of the project would create new habitat. The presence of man and his machines would render additional habitat close to roads and facilities unusable by the more wary and inflexible species. Many species however, would be unaffected while still others would soon adjust in varying degrees. Fortunately most critical bird habitats are some distance from the scene of proposed construction and would remain unaffected.

Several pairs of Hudsonian godwits and small numbers of white-fronted geese and swans are the most prominent groups that might be displaced during the nesting season. The extent to which displaced nesting birds can be absorbed in other nesting habitat is unknown, but there is reason to assume that reproduction might be less during the first year after displacement.

Even with tight internal controls on personnel activities, some harassment of colonial nesting birds, grizzlies, and perhaps reindeer might be expected. An effective educational program could reduce consequences of that nature.

Human use of waterfowl, ptarmigan or other birds would not be adversely affected.

As far as can be determined, no fox or grizzly bear dens would be destroyed.

No adverse effects on trapping or trappers would be expected.

Reindeer might initially avoid or be deflected in their seasonal movements by facilities and activity around Parsons Lake. However, they would be expected to adjust quickly. The worst possible consequences would be slightly more intense herding requirements and possible collisions between animals and machines. The main herd would not be wintering close to the developments for a number of years, however, because of range requirements.

Fish habitat and habits in streams near Parsons Lake might be adversely affected by silting, but only if high cumulative totals of silt were allowed to enter streams at critical times of the year. Some sedimentation a short distance below road crossings would be inevitable. However, maximum induced rates should occur in spring when natural silt loads are highest. Banks would have to be stabilized.

4.1 UNAVOIDABLE IMPACTS

Development would modify existing environmental conditions. Unavoidable consequences are those that cannot be prevented by efforts at prevention or mitigation. Section 3.0 lists substantial effects on the basis of fulfilment of the summary project description, omitting the alternatives and the consideration of supplementary development. This section discusses those principal effects that are unavoidable and could be considered adverse.

Gaseous emissions from several sources would add contaminants to the atmosphere, but in such small amounts that air-quality parameters would not be pushed beyond acceptable thresholds. It is unlikely that federal standards would be exceeded or even that present Inuvik maxima would be equalled at any of the planned facility sites.

Local climate would be modified around gas plants during periods of extreme cold.* Ice fogs could make the use of airstrips difficult on some winter days.

Without any serious impairments of any phase of the natural hydrologic cycle, local surface drainage would be disrupted along dykes, roads, airstrips and pads in the Parsons Lake area.

Adequate use of bridges and culverts would minimize this kind of physical effect, but would not eliminate it altogether.

Grayling movements should not be impeded if bridges or proper culverts were installed.

Establishment of quasi-permanent gas production facilities on the Delta would displace the renewable resources critically dependent on the land to be covered with insulating gravels. Commitment of the present regimes of plants and animals would be irreversible, but after abandonment and restoration new regimes would develop. Animals prevented by noise or other aspects of development activity from using adjacent habitat would be expected to resume normal use after abandonment.

4.2 ECOSYSTEM AND RESOURCE BENEFITS

Not all environmental change is adverse. In fact, change in ecosystems is a continuing natural feature of their existence.

It follows that changes brought about by the introduction of extraneous forces to environmental systems might sometimes be beneficial. Some effects of the development project that would bring foreseeable benefits to inhabitants of the natural systems of the Delta, or to man, are identified in this section.

System Effects

Birds would make use of gravel introduced to the area for loafing, as a source of grit, and perhaps for nesting sites after abandonment, as they now do roads and little-used staging-area pads. Ptarmigan and early-arriving passerines utilize gravel dropped from trucks along winter roads. Other species come to roads in summer. White-fronted geese and other waterfowl have been observed on gravel pads early in the snow-melt period.

Birds and small mammals favouring more open tundra sites would benefit from removal of willows and alders under pipeline systems.

Ground squirrels and foxes would be expected to den in abandoned gravel roads and pads if these were restored. Denning habitat for those species is scarce on the floodplain.

Reindeer would use abandoned gravel roads as travel lanes, as caribou use long, sinuous eskers elsewhere in northern Canada.

4.3 SENSITIVITY

Arctic ecosystems have been popularly described as fragile and sensitive. This reputation was probably earned because of damage to ice-rich tundra through the process of thermokarst. Since thermokarst is now appreciated and can be prevented, that particular aspect of arctic sensitivity is no longer a central issue. The question whether other, dynamic aspects of arctic ecosystems are more or less fragile than at lower latitudes is still the subject of investigation.

In this instance, the proposed development plan specifies that special precautions would be taken to prevent siltation and that fish migration routes would not be impeded. Furthermore, adequate regulation and enforcement of fishing should prevent abuse of the resource, and effluents introduced into water bodies would be regulated by government to ensure the safety of aquatic systems.

The proposed development would impose perturbations only on very local segments of the terrestrial system.

The construction and presence of the facilities should not upset any major subsystem. Emissions from the operation would be dispersed over a very large area and would be extremely diluted. The concentrations and volumes of emissions could probably be absorbed by the system without significant change.

4.4 FOOD WEB

The concept of a food web involves the way materials are transferred as foodstuff from green plants to herbivores, then to carnivores. One of the consequences of the web is that nonmetabolizable substances can reach toxic concentrations in the upper trophic levels. They can also affect organisms remote from the area where they were first introduced. Of particular concern are chlorinated hydrocarbons and heavy metals.

The proposed development would not utilize pesticides or other chlorinated hydrocarbons, but heavy metals could accidentally be introduced to the food web. Concentrations in predator tissue could eventually reach harmful levels, although stated dyking and contingency plans would prevent this possibility.

4.5 KEY SPECIES

Economics

A fishery, a reindeer herd, bears and furbearers represent sources of revenue from biological resources within the development region. The reindeer herd, recently acquired by a resident of Tuktoyaktuk, is the total source of income for the owner and provides a substantial part of the herders' livelihood. It would not be materially affected.

Trapping in the development area does not completely support any individual or family, nor does it provide a very large contribution to native income. Except for muskrats in localized lakes, and foxes when there are no rabies epidemics, the development region does not produce numbers of furbearers. The pattern of fur returns to trappers from all three communities should not be affected. As described, the development would not directly affect the commercial fishery or the reindeer herd.

Subsistence

The species of animals most used by native people domestically are geese, ptarmigan, whitefish, and caribou. Caribou are hunted outside the development region. The development would not reduce the availability of whale, fish or bird resources as they are presently exploited.

Rare and Endangered Species

The barren-ground grizzly bear is considered to be a threatened species. The study region contains a large portion of the Delta area population.

The status of the Hudsonian godwit is not clear. While numbers may be increasing, the species is nevertheless considered "depleted". The Delta is one of its few known breeding regions.

5.0 SUMMARY

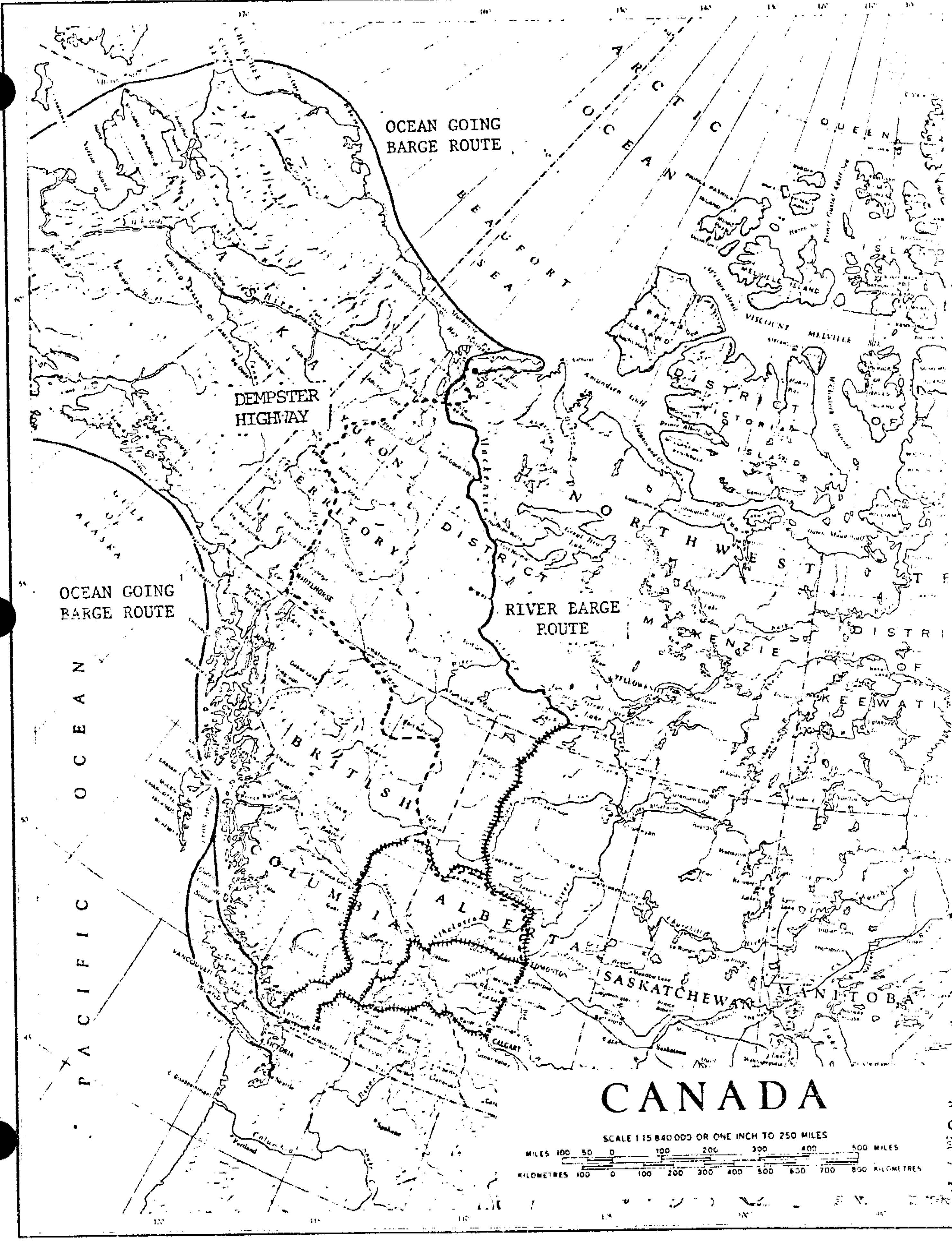
The proposed development would affect different segments of the environment in varying degrees. Likewise, some development activities would influence the environment more than others. Those parts of the proposed development judged to be of most concern are listed below. Criteria used in this judgment included the extent of the impact, its frequency and timing, the value of the resource or activity, the relationship between the affected part of the environment and the whole ecosystem, long-range or permanent effects, and the opportunity for natural or assisted restoration.

- Siltation of streams in the Parsons Lake area.
- Ice fogs around gas plants.
- Loss of upland bird habitats.
- Possible harassment of colonial nesting birds and grizzlies by extracurricular human activities.

APPENDIX

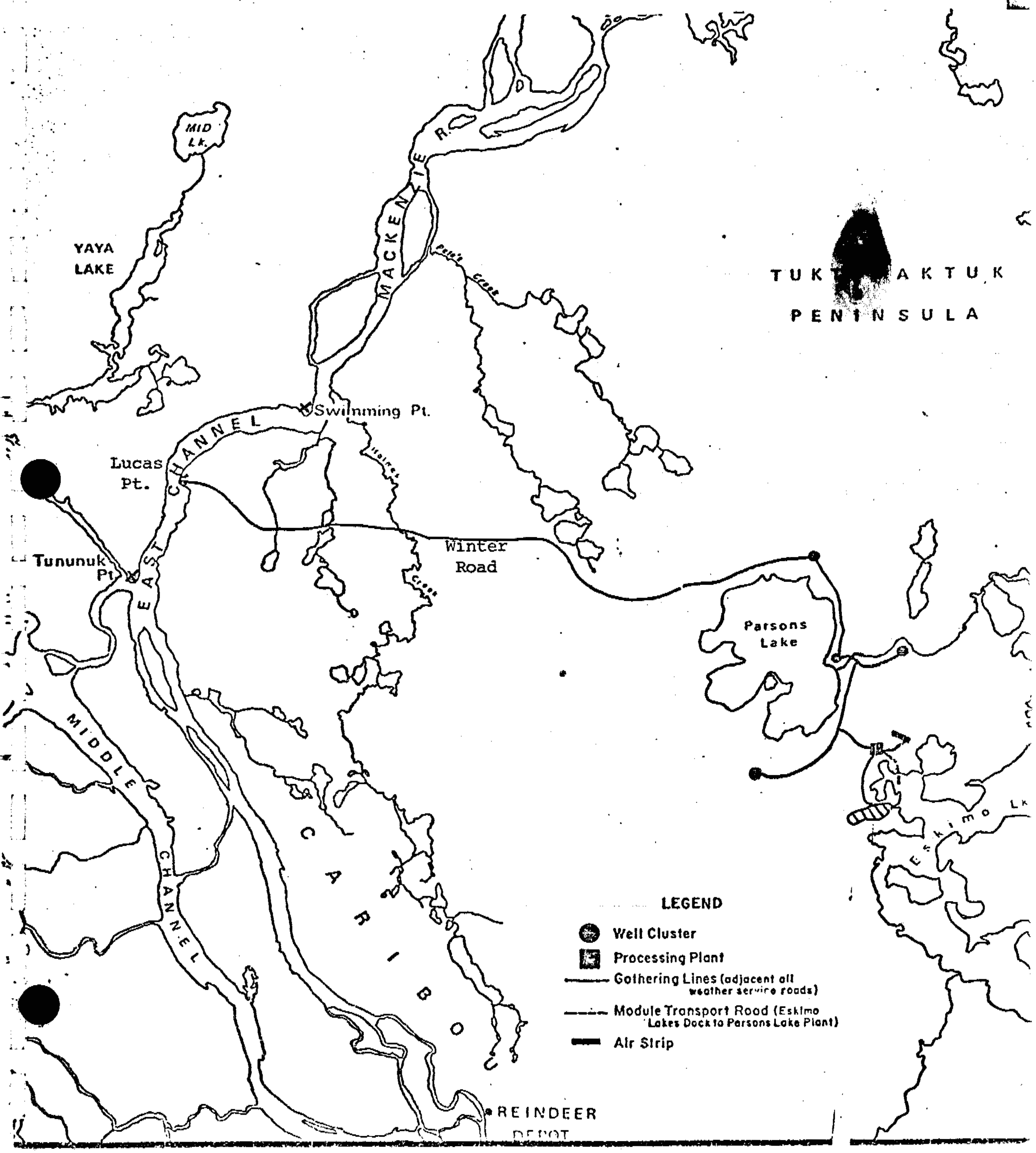
The following material is included in the Application:

1. Development schedule for the Parsons Lake project.
2. General plan of development area (1:250,000).
3. General plan of development area (1:50,000).
4. General plan of development area (1"=2,000').
5. Geotechnical map (1:50,000).
6. Map of transportation routes (1:25C,000).
7. Locations of water sampling sites (1:50,000).
8. Vegetation map (1:50,000).
9. Surficial geological map (1:50,000).
10. Aquatic resources map (Survey sites) (1:50,000).
11. Wildlife habitat maps (1:50,000).


OCEAN GOING
BARGE ROUTE
ARCTIC OCEAN
BEAUFORT SEA
DEMPSTER
HIGHWAY
YUKON TERRITORY
OCEAN GOING
BARGE ROUTE
RIVER BARGE
ROUTE
MACKENZIE DISTRICT
NORTHWEST TERRITORIES
PACIFIC OCEAN
GULF OF ALASKA
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
CANADA
SCALE 1:15 840 000 OR ONE INCH TO 250 MILES
MILES 100 50 0 100 200 300 400 500 MILES
KILOMETRES 100 0 100 200 300 400 500 600 700 800 KILOMETRES

GENERAL PLAN FOR DEVELOPMENT AREA

(1:250,000)



LIST OF TABLES

TABLE 2.1

PROCESS-PLANT FEED-GAS ANALYSIS

Component	Mole %
N_2	1.50
CO_2	3.30
C_1	87.50
C_2	3.59
C_3	1.60
iC_4	.35
nC_4	.55
iC_5	.24
nC_5	.22
nC_6	.36
nC_7	.35
nC_8	.16
nC_9	.08
nC_{10}	.05
nC_{11}	.02
nC_{12+}	.13
	100.00

TABLE 2.2

PARSONS LAKE GAS PLANT

TENTATIVE MATERIAL BALANCE

Comp.	Mol. Wt.	U.S. Gal. /Mol	1 Plant Inlet Fluid Mol/day	2 Plant Inlet Vapour Mol/day	3 Plant Inlet Liquid Mol/day	4 Chiller Separator Vapour Mol/day	5 Chiller Separator Liquid Mol/day	6 Feed Tank Vapour Mol/day	7 Feed to Fract. Mol/day	8 Fract Ovhd. Mol/day	9 Fract. Bottoms Mol/day	10 Rich Vapour Mol/day	11 Rich Liquid Mol/day	12 Deeth. Ovh'd Mol/day	13 Deeth. Bottoms Mol/day	16 Reinjection Gas Mol/day	18 Total Sales Gas Mol/day
N_2	28.016	-	19,837	19,802	35	19,684	118	144	9	9	-	146	7	7	-	153	19,837
CO_2	44.010	6.38	43,546	43,144	402	41,684	1,460	1,315	547	547	-	1,388	474	474	-	1,862	43,546
C_1	16.042	6.40	1,155,584	1,149,362	6,222	1,128,912	20,450	21,918	4,754	4,754	-	23,138	3,534	3,534	-	26,672	1,155,584
C_2	30.068	9.56	47,384	46,567	817	43,303	3,264	2,221	1,860	1,860	-	2,215	1,866	1,808	58	4,023	47,384
C_3	44.094	10.42	21,248	20,378	870	16,662	3,716	1,364	3,222	3,222	-	1,071	3,515	206	3,309	1,277	21,248
iC_4	58.120	12.38	4,576	4,181	395	2,905	1,276	244	1,427	1,415	12	186	1,471	-	1,473	186	4,564
nC_4	58.120	11.93	7,266	6,456	810	3,978	2,478	369	2,919	2,826	93	253	2,942	-	2,942	253	7,173
iC_5	72.146	13.85	3,122	2,513	609	1,221	1,292	105	1,796	123	1,673	9	219	-	219	9	1,449
nC_5	72.146	13.71	2,903	2,222	681	905	1,317	87	1,911	31	1,880	3	115	-	115	3	1,023
C_6	86.172	15.57	4,694	2,713	1,981	634	2,079	68	3,992	-	3,992	-	68	-	68	-	702
C_7	100.205	17.46	4,608	1,772	2,836	231	1,541	30	4,347	-	4,347	-	30	-	30	-	261
C_8	114.23[illegible]	19.39	2,127	455	1,672	29	426	6	2,092	-	2,092	-	6	-	6	-	35
C_9	128.2[illegible]9	21.32	1,048	122	926	4	118	1	1,043	-	1,043	-	1	-	1	-	5
C_{10}	142,286	23.24	718	44	674	-	44	-	718	-	718	-	-	-	-	-	-
C_{11}	156.312	25.28	212	7	205	-	7	-	212	-	212	-	-	-	-	-	-
$C_{12}+$	202.900	28.30	1,716	32	1,684	-	32	-	1,716	-	1,716	-	-	-	-	-	-
			1,320,589	1,299,770	20,819	1,260,152	39,618	27,872	32,565	14,787	17,778	28,409	14,250	6,029	8,221	34,438	1,302,811
LB./HR.			1,092,571	1,026,788	65,783	965,319	61,469	24,983	102,269	23,175	79,094	24,024	24,134	5,883	18,251	29,907	1,013,477
MOL. WEIGHT			19,856	18.96	75.83	18.38	37.24	21.51	75.37	37.61	106.78	20.30	40.65	23.42	55.28	20.84	18.67
SP. GR. @ 60°F			-	0.655	0.648	0.635	0.487	0.743	0.640	1.299	0.708	0.701	0.497	0.808	0.555	0.720	0.645
USGPM @ 60°F			-	-	202.9	-	252.5	-	319.7	-	223.4	-	97.1	-	65.8	-	-
BBLS./DAY			-	-	6,957	-	8,657	-	10,960	-	7,659	-	3,328	-	3,255	-	-
MMSCFD @ 14.73 PSIA & 60°F			5,000	492.1	-	477.1	-	10.6	-	5.6	-	10.8	-	2.3	-	13.0	493.3
TEMP. (°F)			85	85	85	-20	-20	85	85	100	383	0	0	-10.0	218	100	25
PRESS. (PSIA)			1,100	1,100	1,100	1,070	1,070	500	500	170	185	470	470	430	445	1,080	1,700
VAPOUR PRESSURE @ 100°F (psia)			-	-	-	-	-	-	-	-	5.60	-	-	-	-	-	-

TABLE 3 - 1

COMPARISON OF MONTHLY

MEAN HOURLY TEMPERATURES (°C)

MONTH	PARSONS LAKE	SWIMMING POINT	INUVIK	TUKTOYAKTUK
	(1973-74 Data)		(1960-1970 Data)	
July	10.2	12.0	13.2	10.5
August	7.2	10.7	10.2	8.7
September	3.2	5.9	2.4	2.4
October	-10.1	-11.9	- 8.0	- 7.5
November	-21.6	-22.6	-21.5	-20.4
December	-24.7	-23.6	-26.2	-24.3
January	-23.2	-23.6	-31.5	-30.2
April	-21.6	-22.0	-14.8	-17.1
May	- 6.2	- 5.5	- 0.6	- 4.1

TABLE 3 - 2

MONTHLY MEAN HOURLY WIND SPEEDS (MPH)

AT SWIMMING POINT AND PARSONS LAKE

MONTH		SWIMMING POINT	PARSONS LAKE
July	1973	8.1	11.6
August	1973	7.8	11.5
September	1973	6.4	9.1
October	1973	6.1	8.0
November	1973	6.4	8.7
December	1973	7.0	8.3
January	1974	12.3	17.0
February	1974	5.3	7.8
March	1974	5.5	*
April	1974	10.2	10.8
May	1974	10.2	10.9

* No Data Available

TABLE 3 - 3

MEAN PRECIPITATION REGIMES

AT INUVIK AND TUKTOYAKTUK (1960-1970)

	Inuvik		Tuktoyaktuk	
Month	Rainfall (cm)	Snowfall (cm)	Rainfall (cm)	Snowfall (cm)
January	0.03	21.6	0.00	5.1
February	0.00	11.9	0.00	5.3
March	0.00	18.5	0.00	3.6
April	0.00	15.0	0.00	4.8
May	0.51	14.0	0.3	4.1
June	1.07	2.3	1.0	3.3
July	3.40	0.3	2.2	0.3
August	3.84	4.3	2.8	0.5
September	1.09	11.4	1.0	4.1
October	0.20	34.5	0.1	11.9
November	0.00	18.5	0.00	5.1
December	0.00	21.6	0.00	5.1
Year	10.14	173.9	7.4	53.2

TABLE 3 - 4

AVIAN POPULATION OF THE PARSON'S LAKE AREA

AERIAL SURVEYS 1973

Species	NESTING PERIOD (June 18 - 21) Number Observed	Species Composition (%)	Birds per Square Mile	MOULTING PERIOD (July 19 - 25) Number Observed	Species Composition (%)	Birds per Square Mile
Arctic Loon	55	8.55	1.486	20	3.58	0.540
Red Throated Loon	10	1.56	0.270	25	4.48	0.675
Unidentified Loon	28	4.35	0.757	4	0.72	0.108
Whistling Swan	26	4.04	0.703	63	11.29	1.703
White-fronted Goose	30	4.67	0.811	NIL	NIL	NIL
Mallard	2	0.32	0.050	NIL	NIL	NIL
Pintail	12	1.87	0.324	52	9.32	1.405
American Wigeon	10	1.56	0.270	NIL	NIL	NIL
Greater Scaup	176	27.37	4.757	118	21.15	3.189
Old Squaw	68	10.58	1.838	78	13.98	2.108
White-winged Scooter	91	14.15	2.459	15	2.69	0.405
Surf Scooter	18	2.80	0.486	NIL	NIL	NIL
Unidentified Scooter	24	3.73	0.649	NIL	NIL	NIL
Dabbling Duck	NIL	NIL	NIL	1	0.18	0.027
Diving Duck	NIL	NIL	NIL	74	13.27	2.000
Unidentified Duck	12	1.87	0.324	13	2.33	0.351
Red-breasted Merganser	7	1.09	0.189	NIL	NIL	NIL
Marsh Hawk	NIL	NIL	NIL	1	0.18	0.027
Willow Ptarmigan	14	2.18	0.378	NIL	NIL	NIL
Sandhill Crane	1	0.16	0.027	NIL	NIL	NIL
Whimbrel	7	1.09	0.189	4	0.72	0.108
Parasitic Jaeger	1	0.16	0.027	NIL	NIL	NIL
Long-tailed Jaeger	1	0.16	0.027	NIL	NIL	NIL
Unidentified Jaeger	2	0.32	0.050	NIL	NIL	NIL
Glaucous Gull	5	0.77	0.135	12	2.15	0.324
Herring Gull	NIL	NIL	NIL	1	0.18	0.027
Arctic Tern	33	5.13	0.892	64	11.47	1.729
Common Raven	6	0.96	0.162	NIL	NIL	NIL
Unidentified	4	0.64	0.108	12	2.15	0.324
TOTAL	643	100	——	558	100	——

TABLE 3.5

WATER CHEMISTRY OF THE PARSONS LAKE AREA

(SEPTEMBER 1975)

PARAMETER	SITE #1	SITE #2	SITE #3	SITE #4	SITE #5	SITE #6	SITE #7
TOTAL SOLIDS (mg/L)	120	131	256	2931	3039	2200	210
ALKALINITY (mg/L)	36	44	88	64	68	68	36
HARDNESS (as $CaCO_3$)	69	69	90	641	507	76	80
SALINITY (as NaCl)	98	87	175	2848	2886	2057	174
pH	7.1	6.8	7.6	7.9	7.8	8.0	6.9
COLOR (Platinum Cobalt Color Units)	15	10	25	10	10	15	50
TURBIDITY (Turbid Units)	8.0	1.9	1.9	1.9	2.1	3.0	6.8
AEROBIC VIABLE COUNT (Colonies/ml)	474	63	3510	129	115	258	311
COLIFORM (MPN)	0/100	0/100	0/100	0/100	0/100	0/100	0/100
PHOSPHATE (mg/L)	0.20	0.16	0.13	0.16	0.16	0.16	0.25
NITRATE (mg/L)	0.97	1.20	1.42	1.68	1.64	1.55	1.95
NITRITE (mg/L)	0.007	0.008	0.004	0.005	0.004	0.005	0.010
TOTAL SULPHIDES (mg/L)	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
SOLUBLE SILICA (mg/L)	1.5	1.5	2.0	1.5	1.5	1.5	1.5
MERCURY (mg/L)	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*	0.2*
ARSENIC (mg/L)	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
COBALT (mg/L)	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
LEAD (mg/L)	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
DISSOLVED OXYGEN (ppm)	NR	NR	12.04	NR	NR	NR	NR
BIOLOGICAL OXYGEN DEMAND (B.O.D.) (ppm)	NR	NR	2.0	NR	NR	NR	NR
CHEMICAL OXYGEN DEMAND (C.O.D.) (ppm)	NR	NR	28.0	NR	NR	NR	NR

* Figures are less than recorded.

LIST OF FIGURES

FIGURE 2.1

PROCESS FLOW DIAGRAM

(Numbers refer to material balance in Table 2.2)

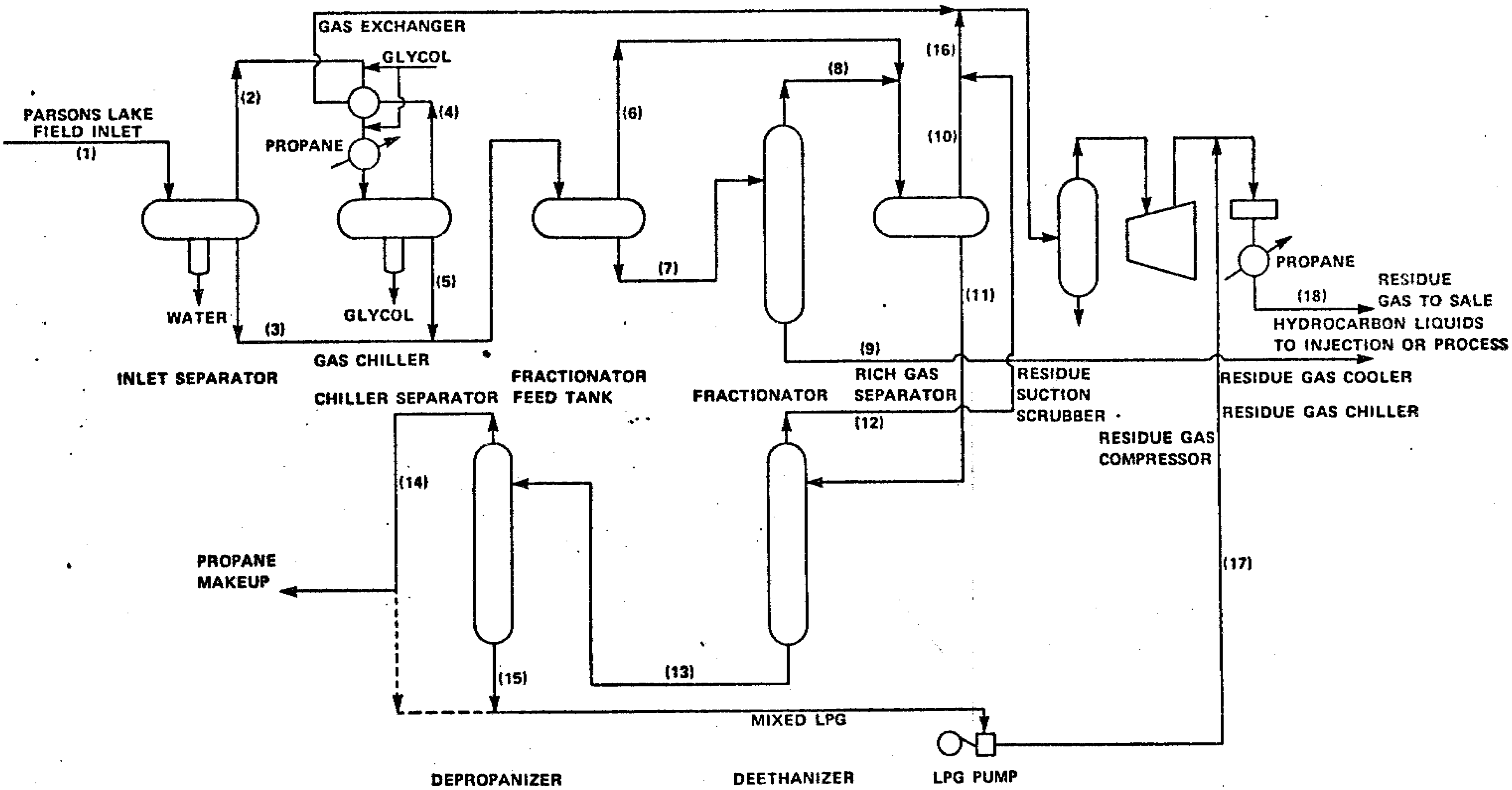


FIGURE 2.2

STRAIGHT-HOLE WELL DESIGN

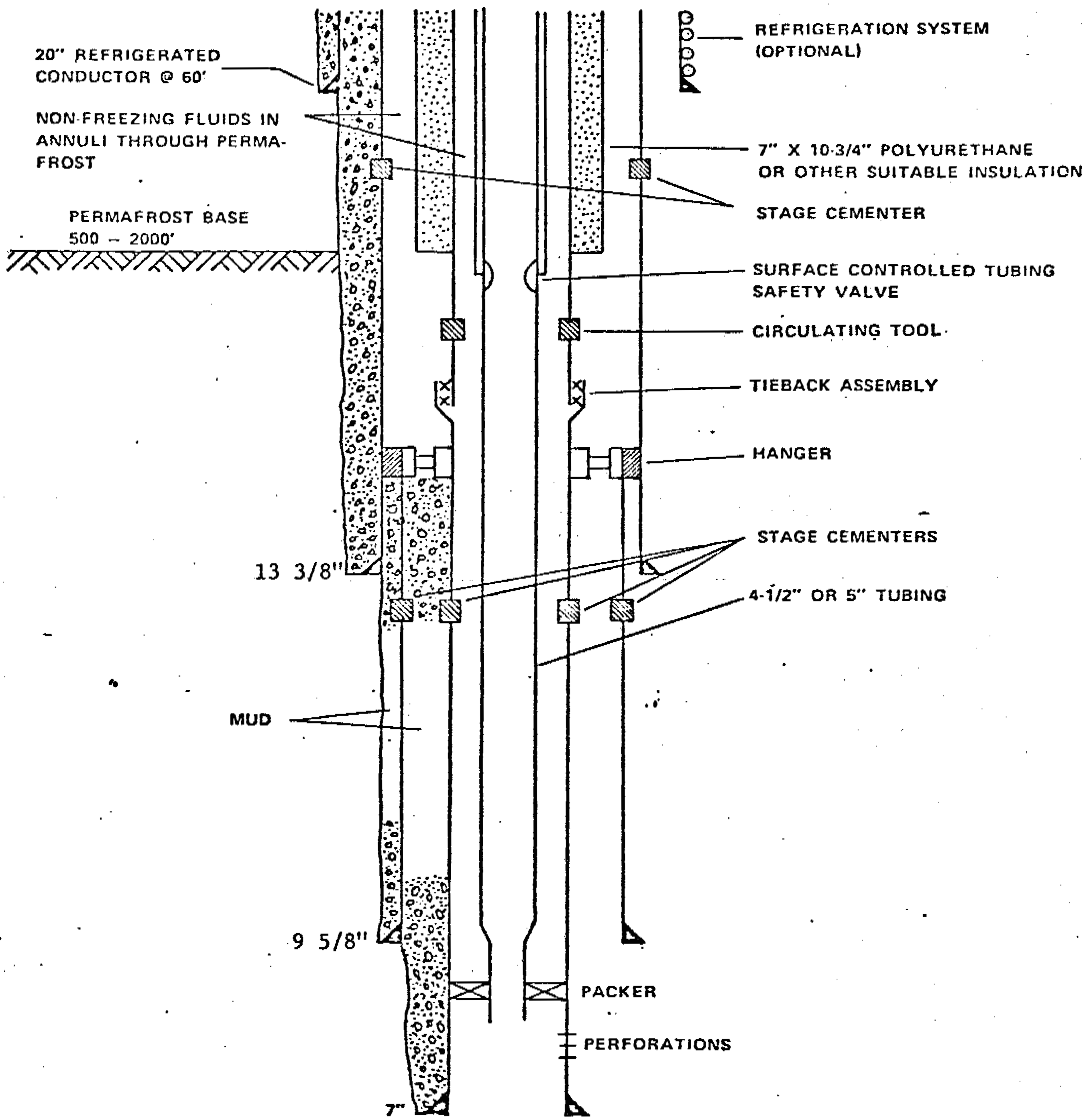
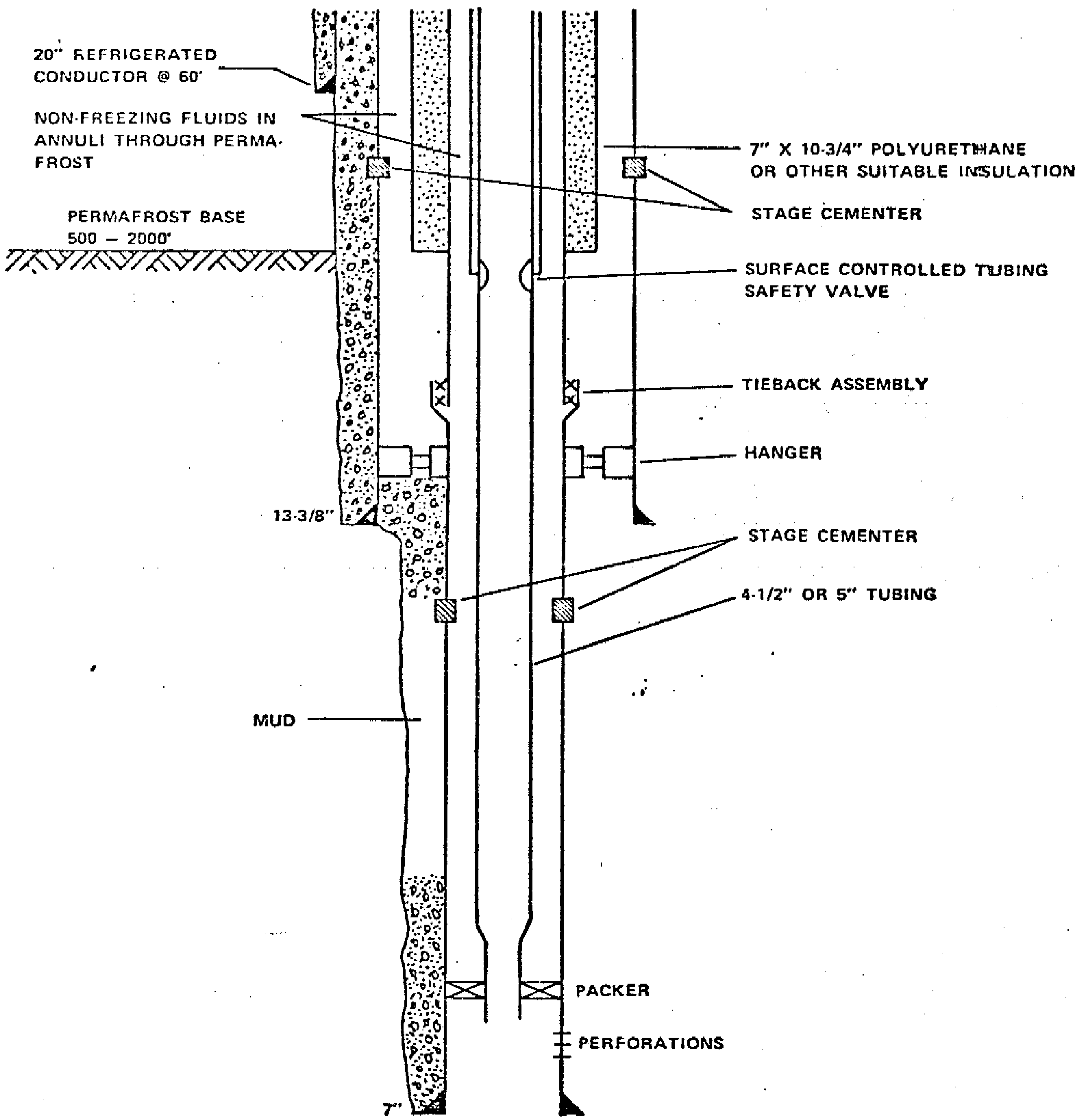


FIGURE 2.3

DEVIATED-HOLE WELL DESIGN



1973–1974 WIND ROSES

SWIMMING POINT AND PARSONS LAKE

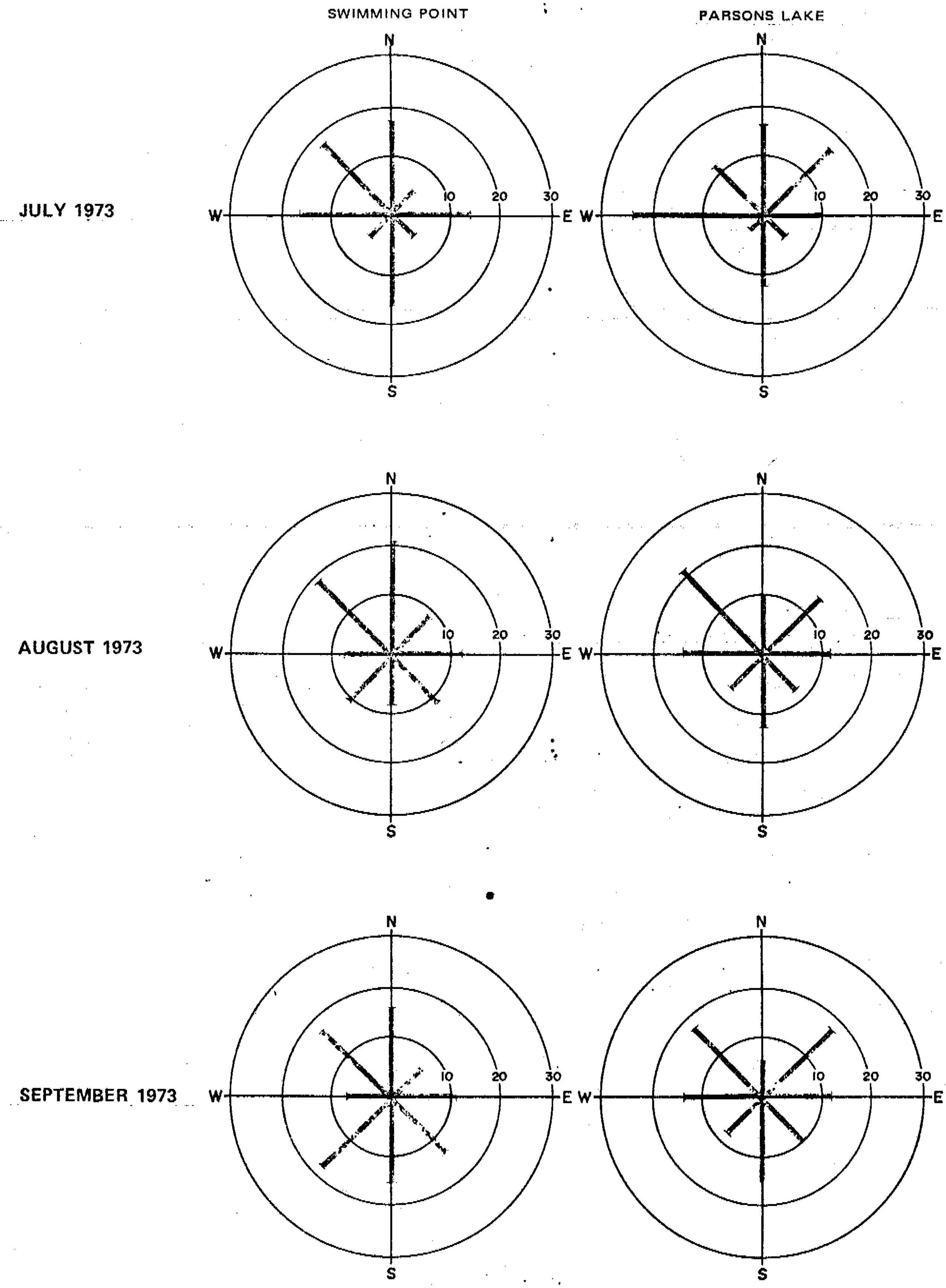


FIGURE 3.1

1973–1974 WIND ROSES
SWIMMING POINT AND PARSONS LAKE

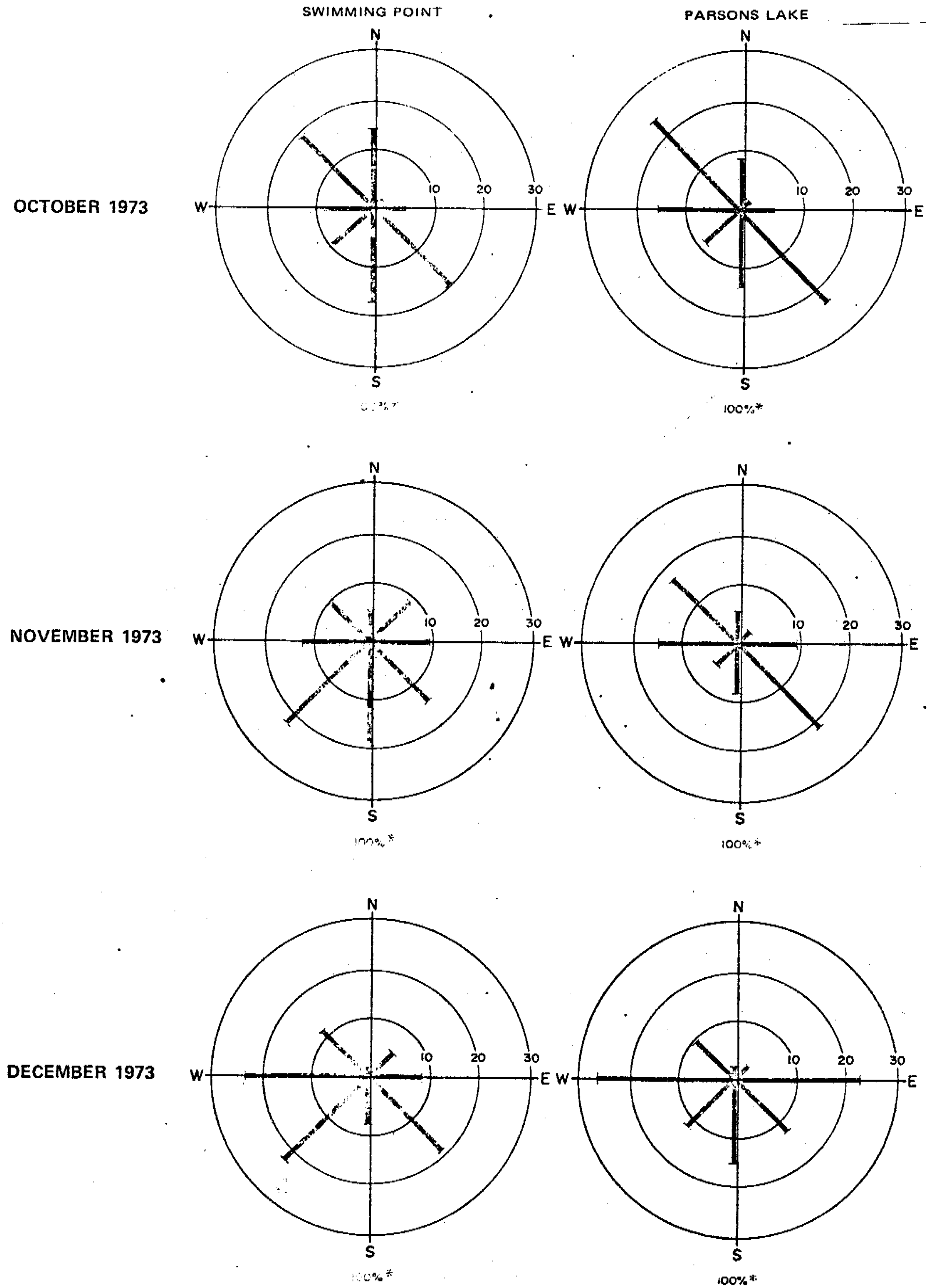


FIGURE 3.2

1973–1974 WIND ROSES
SWIMMING POINT AND PARSONS LAKE

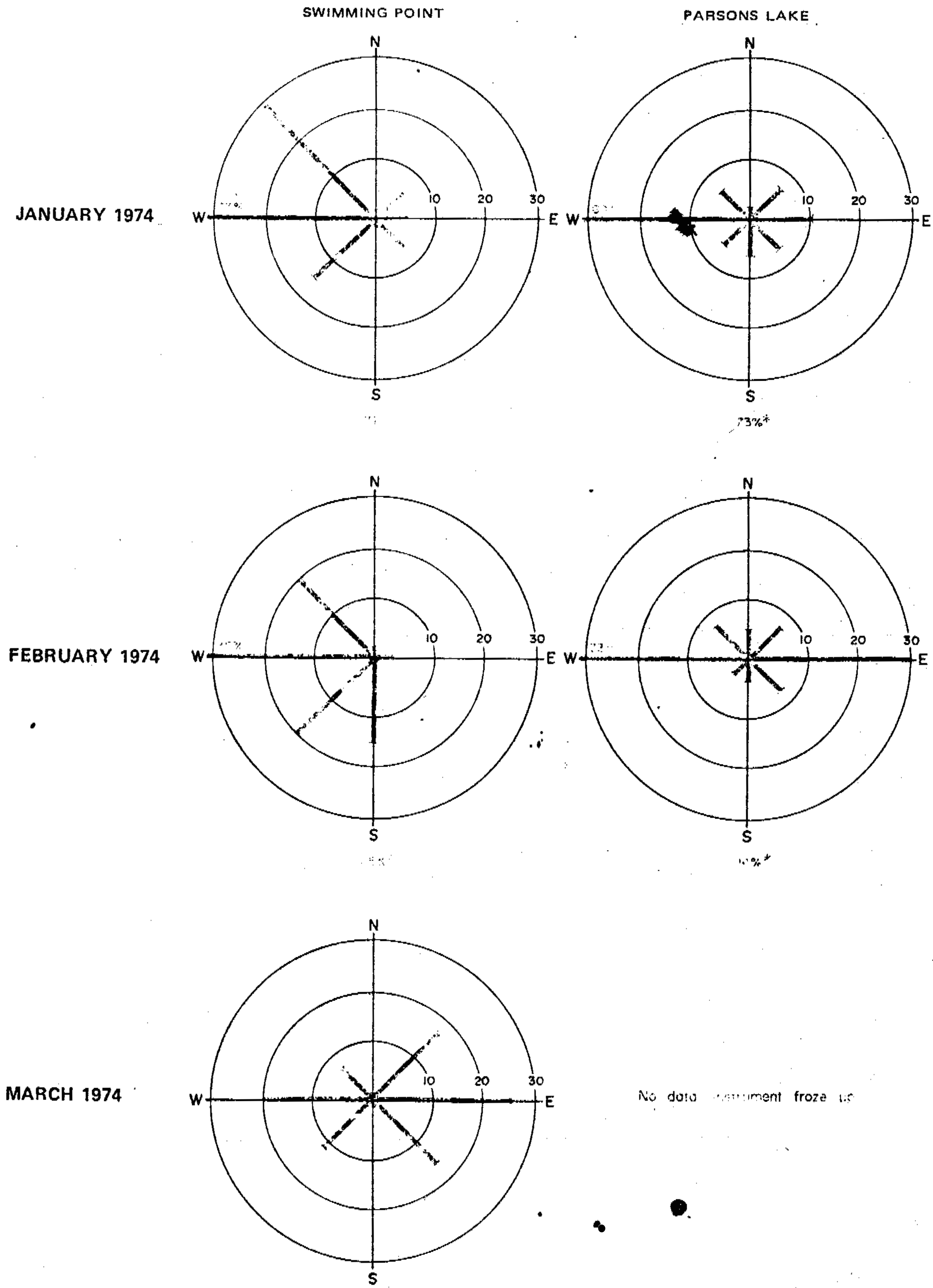


FIGURE 3.3

1973–1974 WIND ROSES
SWIMMING POINT AND PARSONS LAKE

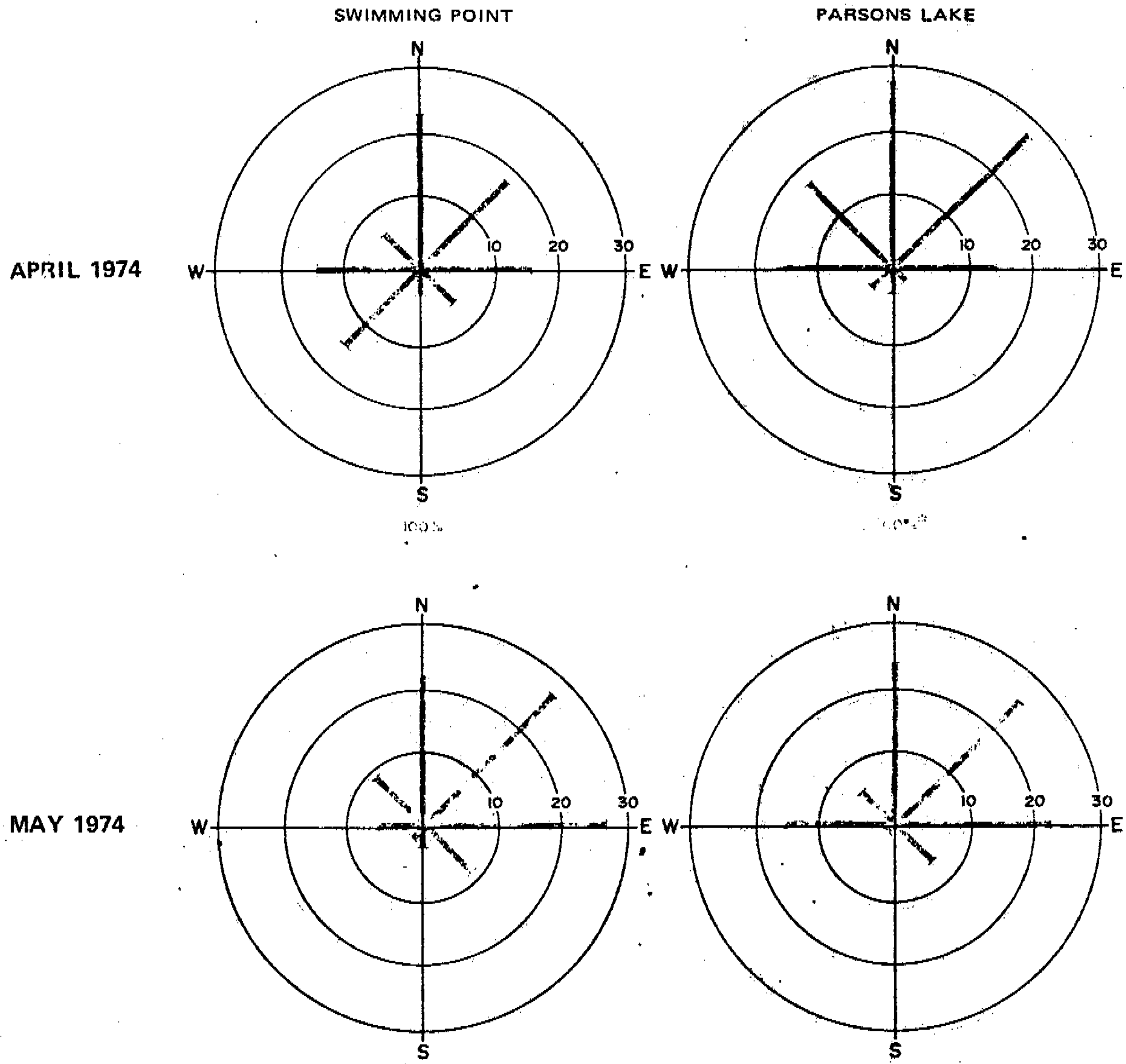


FIGURE 3.4