1126

Karen

BADAMI DEVELOPMENT PROJECT

Project Description and Environmental Assessment

BP EXPLORATION

BADAMI DEVELOPMENT PROJECT

Project Description and Environmental Assessment

January 1995

BP EXPLORATION (ALASKA) INC.
P.O. Box 196612
Anchorage, Alaska 99519-6612

EXECUTIVE SUMMARY

BP Exploration (Alaska) Inc. (BPXA) is evaluating the opportunity to develop the Badami oil field. When compared with other North Slope projects, the proposed Badami Development Project is relatively small in scope. It involves an onshore production well pad, an onshore facilities pad, a 27.9-mile buried pipeline, a dock, a short in-field road system, gravel sources, and an airstrip. There are no plans for an access road to connect Badami with existing Prudhoe Bay area facilities.

The field is located primarily offshore beneath Mikkelsen Bay on Alaska's North Slope approximately 25 miles east of existing North Slope oil field development. The purpose of this document is to support project permit applications by describing the proposed project and evaluating its potential environmental impact. The description of the planned Badami project as contained in this document represents the extent of development conceptually planned at this time. It is likely that, as project engineering evolves, permits will be modified, and the overall footprint of the project may be reduced.

In 1995, BPXA plans to drill two appraisal wells (Badami #4 and Badami #5) to further delineate the Badami reservoir. These wells will be located offshore and drilled from ice pads. The well locations and testing programs are targeted to prove the extent of reserves needed for the Badami Development Project to be economical. Information from these wells is expected to confirm information about the reservoir gained from existing well results and seismic analysis. The results of this drilling program will be analyzed and completed in the summer of 1995.

At the same time, BPXA has filed permit applications for development of this oil field. The first activity will be opening a gravel source at East Badami Creek in early 1996, followed by construction of gravel field facilities, including a well pad, facilities pad, a dock, an airstrip, and an in-field road system connecting these facilities. Development drilling will begin in the winter of 1996-1997, when the Badami Pipeline will also be constructed. Modules will be transported to the site and installed in the summer of 1997, and project start-up will be in the fourth quarter of 1997.

The study area for the environmental assessment is located between the Endicott Access Road on the west side of the east channel of the Sagavanirktok River, and Bullen Point on the east side of Mikkelsen Bay. It extends from the nearshore Beaufort Sea coast approximately 15 miles south. In planning for this proposed project, BPXA has taken numerous steps to mitigate the potential environmental impact. The most important of

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. PURPOSE AND NEED FOR THE PROPOSED ACTION

1.1 PURPOSE

BP Exploration (Alaska) Inc. (BPXA) proposes to develop the Badami oil field, which is located at Mikkelsen Bay approximately 25 miles east of the Prudhoe Bay Unit (Figure 1-1). Development of the Badami field poses significant engineering, environmental and regulatory challenges. When compared with other North Slope projects, the proposed Badami Development Project is relatively small in scope. It involves an onshore production well pad, an onshore facilities pad, a 27.9-mile buried pipeline, a dock, a short in-field road system, gravel sources, and an airstrip. There are no plans for a gravel access road to connect Badami with existing Prudhoe Bay facilities.

1.2 NEED

Development of this resource will increase domestic energy supplies and will provide economic benefits to BPXA, the North Slope Borough, the State of Alaska, and the United States. The Badami hydrocarbon reservoir is currently estimated to contain potential recoverable reserves of up to 150 million barrels of oil and up to 100 billion cubic feet of natural gas. The field therefore represents a significant addition to national energy reserves. While relatively small by Alaska North Slope standards, Badami is a giant field in continental U.S. terms. The State of Alaska stands to benefit directly by the infusion of new capital expenditures into the economy. Over the life of the project, additional benefits will accrue to the State and to the North Slope Borough through the payment of royalty and severance, income, and ad valorem taxes.

1.3 DEVELOPMENT CHALLENGES AND PHILOSOPHY

Because the field is remote from existing infrastructure, new and innovative approaches are required to reduce the capital costs of the development on a cost-per-barrel basis below that of recent developments such as Niakuk and Point McIntyre. These projects benefited from the proximity to, and use of, existing Prudhoe Bay area infrastructure for processing and transportation of oil. In addition, the Badami

Development is being planned and permitted at a time when world oil prices (adjusted for inflation) are at their lowest level in 20 years. Consequently, economic analyses indicate that the project is not feasible assuming typical North Slope development and operational costs. Therefore, a different philosophy and approach for this marginal development are required to bring the field into production. Further, a development project such as Badami has to compete worldwide for BP's investment dollars, often with areas where capital and operating costs are significantly less than in the remote Arctic. The successful development of Badami should act as a catalyst and model for potential future oil developments in the Arctic, especially those that are relatively small by North Slope standards.

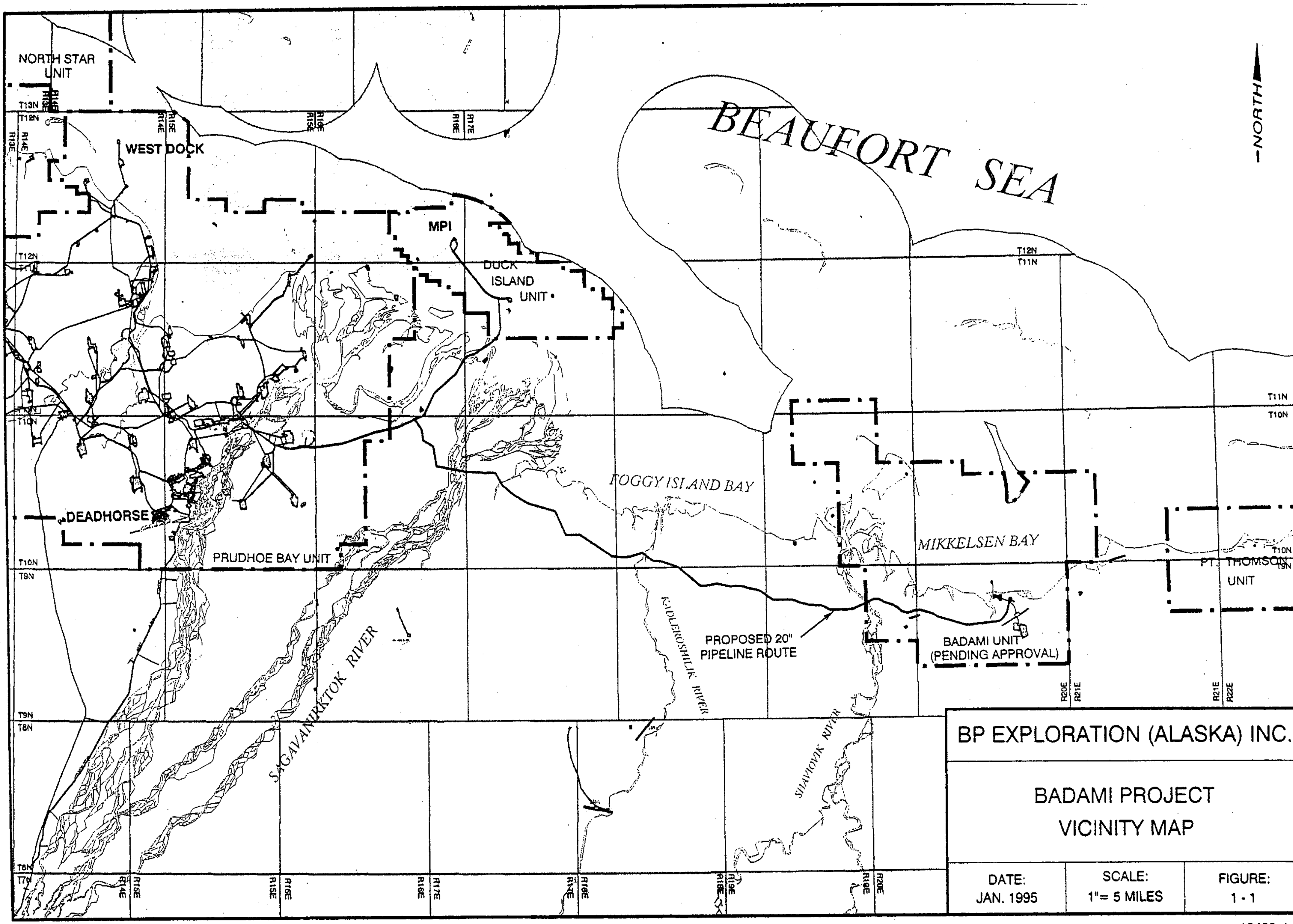
Although development of the Badami project requires a new approach to constructing and operating an oil field, BPXA is committed to maintaining its health, safety, and environmental policies and operating standards. BPXA's proposed development plans for Badami, as described in this document, ensure that these new and innovative approaches to operating in the Arctic are in compliance with all applicable laws and regulations. The extensive environmental mitigation measures incorporated in the project are described in Section 6.

1.4 PROJECT SCOPE AND MILESTONES

Technological and operational innovations planned for the Badami project include a buried oil pipeline, minimally staffed facilities, extensive use of extended-reach drilling, and no gravel access road to existing oil field infrastructure. These innovations also offer distinct environmental benefits. The major components of the planned Badami project include:

- A single-phased project with stand-alone production and process facilities;
- A buried oil pipeline carrying chilled crude to the Endicott sales oil pipeline;
- Project construction without a permanent gravel access road from existing oil fields;
- A dock in Mikkelsen Bay for marine access for sealift, supplies, and emergency response;
- Remote and automated project operation in a minimally manned mode; and
- Acceptance of operational shutdowns of several hours or longer.

The major milestones of the Badami Development Project are described in Table 1-1.


BEAUFORT SEA
NORTH
NORTH STAR UNIT
WEST DOCK
MPI
DUCK ISLAND UNIT
DEADHORSE
PRUDHOE BAY UNIT
FOGGY ISLAND BAY
MIKKELSEN BAY
PT. THOMSON UNIT
SAGAVANIRKTOK RIVER
KADLEROSHILIK RIVER
SHAVIOVIK RIVER
PROPOSED 20" PIPELINE ROUTE
BADAMI UNIT (PENDING APPROVAL)
T13N
T12N
T11N
T10N
T9N
T8N
T7N
R13E
R14E
R15E
R16E
R17E
R18E
R19E
R20E
R21E
R22E
BP EXPLORATION (ALASKA) INC.
BADAMI PROJECT
VICINITY MAP
DATE: JAN. 1995
SCALE: 1"= 5 MILES
FIGURE: 1 - 1

ex12462.dgn

TABLE 1-1
MAJOR MILESTONES
BADAMI DEVELOPMENT PROJECT

MILESTONE	TIME FRAME	DESCRIPTION
Delineation Drilling	Winter 1994-95	BPXA will be drilling two delineation wells (Badami #4 and #5) in Mikkelsen Bay to further assess the reservoir to prove up a threshold of reserves (approximately 150 million barrels) to make development economic.
Geotechnical Studies, Route Survey and Hydrology	1994-95	A geotechnical (soils) drilling program and hydrological surveys were initiated in the summer of 1994. The geotechnical work will be continued during the winter and summer of 1995. Detailed route surveys will be conducted in the summer of 1995 along with collection of additional geotechnical and hydrologic information.
Additional Environmental Studies	Summer 1995	The results of environmental studies conducted during the summers of 1993 and 1994 are summarized in Section 4 of this document along with the results of a summer 1994 oceanographic survey in Mikkelsen Bay in the vicinity of the proposed dock. The environmental work will be concluded in the summer of 1995 with limited fish studies to verify predictions based on previous fish monitoring programs.
Detailed Engineering	Mid-1995	Detailed engineering will commence in mid-1995. This will provide the necessary information for the major operational permits (see Section 1.6).
Project Sanction	October 1995	Assuming the results of the Badami #4 and #5 delineation wells and firm cost estimates are favorable, in October 1995 the Badami project will be presented to the BP Board of Directors for approval and funding. By that time, BPXA desires to have the major land use/construction permits in hand and the right-of-way lease process sufficiently advanced to provide assurance of successful completion.
Gravel Construction	Winter 1995-96	Gravel construction will commence in early 1996 utilizing equipment mobilized over ice roads. Most gravel works at the Badami field development will be done in a single winter season, including opening of the East Badami mine site.
Development Well Drilling	Winter 1996-97	Development drilling will commence using a single rig as soon as the rig can be mobilized to the site via ice road in late 1996. Most wells will be directionally drilled into the reservoir beneath Mikkelsen Bay.
Pipeline Construction	Winter 1996-97	Pipeline construction will commence in winter 1996-97 and is expected to take approximately 3 months to complete. Small gravel mine sites will be opened in the floodplains of the Shaviovik and Kadleroshilik rivers to provide material for pipeline trench backfill, small valve pads, and maintenance stockpiles. Right-of-way maintenance work will follow late in the summer of 1997 to ensure stabilization. Additional follow-up work to revegetate the berm will be required in subsequent summers.
Sealift	Summer 1997	Modules for process and living facilities will be brought into Badami by sealift in the summer of 1997 and offloaded at the dock.
Production	Late 1997	Production from Badami will commence at the end of 1997 and build up to peak rates of up to 50,000 barrels per day.

1.5 PROJECT PLANNING AND STAKEHOLDER INVOLVEMENT

The new approaches and thinking that have been incorporated in the Badami project include technological innovations and the development of partnerships with external stakeholders. These stakeholders include contractors, the State of Alaska, federal agencies, and the North Slope Borough. BPXA has brought a number of these stakeholders into the Badami project planning process earlier and more comprehensively than has typically been done on past development projects. As discussed in Section 7, BPXA has held a number of workshops and progress meetings with the regulatory agencies to inform them of design concepts and to solicit ideas, comments, and concerns. For example, workshops have been held on Beaufort Sea fisheries and causeway studies and on pipeline design criteria.

BPXA is committed to continue this process during the permitting and construction phases of the project. In addition, BPXA, at the suggestion of the State Pipeline Coordinator's Office, which will process the Right-of-Way Lease application, has held a number of informational meetings with interested third parties to review the Badami project in Anchorage, Fairbanks, and the North Slope Borough. Invitees have included business community representatives, local legislators and their staff, environmental organizations, labor organizations, and others. A list of stakeholder meetings and consultations is provided in Section 7.

BPXA has attempted to address all the substantive issues and questions raised in the agency and public meetings. Information requested in those meetings has, to the extent available, been provided in this document, the permit applications, and other supporting documents. As a result, a significant effort has been made to enhance the quality and comprehensiveness of these documents in order to minimize the potential for delays in the permitting process.

1.6 PERMITS AND APPROVALS

At this time, BPXA is concurrently applying for all the major construction and land use approvals required for the Badami Development, which include:

- U.S. Army Corps of Engineers Section 404 and Section 10,
- Alaska Department of Natural Resources Right-of-Way Lease,
- Alaska Department of Natural Resources Lease Operations Plan Approval,
- Alaska Department of Natural Resources Competitive Material Sales Contracts,
- Alaska Department of Natural Resources Temporary Water Use,

- Alaska Department of Fish and Game Title 16, and
- Alaska Division of Governmental Coordination Coastal Consistency Review.

The permit application packages address information needs identified by agencies in consultations and meetings during the pre-application process. The major areas of interest and concern included:

- The alternatives considered and rejected for the major project components (e.g., pipeline routings and construction modes, site access, drilling pad locations, dock);
- The design and geotechnical and thermal performance of a buried chilled-oil pipeline;
- Cross drainage along the pipeline right-of-way;
- Rehabilitation of the pipeline right-of-way (monitoring, stabilization, and revegetation);
- Pipeline leak detection, spill prevention and response; and
- Impacts of the proposed dock in Mikkelsen Bay.

BPXA will apply for the major operational permits when detailed design information is available. These include:

- Alaska Department of Environmental Conservation Air Quality Control Permit to Operate/Prevention of Significant Deterioration (air emissions);
- Alaska Department of Environmental Conservation Oil Discharge Prevention and Contingency Plan;
- Environmental Protection Agency National Pollutant Discharge Elimination Program (NPDES) Permit (for domestic wastewater);
- Alaska Oil and Gas Conservation Commission Class II Injection Well; and
- North Slope Borough Rezoning Amendment to the Badami Resource Development District and Development Permit.

1.7 SCOPE OF PROJECT DESCRIPTION AND ENVIRONMENTAL ASSESSMENT

This Project Description and Environmental Assessment is designed to provide all the necessary information to support the major construction and land use permit applications listed in Section 1.6. Alternatives to the proposed action that were considered are analyzed in Section 2 as a basis for the alternatives evaluation required by the National Environmental Policy Act (NEPA), the Section 404 (b)(1) Guidelines, and 33 CFR Part 230.5(e). The major project components and activities that constitute the proposed action are described in Section 3. The Environmental Assessment (Sections 4 and 5) is intended to provide information to the Corps of Engineers to assist in satisfying the NEPA requirements at 33 CFR Part 230, specifically as provided at 33 CFR Part 230, App. B, 8b. Mitigation measures incorporated into project design are detailed in Section 6, which is intended to establish the basis for regulatory review for conformance with the requirements to the Section 404 (b)(1) Guidelines. The extensive agency, public, and third-party consultations that have been conducted by BPXA as an integral part of the planning process are listed in Section 7. Planned engineering and environmental studies are outlined in Section 8.

Appendix A of the Application for Right-of Way Lease to the Alaska Department of Natural Resources provides the engineering design basis for the Badami Pipeline. This appendix expands on the information contained in the application for the right-of-way lease, describing the basis for the Badami Pipeline design concept. It also describes how design standards will be used in the process of final design. Because of the innovative nature of the proposed Badami chilled-oil buried pipeline, BPXA requests that this document be considered an integral part of the overall permit application package to federal and state reviewing agencies.

2. ALTERNATIVES

As part of conceptual project planning, BPXA has evaluated a series of alternatives for design, construction, and operation of the Badami Development Project. The proposed project was formulated based on a balance of environmental, technical, economic, and logistical considerations. Analysis of alternatives is an important part of both project development and of the overall project review and approval process. Identification and analysis of project alternatives are needed to comply with the requirements of the National Environmental Policy Act and to fulfill the requirements of the 404(b)(1) Guidelines for review of Section 404 permit applications.

Alternatives were identified for five major project components:

- Field development — location and size of production and facilities pad(s);
- Pipeline mode — elevated or buried (onshore or offshore);
- River crossings — elevated or buried;
- Access — air, ground, and marine; and
- Material sites — location.

The same general procedure was used in evaluation of alternatives for each project component. First, project needs associated with each component were identified, including both construction and operational requirements. Basic alternatives available to fulfill project needs were then identified. These alternatives were evaluated against project requirements to assess the feasibility of each choice; feasibility was analyzed in terms of technology, economics, and practicality. The environmental considerations of each feasible alternative were also compared to select the best alternative to meet the specific needs of the project.

Table 2-1 lists alternatives considered during project development and indicates the status of each alternative.

2.1 FIELD DEVELOPMENT

Field development needs associated with the Badami project include well drilling, production from the wells, processing well fluids, a pipeline delivery system, possible

TABLE 2-1
BADAMI PROJECT ALTERNATIVES

PROJECT OPTION	FEASIBILITY	STATUS
FIELD DEVELOPMENT		
Onshore production and facilities pads	Feasible	Proposed Action
Offshore production/facilities island	Feasible	Alternative
Offshore drilling island, onshore production and facilities pad	Feasible	Alternative
Offshore drilling platform	Not feasible for this project (water too shallow)	Rejected
PIPELINE		
Elevated on VSMs, transporting single- or multi-phase flow at warm temperatures	Feasible	Alternative
Onshore - buried in permafrost, transporting chilled, single phase flow	Feasible	Proposed Action
Combination of elevated and buried segments	Not feasible for this project (uneconomical and impractical)	Rejected
Offshore - buried below ice gouge depth, transporting chilled, single phase flow	Not feasible for this project (requires additional engineering and research)	Rejected
RIVER CROSSINGS		
Elevated on strengthened VSMs	Feasible	Alternative
Buried below scour depth.	Feasible	Proposed Action
Combination bridge span/gravel fill	Not feasible for this project (uneconomical)	Rejected
ACCESS		
Airstrip	Feasible	Proposed Action
Gravel road	Feasible (not economical for this project)	Rejected
Ice road	Feasible	Proposed Action
Tundra travel	Feasible	Proposed Action
Barge / solid-fill 1200-ft dock	Feasible	Alternative
Barge / solid-fill 2400-ft dock	Feasible	Proposed Action
Barge / pile-supported dock	Not feasible for this project (cannot support modules for onshore development)	Rejected
Barge / breached solid-fill dock	Not feasible for this project (cannot support modules for onshore development)	Rejected

TABLE 2-1 (Cont'd)
BADAMI PROJECT ALTERNATIVES

PROJECT OPTION	FEASIBILITY	STATUS
ACCESS (Cont'd)		
Barge / solid-fill dock with intermediate barge section	Not feasible for this project (uneconomical)	Rejected
Barge / dredge channel to shore	Not feasible for this project (cannot support modules for onshore development)	Rejected
Freeze barge in place, build ice road to shore	Not feasible for this project due to seasonal limitations	Rejected
Barge / gravel structure with additional barge at end	Not feasible for this project (uneconomical)	Rejected
Sink series of barges	Not feasible for this project (uneconomical)	Rejected
Mulberry bridges	Not feasible for this project (cannot support modules for onshore development)	Rejected
MATERIAL SITES		
East Badami Creek site	Feasible	Proposed Action
Shaviovik River site	Feasible	Proposed Action
Kadleroshilik River site	Feasible	Proposed Action
East Channel Sagavanirktok River site	Not feasible for this project (uneconomical)	Rejected
Re-use of gravel from abandoned airstrip (lies mostly within S3, T9N, R19E)	Not feasible (owner of gravel resources needs to demonstrate no environmental liability associated with use of gravel; less economical due to location)	Rejected
Use material from existing Duck Island Gravel Mine	Feasible	Proposed Action

enhanced oil recovery systems, and support facilities required for safe and reliable operation of the field. Basic support systems consist of communications, spill response capability, utilities, and camp facilities. Regardless of field development location and size, a pad needs to be constructed to provide a foundation for facilities and to ensure safe and reliable working conditions.

2.1.1 Options

The location of field development facilities depends on the location of the Badami reservoir. Based on the results of the Badami #1 and Badami #2 wells, and on three-dimensional seismic analysis, most of the Badami reservoir appears to be located primarily offshore beneath Mikkelsen Bay. With directional drilling techniques, the location from the top of a well to the bottom of the well can deviate by as much as 12,000 feet; with extended-reach drilling, deviations as great as 15,000 feet could be achieved. Thus, both offshore and onshore locations are feasible and were evaluated for Badami field development. Four basic options for field development were identified:

- Onshore drilling and production pad(s),
- Offshore gravel drilling and production island,
- An offshore drilling island and an onshore production pad, and
- Offshore drilling platform.

Onshore Development

Onshore development would include gravel pads to support drilling and production facilities. Regardless of the location selected, the pad layout would optimize drilling considerations with the need to avoid higher-value wetlands. From an onshore location, wells would have to be arrayed in rows to reach the desired areas of the reservoir, and extensive directional drilling would be required to develop the reservoir.

Offshore Development

Offshore development was evaluated as a means to locate the wells as close to the top of the reservoir as possible. Under this scenario, a gravel island with a template drilling arrangement would be constructed; production facilities would also be located on the island. Template drilling allows a very compact arrangement of wells within a small surface area. It requires that the drill template be located nearly directly above the target area of the reservoir. Based on needs for safe and reliable access, a 2,400-foot gravel-fill causeway would connect the island to the shore.

Offshore Drilling / Onshore Production

Under this option, an offshore island would be constructed to accommodate a template drilling arrangement, and an onshore pad would be constructed for production facilities. This option was identified as a means to reduce gravel construction costs (onshore surface area is much less costly than offshore surface area). A solid-fill causeway would connect the drilling island and the production pad to ensure safe and reliable access.

Offshore Drilling Platform

Use of an offshore drilling platform in Mikkelsen Bay was considered but found to be not feasible for this project. Offshore drilling platforms such as those used in Cook Inlet require water depths of at least 30 feet; water depths in Mikkelsen Bay are no deeper than 20 feet.

2.1.2 Analysis

BPXA has selected onshore development as its proposed action based on economics, identified risks associated with offshore construction, and the lack of significant environmental impacts associated with onshore construction.

The three feasible field development options were compared on the basis of practicality, risk, development cost, operational cost, and environmental considerations. The offshore option has essentially the same cost as the onshore option. Reducing the size of the island by only locating wells offshore and locating production facilities onshore results in some savings. Operating costs for each of these three options are essentially the same.

There are several risks associated with technical uncertainties about the offshore option. The template drilling concept involves a concentration of numerous well bores within a small area. Because these well bores would be passing through deep permafrost, freezeback protection for the soils would be required. Analysis of the cost of chilling soils underneath the template to maintain stability shows that, given the uncertainty about the performance of the chilling process and the current understanding of the location and extent of the Badami reservoir, there may be little, if any, actual cost savings associated with offshore drilling.

Two major environmental considerations include the placement of fill in onshore wetlands and the placement of fill in the nearshore environment. In each of the three options evaluated, fill would be placed in the nearshore Beaufort Sea because a causeway is required for any drilling or production island and a dock is needed to support onshore development. While impacts to wetlands from pad construction can be avoided by locating facilities offshore, most impacts can be mitigated through careful site selection and design (see Sections 5 and 6).

2.2 PIPELINE MODE

A Badami pipeline must be constructed to transport crude oil from the Badami field to market. The pipeline would originate at the production facility and terminate at a tie-in with the Endicott Pipeline. For the Badami project, four possible pipeline options have been identified:

- An elevated pipeline,
- A buried pipeline,
- Combination of buried/elevated mode based on site-specific conditions, and
- A subsea buried pipeline.

2.2.1 Options

Elevated Pipeline

Elevated pipelines are typically used in North Slope oil field development, both as in-field gathering lines and as common carrier sales pipelines. Most segments of the Trans-Alaska Pipeline System (TAPS) that traverse frozen soils are also elevated. Elevated lines are commonly used on the North Slope to prevent heat transfer from the hot oil in the pipeline to frozen soils, since heat would degrade the permafrost.

An elevated Badami pipeline route was identified based on several design criteria, including avoidance of lakes, minimizing the number of stream crossings, optimizing river crossing locations, avoidance of high-value habitats, and the ability to accommodate future road construction within the same corridor. The design would involve placing the pipe on vertical support members (VSMs), as is typical elsewhere on the North Slope. This pipeline route is approximately 30 miles long and would cost approximately $110 million, including river crossings.

Buried Pipeline

While buried oil pipelines have typically not been constructed on Alaska's North Slope, this is the standard mode of construction for unfrozen soils. Buried pipelines in the Arctic are feasible, however, provided that the integrity of the frozen soils can be maintained. This can be accomplished by transport of a cold (chilled) substance. There is a chilled buried fuel-gas pipeline from Pump Station 1 to Pump Station 4 along the TAPS corridor, and both the authorized but unconstructed Alaska Natural Gas Transportation System and the Trans-Alaska Gas System pipelines propose to transport cold natural gas in a chilled, buried mode. In the Northwest Territories in Canada, the Norman Wells oil pipeline has been operating for 10 years. This buried pipeline transports chilled crude oil.

Since testing has shown that Badami crude oil can be chilled and pumped at subfreezing temperatures, a buried pipeline option was considered for this project. This design concept involves full processing of Badami oil to remove water and gas, chilling the oil, and transporting it in a pipeline buried in permafrost below the active layer. After construction, the pipeline would be operated to maintain equilibrium with surrounding soils temperatures.

A buried Badami pipeline route was identified based on several design criteria, including avoidance of lakes, minimizing the number of stream crossings, optimizing river crossing locations, appropriate soils conditions, and favoring wetter versus drier tundra for faster rehabilitation. This pipeline route is approximately 27.9 miles long and would cost approximately $60 million, including river crossings.

Combination of Modes

The possibility of using both elevated and buried modes along the Badami Pipeline was considered. Pipeline mode would be determined by site-specific soils conditions. Use of this option would require transport of chilled oil through both the buried and elevated sections, since it would be uneconomical and impractical to alternate chilled and heated pipeline segments. This option would result in substantial increased material costs over an entirely buried route due to the cost of VSMs for elevated pipeline sections. Construction costs for this option would be significantly higher than either a buried or an elevated pipeline, because each mode would require a separate construction crew and set of equipment. In addition, the technical performance of a chilled pipeline with combined elevated and buried modes is unknown at this time.

Subsea Buried Pipeline

Subsea oil transportation pipelines have been considered for recent development projects on the North Slope, but none has been constructed to date. A subsea buried pipeline was evaluated as an option for the Badami project.

This project concept would involve chilling and pumping Badami crude oil in a buried pipeline under Mikkelsen Bay and Foggy Island Bay, terminating at a tie-in with the Endicott Pipeline. This pipeline would be approximately 25 miles long. The technical feasibility of this option is not completely understood. Major technical design and operational issues affecting feasibility of this option include:

- Protection from ice-gouging,
- Ability to maintain the line and perform repairs, and
- Spill response.

Because of known and potential offshore oil and gas prospects, BPXA is continuing to investigate the feasibility of this design concept. Some progress in evaluating the potential of subsea pipelines has been achieved. However, the state of understanding of the opportunities and constraints of this design option need to be better understood before a subsea pipeline could be proposed for the Badami project. At least another year of engineering evaluation to determine design and operational feasibility would be required before this design option could be proposed. For the Badami project, BPXA has already proposed applying technology new to the North Slope in the form of a buried, chilled crude pipeline. Given the schedule for Badami development, further consideration of innovative approaches in terms of a subsea pipeline is not warranted.

2.2.2 Analysis

A buried, chilled-crude pipeline has been selected as the proposed action for the Badami Development Project. This decision was reached based on confidence in the technical feasibility and constructability of this approach to arctic pipeline design, and on the substantial cost savings associated with a buried line. Preliminary estimates show cost savings of approximately $50 million for a buried rather than an elevated line. Given the marginal economics of the Badami field, this cost savings is critical to the financial feasibility of the project.

2.3 RIVER CROSSINGS

Regardless of the onshore pipeline route selected, four major rivers will need to be crossed: the No Name River, the Shaviovik River, the Kadleroshilik River, and the East Channel of the Sagavanirktok River. Three options for river crossings were investigated:

- Elevated on strengthened VSMs,
- Buried (trenched) below the rivers, and
- Combination of a bridge span and gravel-fill structure in the floodplain.

2.3.1 Options

Elevated Crossing

An elevated pipeline crossing would be constructed using reinforced VSMs, designed to withstand flood and ice forces expected at each river. This is a typical design that has been used elsewhere on the North Slope, notably across the Kuparuk River. The costs of this crossing option would be at least twice the costs of a buried crossing.

Buried River Crossings

The buried pipeline would be installed using trenching at the four major river crossings. The pipeline would be buried below the design scour depth. After construction, the banks would be stabilized to prevent erosion or channel migration.

Bridge and Gravel Fill

This concept would involve placement of gravel berms to support the pipeline in the floodplain, with a pipeline bridge spanning the river channel(s). This design was eliminated from detailed consideration for the Badami project based on environmental and technical constraints. The rivers traversed by the pipeline corridor are dynamic, and channel migration is not uncommon. In addition, bridge design must withstand significant ice and water forces during breakup and summer flood events. In this option, the river channel would be constricted, with the entire flow passing through the spanned section(s). Therefore, the gravel berms would be prone to erosion and potential failure. Frequent maintenance in the floodplain would be required to ensure the performance of the berms. Given the costs of maintenance, the risk of unplanned failure, and the possible effects on fish habitat from frequent maintenance of the gravel structures, this option has been eliminated from detailed consideration.

2.3.2 Analysis

Given the decision to construct a buried pipeline, it is most practical to also bury the pipeline river crossings. Buried crossings also result in a substantial cost savings over elevated crossings.

2.4 TRANSPORTATION / ACCESS

2.4.1 Needs

Badami project transportation needs include the ability to safely transport personnel, supplies, and equipment to and from the site during construction and operations. During construction, large quantities of pipe, gravel, and heavy modules will need to be moved to the site. Drilling operations will require movement of pipe materials, chemicals, and other supplies to the production pad. During ongoing field operations, equipment and supplies will need to be transported to the site. All phases of construction, drilling, and operation will require movement of personnel to and from the Badami area, and hauling of waste (including heavy scrap materials) back to the Prudhoe Bay area for disposal. In addition, BPXA needs to provide access to move drill rigs to and from the field, and to ensure that a relief rig can be quickly mobilized to the site in the event of an emergency. Since this area lacks any infrastructure development, it is also important that

Badami transportation facilities be designed to provide flexibility to meet potential future transportation needs. Table 2-2 summarizes basic project transportation needs and identifies the frequency of those needs.

2.4.2 Options

The Badami area is remote from existing North Slope infrastructure; the nearest transportation facilities are located in the Endicott and Prudhoe Bay units, about 25 air miles west of the site. In the project development process, various options were identified for accessing the site and for moving equipment, supplies, and personnel to and from the site. Several different modes of available transportation were considered. The following sections describe the basic features, costs, and limitations of each mode. Figure 2-1 shows seasonal limitations associated with operation of each mode of transportation.

Air Access

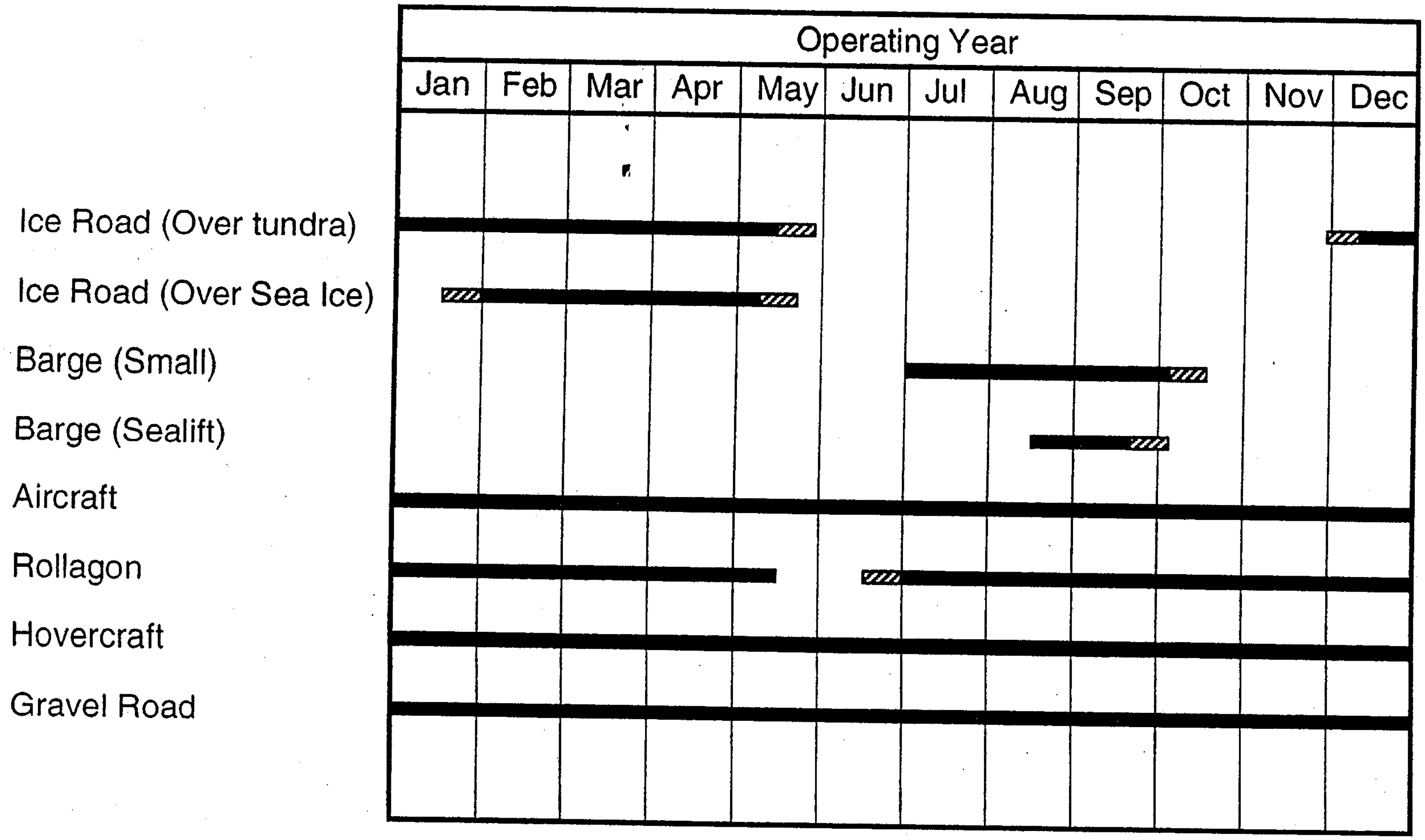
Year round access to the Badami area is possible with construction of a gravel airstrip or a helicopter landing pad. Seasonal access can be provided with an ice airstrip. Air operations can be limited by weather conditions and by aircraft availability. In general, air access is best suited for movement of personnel and for emergency movement of supplies or equipment. Costs vary from $1,000 per hour for a six-passenger helicopter transferring passengers to the site (round trip) to $20,000 per hour for use of a Hercules aircraft for carrying an emergency relief rig to the site. Extensive pre-planning is required for using air access to move major quantities of supplies over 1 ton. The cost to construct a gravel airstrip capable of supporting a fully loaded Hercules is approximately $2,500,000.

Ice Roads

Ice roads are commonly used on the North Slope for winter travel from late December through mid-April. Overland ice roads are typically constructed by spraying fresh water on a snow-covered surface until the ice reaches a minimum thickness of 6 inches. Roads across the sea ice are constructed by grading the sea ice or thickening it with sprayed fresh water as needed to create a surface suitable for vehicular movement. Because ice compresses and degrades under heavy loads, ice roads cannot be used for movement of extremely heavy modules (2,100 tons). Ice road construction and maintenance costs are about $1,250,000 for an approximately 35-mile-long ice road paralleling the proposed pipeline route from Endicott to Badami. Costs for a sea ice route from Endicott to Badami are approximately $1,000,000, including operation and maintenance costs.

TABLE 2-2
BADAMI PROJECT TRANSPORTATION NEEDS

PROJECT ACCESS NEEDS	FREQUENCY		
	ONGOING	INTERMITTENT	DISCRETE
Haul gravel from mine site to construction site(s).		X	
Haul pipeline construction materials.			X
Transport production modules to the Badami production pad. Heaviest modules will weigh approximately 2100 tons; two of these heavy modules are planned at the site.			X
Spill response. Mobilize equipment and personnel to onshore and offshore locations. Need staging area independent of likely spill location (e.g., pad) for staging.	X		
Transport supplies and equipment to the site. Supplies include drill pipe, chemicals, maintenance equipment, muds, etc.	X		
Drill rig transport.		X	
Personnel transport.	X		
Waste handling. Includes hauling back domestic waste, waste stored in barrels, and scrap. In initial years, drilling wastes may also be hauled back. Note that some wastes can be disposed of on site by injection, etc.		X	
Capability for emergency transport of relief rig.	X		
Provide basic infrastructure for potential future development in the area.	X		



BP EXPLORATION (ALASKA) INC.

BADAMI
SEASONAL ACCESS LIMITATIONS

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	2-1

Gravel Roads

A gravel road could be constructed from Endicott to Badami. Initial construction would occur in the winter, and year-round access would be available. Routine maintenance would be required. Four major bridges would have to be constructed for a gravel road. Weight restrictions on the type of bridges typically built for North Slope gravel roads would be a constraint to movement of large modules or drilling rigs. While most North Slope roads have a 30-foot crown width and 2:1 side slopes, a road designed for movement of the modules currently being considered for the Badami project would require a crown width of 40 to 50 feet. Construction of 30 miles of gravel road from Endicott to Badami would cost about $50,000,000, and bridges would cost an additional $60,000,000. Annual maintenance costs would be about $500,000.

Marine Access (from Prudhoe Bay Unit to Badami Unit)

Barges and other boats can travel from the Prudhoe Bay area to the Badami area between mid-June and late September, depending on nearshore ice conditions. Barges are typically chartered from a local supplier on an as-needed basis to move equipment and supplies. The estimated daily costs of using a shallow-draft barge to move materials to and from Badami are $25,000. Docking facilities costing about $250,000 would need to be constructed to allow off-loading of the barges, which have a 6-foot draft.

Marine Access (Sealift to North Slope)

Seagoing barges are typically used to transport large modules (up to 5,600 tons) and other supplies and equipment from the lower 48 states or Southcentral Alaska. Movement of these barges around Point Barrow is limited to a short period from mid-August through mid- to late September. The cost of moving modules from the point of fabrication to the North Slope is approximately $5,000,000. A dock capable of supporting the modules plus the vehicle used to carry the modules would need to be constructed to move the modules from the barge to the pad. The estimated costs of this dock are about $500,000. These barges require an 8- to 10-foot draft to accommodate the large tugboats needed to position the barges.

Tundra Travel (Rollagons and Hovercraft)

Rollagons can travel directly on the ground surface but are limited to seasonal use in the winter and summer months. These vehicles can carry up to 25 tons and cost about $3,000 per day. Hovercraft can be used year round, depending on weather conditions. Costs are similar to those associated with helicopter access. Carrying capacity is limited to 35 tons, depending on the size and shape of the load.

2.4.3 Feasibility Analysis

A feasibility analysis was conducted to determine the viability of each transportation mode to meet each project need. Each mode was compared with project needs to see if it was achievable with existing technology, economic for the Badami project, and practical given North Slope logistics, seasonal constraints, and other project limitations. The feasibility analysis is summarized in Table 2-3.

As shown in this table, air, ice road, and marine access will all be required for the Badami project. A gravel access road extending from Endicott to Badami is uneconomical for a project of this scale. A gravel road was originally planned, but later eliminated from the project concept to minimize both cost and impacts. Since the project is planned to be built without gravel road access, other modes of transportation must be provided. Annual winter ice-roads are planned to provide basic access to the site, and a gravel airstrip that can accommodate Hercules aircraft is needed to ensure emergency access year round. Marine access must also be provided to move heavy modules to the wellsite and to allow cost-effective transportation of equipment and materials to and from the site during the summer.

2.4.4 Design Analysis

Given that some type of marine access is required to allow movement of heavy modules and drill rigs to the site, and for seasonal movement of equipment and supplies, various alternatives for design of marine facilities were evaluated. A screening analysis was conducted to identify a series of possible designs and to compare these options against needs for marine access. The facilities options considered include:

- Dredge channel to shore and unload directly on beach,
- Construct a solid-fill gravel dock to the 10-foot water depth,
- Construct a solid-fill gravel dock to the 6-foot water depth and dredge a channel to the 10-foot depth as needed to transport large modules,
- Construct a pile-supported dock,
- Seasonally freeze a barge in place and construct an ice road to shore,
- Construct a solid-fill gravel dock to the 6-foot water depth and sink a barge at the end of the dock when needed to transport large modules,
- Construct a solid-fill gravel dock with a bridge over a breached section,
- Construct a solid-fill gravel dock with an intermediate barge section (replace barge with culverts after module transport),
- Sink a series of barges to construct a dock, and
- Use Mulberry bridges (prefabricated military bridge).

TABLE 2-3
FEASIBILITY ANALYSIS

PROJECT NEED/ MODE OF ACCESS	FEASIBILITY ANALYSIS: DESIGN/ TECHNOLOGY	FEASIBILITY ANALYSIS: PRACTICABILITY	FEASIBILITY ANALYSIS: COST	MODIFY NEED	CONCLUSION
<u>**Transport Production Modules**</u>					
Air access	—	Modules too heavy for air transport	High costs even for small cargoes	Use smaller modules (not economical or practical: requires on-site fabrication, increased labor costs and longer construction period)	Eliminated (not feasible)
Gravel road	<2% grade required; large bridges needed	Many existing bridges within PBU would also need upgrading	Highest construction cost, moderate operational cost	Use smaller modules (see above); winter transport (requires schedule delay)	Eliminated (not practical or economical)
Ice road	Ice roads not reliable; may not provide required structural integrity	Seasonal limitations	Lowest construction cost, moderate operational cost	Use smaller modules (see above)	Eliminated (not feasible)
Barge	Standard practice	Standard practice	Moderate construction cost, low operational cost	—	**Retain**
Tundra travel (Rollagon, hovercraft)	—	Modules too heavy for vehicles	No construction cost, high operational cost	Use smaller modules (see above)	Eliminated (not feasible)
<u>**Spill Response**</u>					
Air access	Can use to bring emergency equipment to site	Practical; necessary part of response; does not provide direct access to affected onshore or offshore areas	Moderate construction cost, highest operational cost	—	**Retain** (to pre-stage/pre-deploy equipment and for emergency transport of personnel and small equipment only)

TABLE 2-3 (Cont'd)
FEASIBILITY ANALYSIS

PROJECT NEED/ MODE OF ACCESS	FEASIBILITY ANALYSIS			MODIFY NEED	CONCLUSION
	DESIGN/ TECHNOLOGY	PRACTICABILITY	COST		
Spill Response (Cont'd)					
Gravel road	Can use to access onshore areas	Does not provide access to offshore areas	Highest construction cost, moderate operational cost	—	Eliminated (gravel road construction not economical for this project)
Ice road	Can use to access onshore areas	Does not provide access to offshore areas; seasonal limitations	Lowest construction cost, moderate operational cost	—	**Retain** (to pre-stage/pre-deploy equipment only)
Marine access	Can use to deploy equipment and access offshore areas	Provides capability for access in open water season and for staging in winter; some constraints in broken ice conditions	Moderate construction cost, low operational cost	—	**Retain** (needed to access marine water during open water season and during broken ice conditions)
Tundra travel (Rollagon, hovercraft)	Can use to bring emergency equipment to site	Reasonable access for response; can provide access for most of the year	No construction cost, high operational cost	—	**Retain** (to pre-stage/pre-deploy equipment and for emergency transport of personnel and small equipment only)
Transport Supplies and Equipment					
Air access	Standard design	Cannot transport pipe materials or some chemicals	Moderate construction cost, highest operational cost	—	**Retain** (Use if necessary)
Gravel road	Standard practice	No constraints	Highest construction cost, moderate operational cost	—	Eliminated (gravel road construction not economical for this project)

TABLE 2-3 (Cont'd)
FEASIBILITY ANALYSIS

PROJECT NEED/ MODE OF ACCESS	FEASIBILITY ANALYSIS: DESIGN/ TECHNOLOGY	FEASIBILITY ANALYSIS: PRACTICABILITY	FEASIBILITY ANALYSIS: COST	MODIFY NEED	CONCLUSION
Transport Supplies and Equipment (Cont'd)					
Ice road	Standard design	Seasonal limitations	Lowest construction cost, moderate operational cost	Stockpile material on site	**Retain** (use seasonally)
Barge	Standard design	Seasonal limitations	Moderate construction cost, lowest operational cost	Stockpile material on site	**Retain** (use seasonally)
Tundra travel (Rollagon, hovercraft)	Typically used as back-up when circumstances require	Seasonal limitations, weight restrictions	No construction cost, high operational cost	—	**Retain** (use seasonally)
Drill Rig Transport					
Air access	—	Standard rig too heavy for air transport	—	—	Eliminated (not feasible)
Gravel road	Standard bridge design will not support rigs	Bridges a constraint	Excessive construction cost	Operate seasonally (then can use ice roads)	Eliminated (not economic or practical)
Ice road	Standard design	Seasonal limitations	Lowest construction cost, moderate operational cost	Reschedule rig to operate seasonally or remain on site throughout summer season	**Retain** (use seasonally)
Barge	Standard design	Seasonal limitations	Moderate construction, lowest operational cost	Reschedule rig to operate seasonally or remain on site throughout winter season	**Retain** (use seasonally)
Tundra travel (Rollagon, hovercraft)	—	Rig too heavy for these vehicles	—	—	Eliminated (not feasible)

TABLE 2-3 (Cont'd)
FEASIBILITY ANALYSIS

PROJECT NEED / MODE OF ACCESS	FEASIBILITY ANALYSIS: DESIGN/ TECHNOLOGY	PRACTICABILITY	COST	MODIFY NEED	CONCLUSION
Personnel Transport					
Air access	Standard design	Weather dependent	Moderate construction cost, high operating costs	—	**Retain** (use as needed)
Gravel road	Standard design	Some weather constraints	Highest construction cost, lower operating costs	—	Eliminated (gravel road construction not economical for this project)
Ice road	Standard design	Seasonal limitations	Lowest construction cost, lower operating costs	—	**Retain** (use during winter season as practical)
Barge	Standard design	Seasonal limitations; barges usually not used to move personnel	Moderate construction cost, lowest operating cost	—	**Retain** (occasional use)
Tundra travel (Rollagon, hovercraft)	Standard practice	Seasonal limitations	No construction cost, high operational cost	—	**Retain** (use as needed)
Waste Handling					
Air access	—	Weight restriction; some safety and regulatory constraints on moving wastes by air	Moderate construction cost, highest operating cost	—	Eliminated (not economical or practical)
Gravel road	Standard design	Practical	Highest construction cost, moderate operating cost	—	Eliminated (gravel road construction not economical for this project)
Ice road	Standard design	Seasonal limitations; some wastes cannot be stored more than 90 days	Lowest construction cost, moderate operating cost	Store wastes for regular removal	**Retain** (use seasonally)

TABLE 2-3 (Cont'd)
FEASIBILITY ANALYSIS

PROJECT NEED/ MODE OF ACCESS	FEASIBILITY ANALYSIS: DESIGN/ TECHNOLOGY	FEASIBILITY ANALYSIS: PRACTICABILITY	FEASIBILITY ANALYSIS: COST	MODIFY NEED	CONCLUSION
Waste Handling (Cont'd)					
Barge	Standard design	Seasonal limitations; some wastes cannot be stored more than 90 days	Moderate construction cost, lowest operating cost	Store wastes for regular removal	**Retain** (use seasonally)
Tundra travel (Rollagon, hovercraft)	—	Seasonal limitations	No construction cost, high operational cost	—	**Retain** (use as needed)
Emergency Relief Rig Transport					
Air access	Standard	—	Moderate construction cost, very high operating cost	—	**Retain**
Gravel road	Standard design	Practical	Highest construction cost, moderate operating cost	—	Eliminated (gravel road construction not economical for this project)
Ice road	Standard design	Not practical (seasonal limitation not acceptable for emergency requirement)	Lowest construction cost, moderate operating cost	Do not drill in summer months	Eliminated (does not meet need)
Barge	—	Not practical (seasonal limitation not acceptable for emergency requirement)	Moderate construction cost, lowest operating cost	Do not drill in winter months	Eliminated (does not meet need)
Tundra travel (Rollagon, hovercraft)	—	Seasonal limitations; weight restrictions	No construction cost, high operational cost	Disassemble rig	**Retain** (use as needed)
None (store on site)	Standard	Poor reliability due to very limited use	No construction cost, extremely high rental or purchase cost	—	Eliminated (not practical or economical)

As shown on Table 2-4, only four of these options are capable of meeting Badami project marine access requirements. The need to move modules to an onshore pad and to transport heavy drilling rigs eliminated several design alternatives from detailed consideration. The viable alternatives all involve either construction of a solid-fill gravel structure, use of barges sunk in place, or a combination of the two. The costs, environmental effects, and logistical considerations of each of these four dock alternatives were then compared (Table 2-5). Based on this comparison, construction of a solid-fill gravel dock to the 10-foot water depth is the most economical alternative, and also provides maximum flexibility for potential future marine-access needs in the region.

Construction of a longer dock results in additional fill in the nearshore zone. The need for this fill can be avoided by reducing the length of the dock and dredging as needed to allow access by sealift barges. However, disposal of dredge spoils would also result in placement of fill in the nearshore zone, and could result in some potentially adverse water-quality impacts. Use of barges sunk in place is uneconomical compared to the other two construction options.

Two potential locations for the Badami dock have been identified. The proposed location was selected because it provides maximum flexibility for possible future project needs. Although not planned at this time, there is some possibility that additional information about the Badami reservoir will indicate the need to consider drilling production wells from an offshore location. In this case, the proposed dock is located in an optimal location to reach nearly the entire reservoir. A modification of the dock head would be required to convert it to an offshore drilling island.

The alternative location (Figure 2-2) would result in a minor reduction of wetlands fill (less than 1 acre), and allows direct access for module movement from the dock to the facilities pad. However, this location does not provide flexibility if offshore drilling is needed.

2.5 MATERIAL SITES

Up to 3.1 million cubic yards of gravel could be required for the Badami Development Project. For any project, gravel mine site selection is based on locating adequate quantities of suitable material that are within a reasonable distance from the construction area and that can be mined in an economic and environmentally sound manner. For the Badami project, several sources of gravel have been considered. These include the:

- East Badami Creek floodplain,
- West Badami Creek floodplain,
- Shaviovik River floodplain,
- Abandoned Shaviovik airstrip,

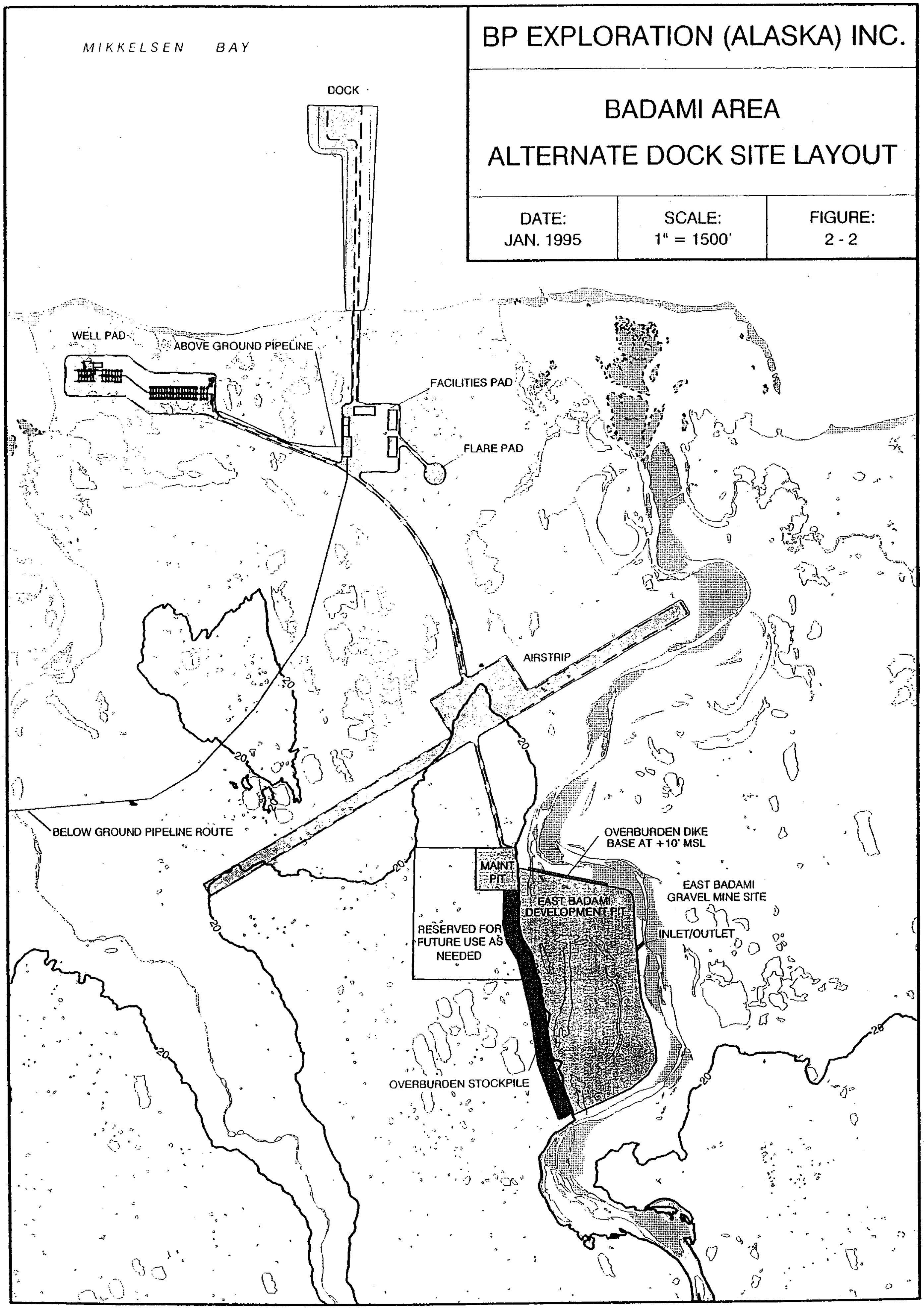
TABLE 2-4
DOCK STRUCTURE ALTERNATIVES — FEASIBILITY SCREENING

FACILITIES OPTIONS	STRUCTURE FEASIBLE TO MEET NEEDS?								
	TRANSPORT MODULES	DRILL RIG TRANSPORT	SPILL RESPONSE	TRANSPORT SUPPLIES AND EQUIPMENT	PERSONNEL TRANSPORT	WASTE HANDLING	TRANSPORT EMERGENCY RELIEF RIG	SERVES POTENTIAL FUTURE NEEDS	RETAIN? (YES/NO)
Dredge channel to shore	No	No	No	Yes (limited)	Yes (limited)	No	No	No	No
Gravel-fill dock (minimum 10-foot depth)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**YES**
Pile-supported dock	No	No	Yes	Yes	Yes	Yes	No	Depends on need	No
Freeze barge in place, build ice road to shore	No	Yes (limited)	Yes (limited)	Yes (limited)	Yes (limited)	Yes (limited)	Yes (limited)	No	No
Gravel dock to 6-foot water depth, dredge to 10-foot depth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**YES**
Gravel structure with barge at end	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**YES**
Gravel dock with a light-duty bridge over a breached section	No	No	Yes	Yes	Yes	Yes	No	Depends on Need	No
Gravel dock with an intermediate barge section (replace with culverts after module transport)	Yes	Yes	Yes	Yes	Yes	Yes	No	Depends on need	No
Sink series of barges	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**YES**
Mulberry bridges	No	No	Yes	Yes	Yes	Yes	No	Depends on need	No

TABLE 2-5
DOCK STRUCTURE ALTERNATIVES — DETAILED ANALYSIS

FEASIBLE DOCK OPTIONS	COST COMPARISON (THOUSANDS)[1] GRAVEL	DREDGING	BARGE RENTAL	ENVIRONMENTAL CONSIDERATIONS	ANALYSIS
Gravel fill dock (minimum 10-foot depth)	$500	—	—	Results in fill affecting up to 10 acres of the nearshore zone. No significant impacts to marine circulation, water quality, or fish use of nearshore waters expected.	Least expensive option, but requires more capital investment early in the project. Largest quantity of gravel required. Impacts and costs associated with dredging avoided. **This option selected as the proposed action.**
Gravel dock to 6-foot water depth, dredge to 10-foot depth	$250	$500	—	Reduces fill requirements, results in fill affecting up to 5 acres of the nearshore zone. Requires dredging and placement of dredge spoil material on up to 18 acres. No significant impacts to marine circulation, water quality, or fish use of nearshore waters expected.	More expensive, but lower initial capital costs. Optimum design of gravel structure for ongoing use, dredging as needed to allow movement of heavier modules. Impacts of fill for longer dock avoided.
Gravel structure with barge at end	$250	$1500	$1750	Results in fill affecting up to 5 acres of the nearshore zone and placement of structure covering up to 3 acres of the nearshore zone. No significant impacts to marine circulation or fish use of nearshore waters expected. Barge section removed at end of project; easier to rehabilitate than gravel structure.	Significant expense and time required, potentially forcing delayed offloading/departure of sealift convoy, resulting in additional costs.
Sink series of barges	$250	$1500	$2700	Results in placement of structure covering up to 6 acres of the nearshore zone. No significant impacts to marine circulation or fish use of nearshore waters expected. Barges removed at end of project; easier to rehabilitate than gravel structure.	Significant expense and time required, potentially forcing delayed offloading/departure of sealift convoy, resulting in additional costs. If barges purchased to remain in place, cost prohibitive.

[1] Comparisons based on rough order-of-magnitude costs only.



BP EXPLORATION (ALASKA) INC.
BADAMI AREA
ALTERNATE DOCK SITE LAYOUT
DATE:
JAN. 1995
SCALE:
1" = 1500'
FIGURE:
2 - 2
MIKKELSEN BAY
DOCK
WELL PAD
ABOVE GROUND PIPELINE
FACILITIES PAD
FLARE PAD
AIRSTRIP
BELOW GROUND PIPELINE ROUTE
OVERBURDEN DIKE
BASE AT +10' MSL
MAINT PIT
EAST BADAMI
GRAVEL MINE SITE
EAST BADAMI
DEVELOPMENT PIT
INLET/OUTLET
RESERVED FOR
FUTURE USE AS
NEEDED
OVERBURDEN STOCKPILE
20

- Kadleroshilik River floodplain,
- East Channel Sagavanirktok River floodplain, and
- Existing Duck Island mine.

During early project planning, use of three of these sources was eliminated from further consideration. The concept of using reclaimed gravel from the abandoned Shaviovik airstrip was eliminated because this is a relatively small quantity of gravel distant from construction areas. In addition, the gravel would have to be tested to ensure that no contamination exists before BPXA would be willing to purchase this resource from the State of Alaska. The potential West Badami Creek site was not considered based on geotechnical evaluation showing limited quantities of suitable gravel. Development of a new site in the East Channel of the Sagavanirktok River was eliminated because gravel can be obtained from the existing Duck Island mine at a lower cost than development of a new mine.

Proposed mine locations were selected based on Alaska Department of Fish and Game (ADF&G) guidelines (McLean 1993) and in consultation with the Alaska Department of Natural Resources (ADNR) and ADF&G.

3. DESCRIPTION OF THE PROPOSED PROJECT

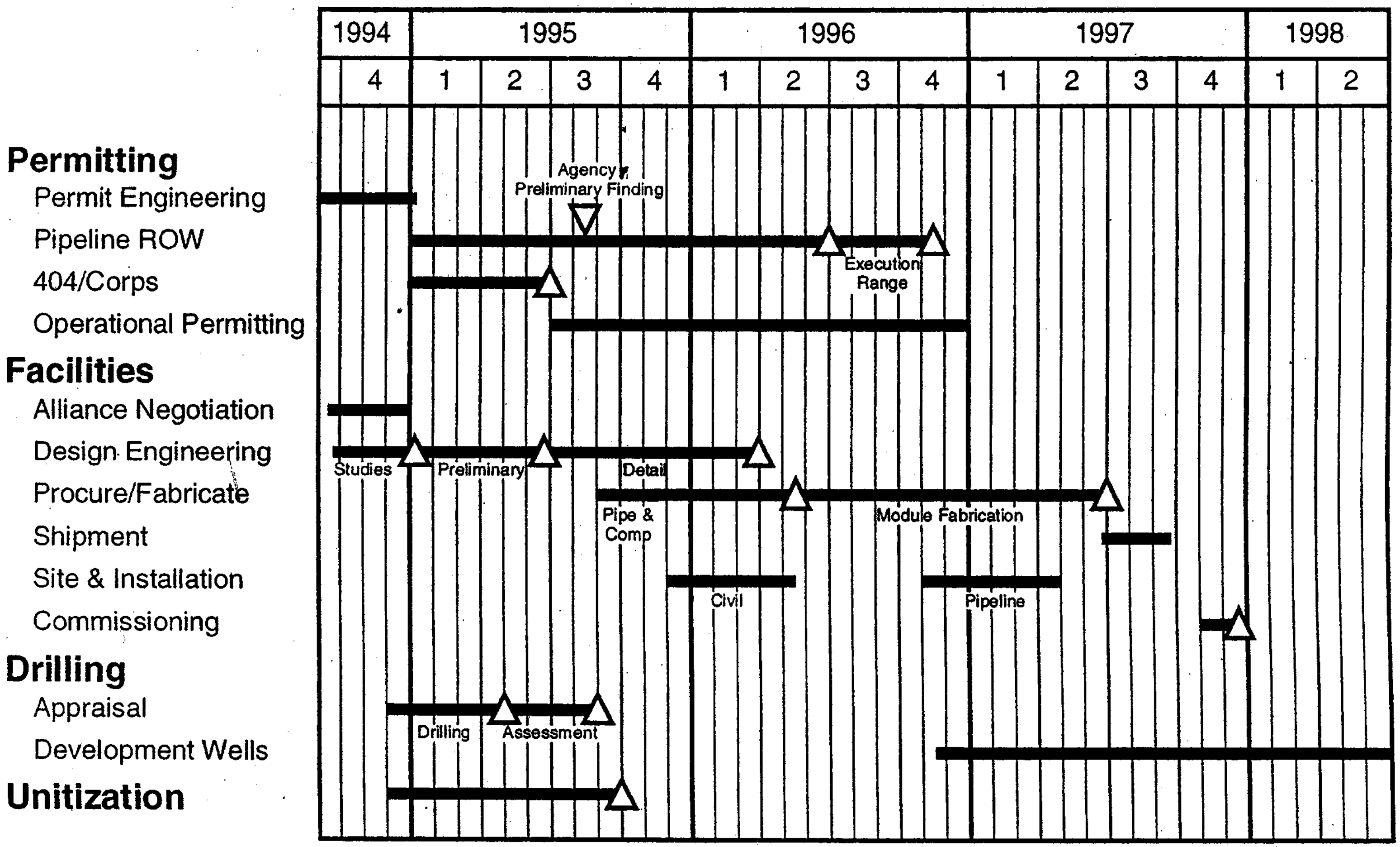
The Badami reservoir is located primarily offshore beneath Mikkelsen Bay, about 25 miles east of existing North Slope oil field facilities (Figure 1-1). Conoco drilled the Badami #1 discovery well in 1990 and the Badami #2 exploration well in 1991. In 1993, BPXA acquired Conoco's interest in the Badami field and initiated planning for continued field appraisal and development. Extensive three-dimensional seismic analysis of the reservoir structure has already been completed.

The proposed Badami development plan, including the field facilities and the pipeline system, has been formulated on the basis of alternatives analysis (see Section 2), conceptual engineering, and extensive interaction with the regulatory and resource agencies (see Section 7). As shown on Exhibit A, Badami project facilities will be located onshore, on the Mikkelsen Bay coastline. The proposed pipeline will extend west from the facilities pad and join the Endicott pipeline about 4 miles east of Prudhoe Bay Unit Drill Site 9.

3.1 DEVELOPMENT PLAN

In 1995, BPXA plans to drill two appraisal wells (Badami #4 and Badami #5) to further delineate the Badami reservoir. These wells will be located offshore and drilled from ice pads. The well locations and testing programs are targeted to prove the extent of reserves needed for the Badami Development Project to be economical. Information from these wells is expected to confirm information about the reservoir gained from existing well results and seismic analysis. The results of this drilling program will be analyzed and completed in the summer of 1995.

At the same time, BPXA has filed permit applications for development of this oil field. The first activity will be opening a gravel source at East Badami Creek in early 1996, followed by construction of gravel field facilities, including a well pad, facilities pad, a dock, an airstrip, and an in-field road system connecting these facilities. Development drilling will begin in the winter of 1996-1997, when the Badami pipeline will also be constructed. Modules will be transported to the site and installed in the summer of 1997, and project start-up will be in the fourth quarter of 1997. Figure 3-1 shows the project schedule.



BP EXPLORATION (ALASKA) INC.

BADAMI DEVELOPMENT
PROJECT SCHEDULE

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3-1

3.2 DRILLING

Directional drilling will be used to reach all target zones of the Badami reservoir, and up to 60 wells may be drilled. At facility start-up, it is expected that as many as 10 wells will be brought into production. The remaining development drilling should be completed by 1999. The average space between wells will be 35-feet in order to minimize the size of the gravel pad, use existing drilling rigs without modification, and allow drilling of additional wells without having to expand the Badami well pad.

In addition to production wells, other wells to be drilled include gas injection, produced water injection, and source water wells. One Class II injection well for disposal of drilling wastes will also be permitted and drilled on the pad.

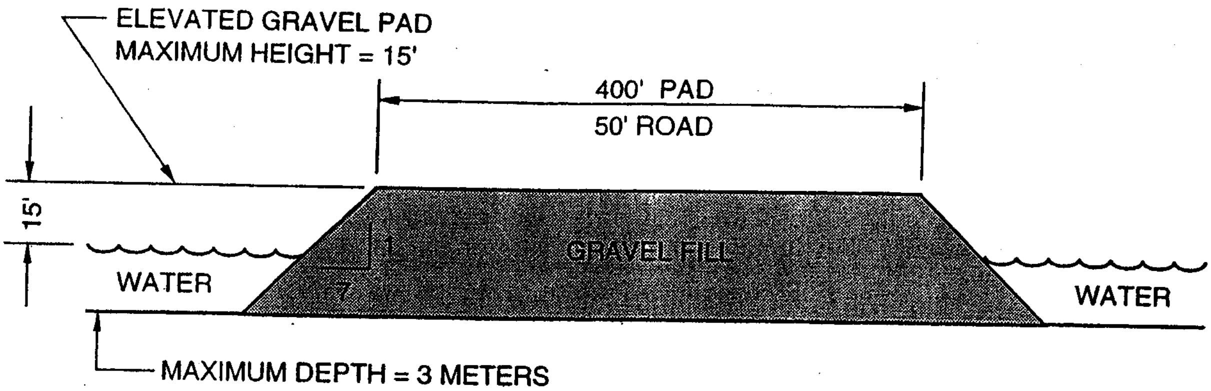
Waterflooding to enhance oil recovery is planned. The most likely technique involves Cretaceous water in a closed-loop "dump-waterflood" system. No plans currently exist to use seawater as a waterflood source.

3.3 PROJECT ACCESS

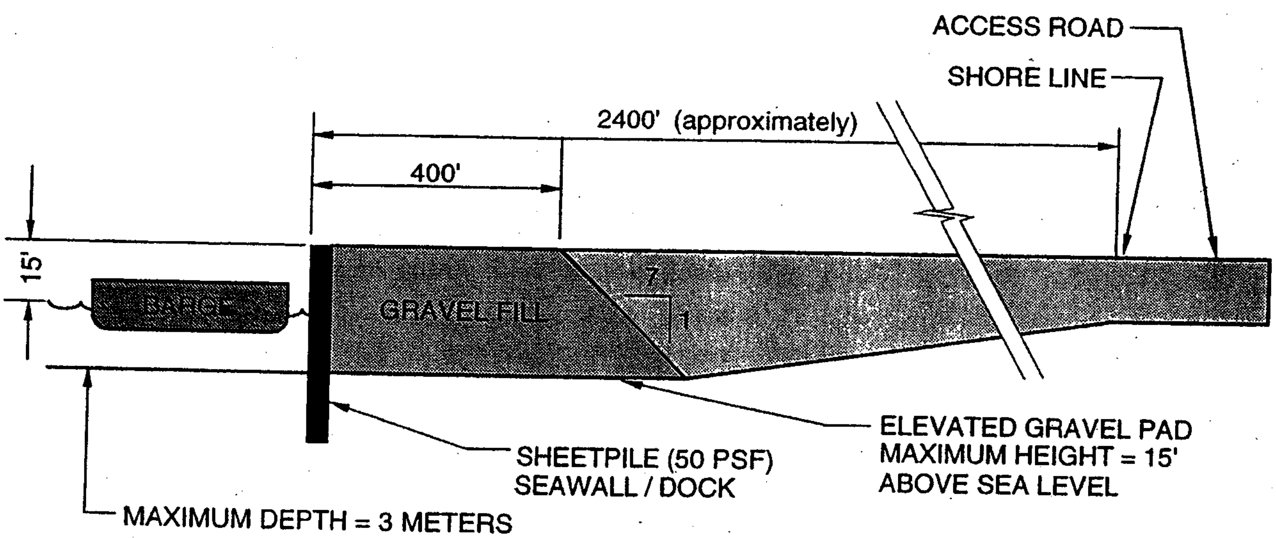
No gravel access road from North Slope facilities is planned for the Badami Development Project. During construction and operation, an ice road will provide winter access to the Badami field. The ice road will extend from the base of the Endicott Causeway to the field, and during most winters will be located just offshore on sea ice. During the winter of 1996-97, two ice roads will be constructed: one along the pipeline route to support pipeline construction, and one along the sea ice route to provide drilling site access. Use of two routes during that winter is needed to avoid potential conflicts between drill rig movement and pipeline construction. A pipeline ice-road route would also be used in subsequent years if necessary to construct modifications or perform repairs. Ice access roads will also be constructed from the pipeline corridor to water and gravel use sites (Exhibit A).

Without a year-round gravel access road, barge access to the site is required. Barges will support drilling and production operations during the open-water season and allow delivery of sea-lifted production modules. To allow barge access to the field, a gravel dock will be built in Mikkelsen Bay. The dock will also be an important facility needed for spill response. In the event of a spill or blowout on the pad, the dock would provide a staging area for the response. It could also be used for staging any spill response required in open-water or broken-ice conditions. The dock, the road connection from the dock to the well pad and from the well pad to the facilities pad, and the two pads were designed to ensure the dock would meet transportation needs associated with future development in the area.

The dock will be approximately 2,400 feet long (Figures 3-2, 3-3, and 3-4) to reach water 10 feet (3 meters) deep. The precise length of the dock will be determined



SECTION L-L'
(TYP. FOR PAD AND ROAD)



SECTION M-M'

BP EXPLORATION (ALASKA) INC.

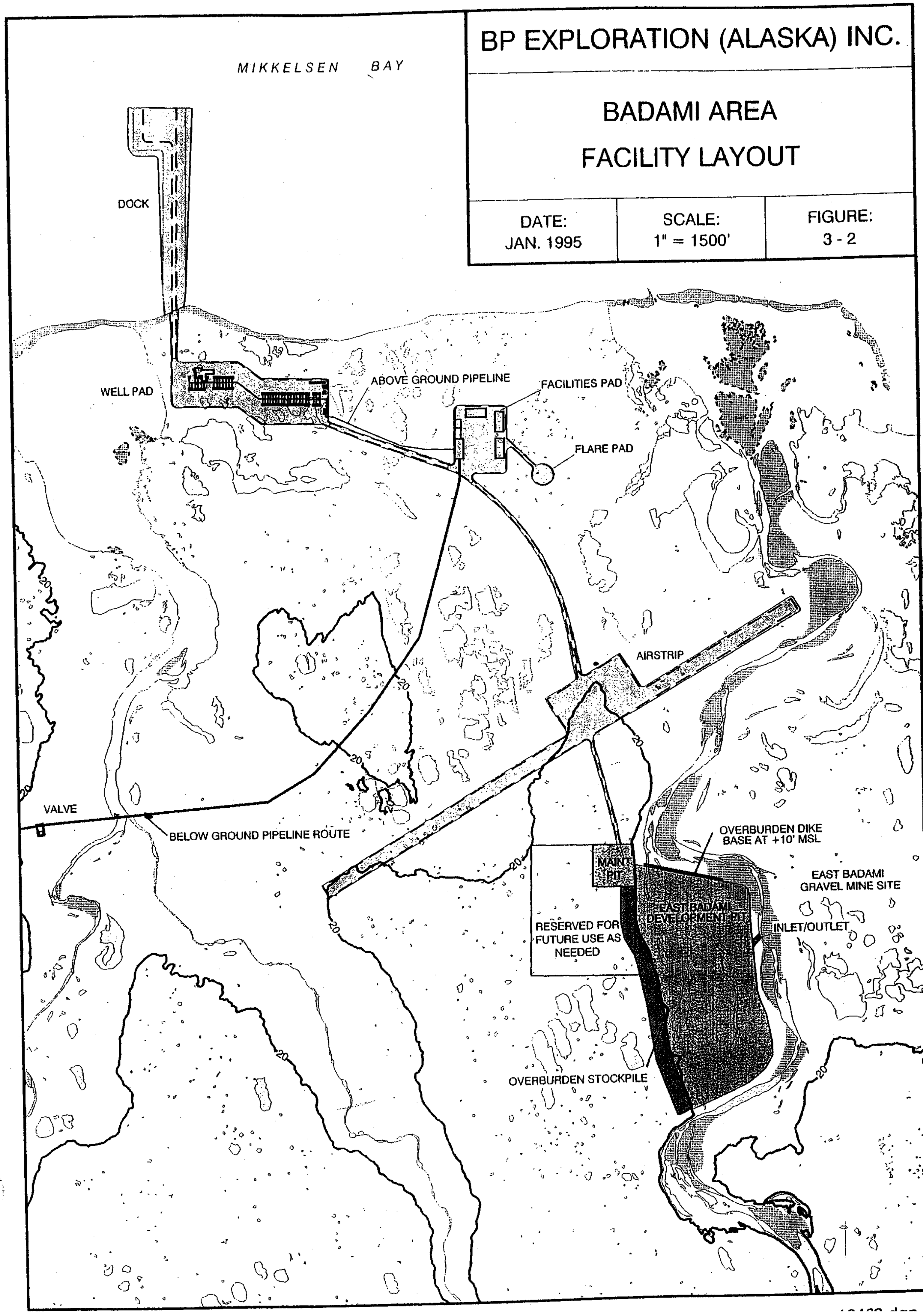
BADAMI
DOCK CROSS SECTIONS

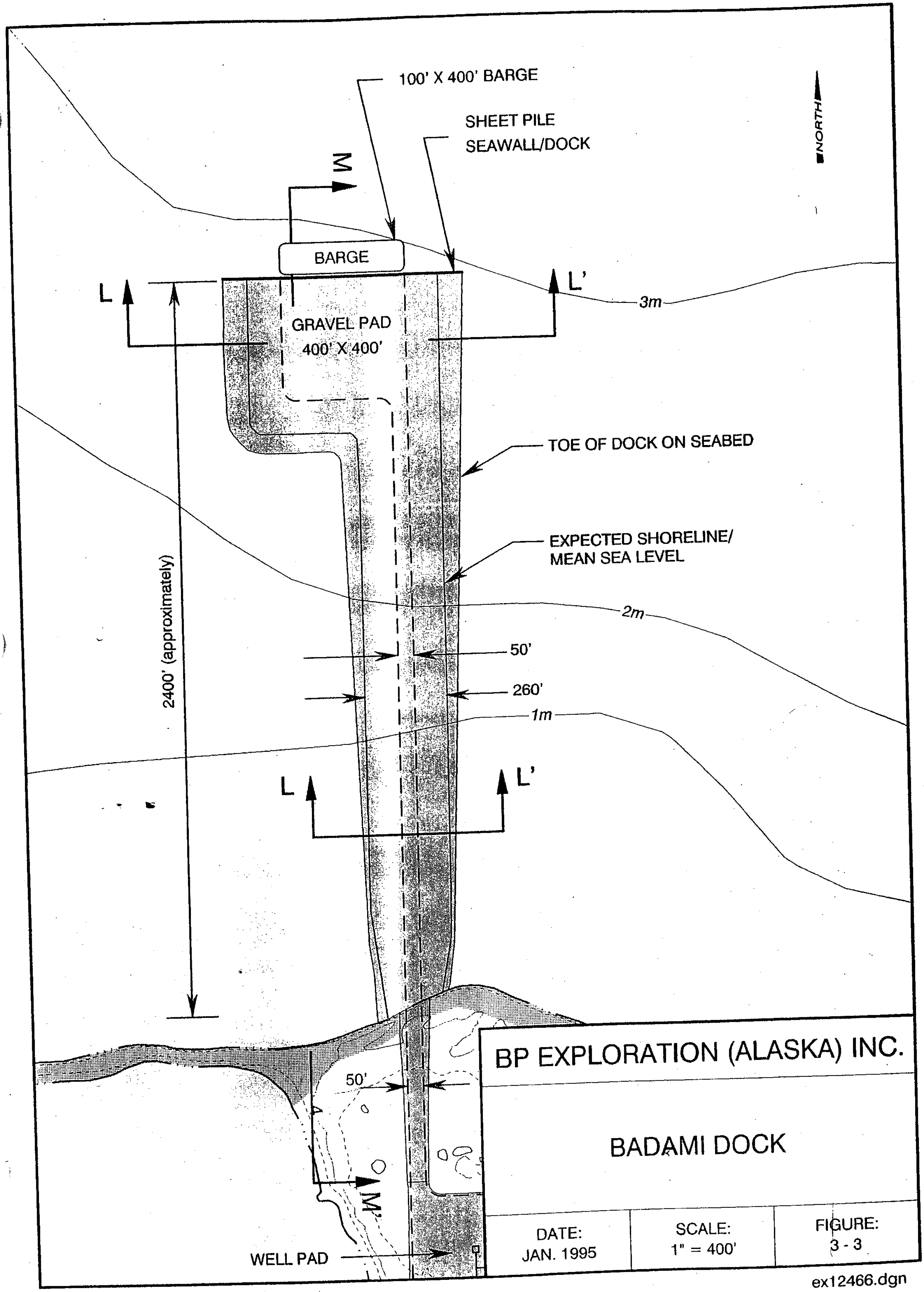
DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3-4

BP EXPLORATION (ALASKA) INC.

BADAMI AREA FACILITY LAYOUT

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 1500'	3 - 2




100' X 400' BARGE
SHEET PILE
SEAWALL/DOCK
NORTH
M
BARGE
L
L'
3m
GRAVEL PAD
400' X 400'
TOE OF DOCK ON SEABED
EXPECTED SHORELINE/
MEAN SEA LEVEL
2400' (approximately)
2m
50'
260'
1m
L
L'
50'
M'
WELL PAD
BP EXPLORATION (ALASKA) INC.
BADAMI DOCK
DATE:
JAN. 1995
SCALE:
1" = 400'
FIGURE:
3 - 3
ex12466.dgn

after completion of detailed bathymetric surveys (to be conducted as part of the summer 1995 field program). The side slopes on the dock will be 7:1. The 400-foot by 400-foot terminus of the dock will be constructed with a sheet-piling face. The length of dock connecting the dock head to shore will be 50 feet wide along the traveled surface to allow movement of large modules. About 741,000 cubic yards of gravel will be required to construct the dock, which will have a freeboard of 15 feet and will require fill of about 23.8 acres of seabed.

A gravel airstrip capable of supporting a fully loaded Hercules aircraft will be constructed south of the facilities pad (Figure 3-2). Approximate maximum dimensions of this airstrip will be 6,500 feet long, 150 feet wide, and a minimum of 5 feet thick. The airstrip will have an adjacent apron 1,000 feet by 500 feet by a minimum of 5 feet thick.

An in-field gravel road system will be constructed to connect the various facilities (Figure 3-2). The roads from the dock to the well pad and from the well pad to the facilities pad will be approximately 0.4 mile long, 50 feet wide on the crown, and a minimum of 5 feet thick. The 50-foot width is required to allow transport of large modules from the dock to the facilities pad. A 30-foot-wide road will also be constructed to connect the facilities pad to the airstrip, and the airstrip to the East Badami Gravel Mine Site. This narrower road will have a total length of approximately 0.7 mile and will be a minimum of 5 feet thick. Culverts will be installed in the in-field road system where necessary to maintain natural surface drainage patterns.

After completion of construction, activities on the site will be supported by barge in the summer, ice roads in the winter, air access year round, and tundra travel (subject to seasonal closure). During fall freeze-up and spring breakup, activities will be supported by air access. The airstrip will allow transport of emergency equipment, including a relief rig, to the site if necessary.

Access will also be needed to the roadless pipeline corridor for rehabilitation of the trench backfill and for on-going maintenance and repair work. Planned pipeline repairs will be performed in the winter using ice road access, and planned rehabilitation work will be accomplished in the late summer using rollagon (tundra travel) access. Access for routine inspections will be via tundra travel and overflights. In the event of an unplanned need for maintenance or repairs, the method of access would be determined by the time of year (see Figure 2-1 for seasonal access limitations). If access was needed during the winter, equipment and materials could be mobilized by helicopter, rollagon, or over an ice road. Summer access could be via helicopter or rollagon. During breakup and freeze-up, when tundra travel is not allowed, access to the pipeline corridor would be limited to helicopter. Heavy-lift helicopters are capable of mobilizing any equipment needed for emergency repairs to the pipeline. During any maintenance and repair work, wooden mats would be used as a work surface as needed to protect the tundra from damage.

3.4 BADAMI FIELD FACILITIES

3.4.1 Well Pad and Facilities

The proposed production well pad facilities are similar to others in place on the North Slope. New wellsite facilities with a nominal annual average capacity of 50,000 barrels per day will be located on the well pad and will include manifold piping, test metering, freeze protection, chemical treatment, a heater, and other related facilities. These will be housed in modules or on skids supported on piles or shallow spread footings, similar to those used at existing North Slope drill sites. The pad will also accommodate up to 60 wells, including 40 production wells, 2 gas injection wells, and 18 produced water injection wells. Some wells will initially be producers and will later be converted to water injectors for reservoir pressure maintenance. BPXA is also planning to drill a Class II injection well at this site.

The wellsite location (Figure 3-2) was selected based on (1) optimizing the ability to directionally drill to reach an offshore reservoir and (2) avoiding wetter tundra. The proposed drill site layout and orientation will permit gradual expansion as development drilling proceeds. This layout provides a suitable configuration to drain the Badami reservoir without major subsurface wellbore crossovers. The wellsite is sized to provide sufficient area for rig movement and storage of rig materials.

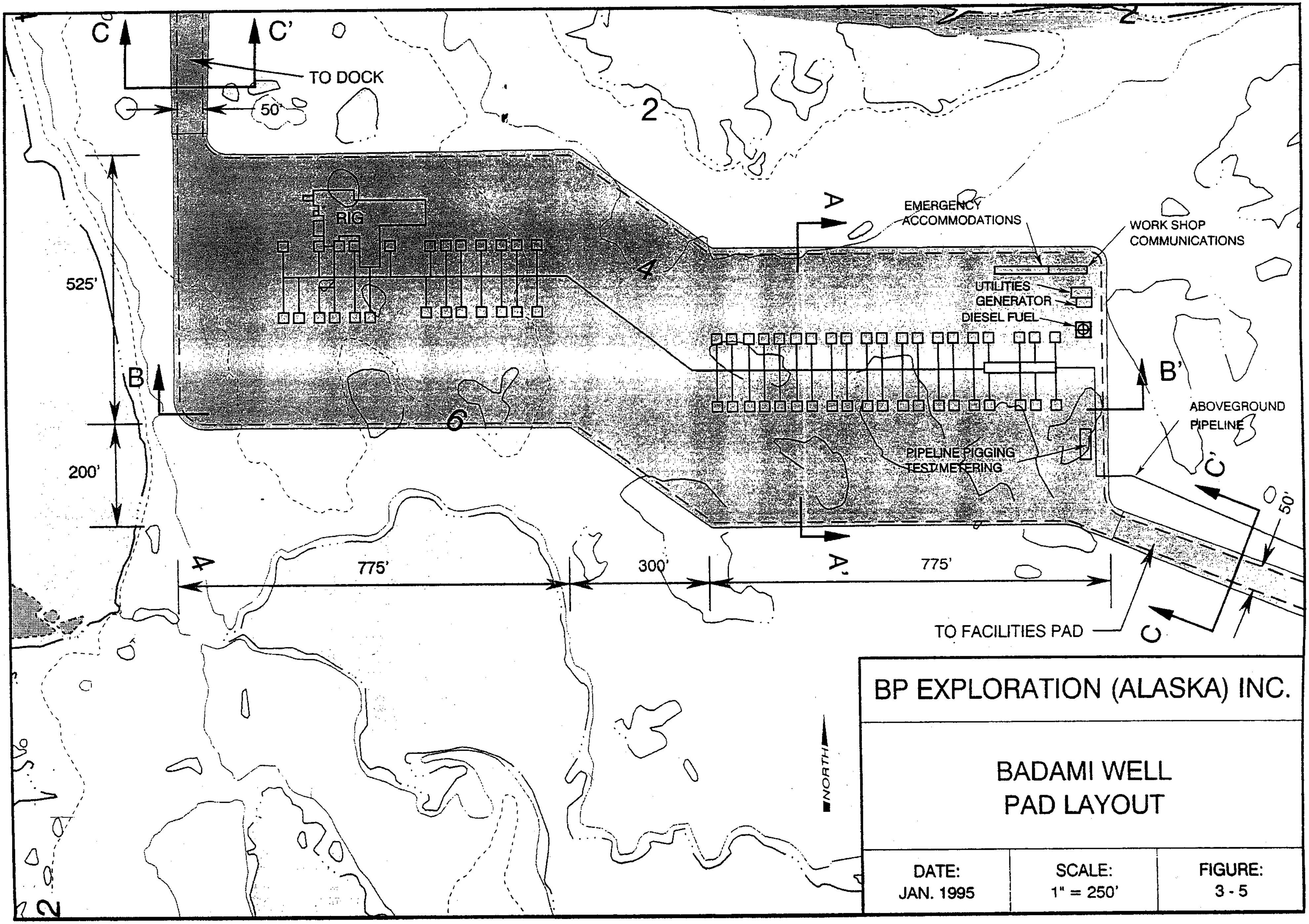
Drilling wastes will be either disposed of through on-site annular injection or hauled off-site for treatment by a cuttings grinder and disposal in the CC-2A injection well (see Section 3.9); space will also be provided for temporary storage of drilling wastes.

The proposed well pad will have approximate working surface dimensions of 1,850 feet by 525 feet, with 2:1 side slopes. The gravel pad will extend a minimum of 5 feet above the existing tundra surface (Figures 3-5 and 3-6). The base of the drillsite will be approximately 1,870 feet by 545 feet and will cover approximately 23.2 acres of tundra. Pad construction will require about 270,000 cubic yards of gravel.

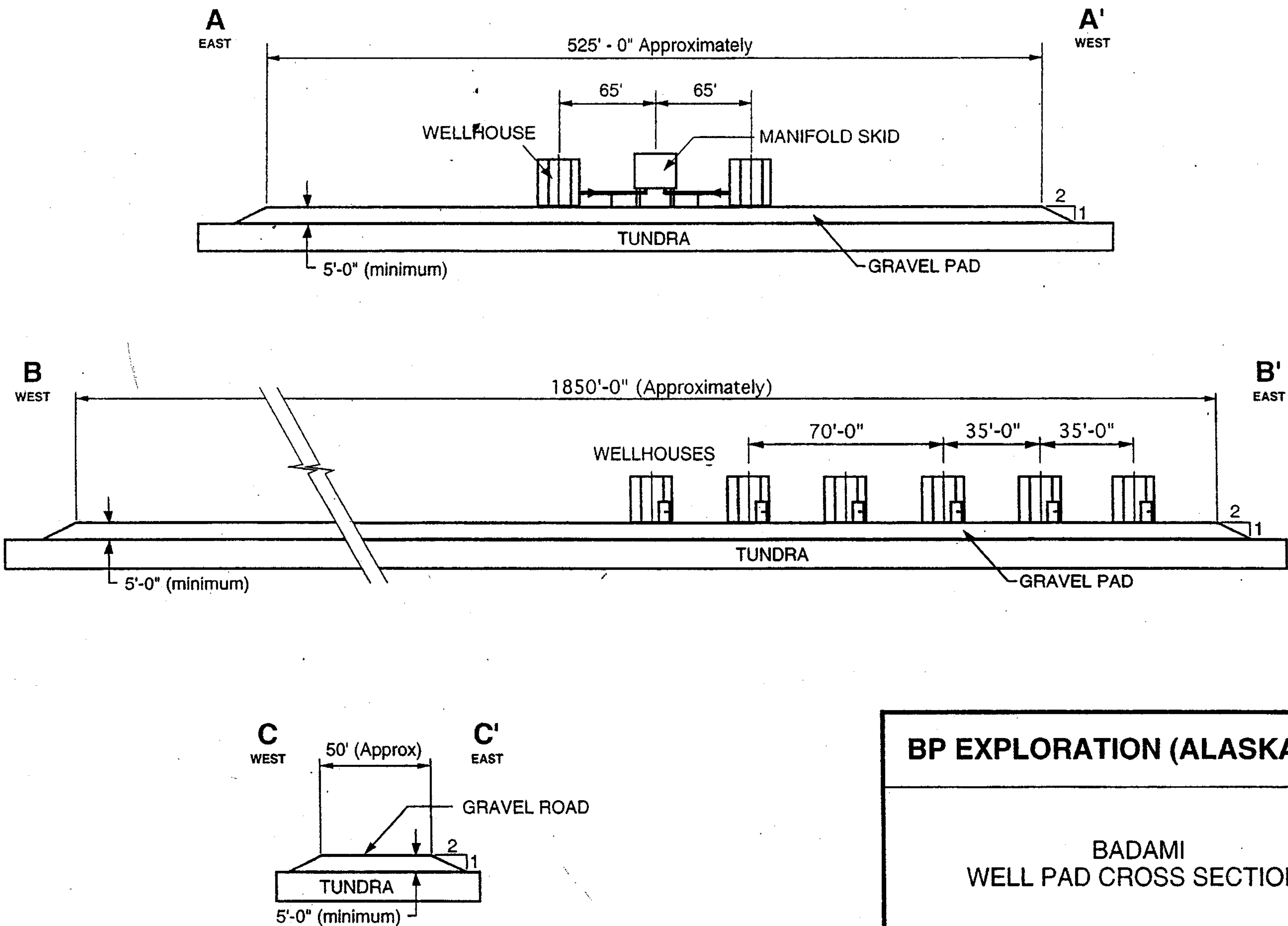
3.4.2 Badami Main Production Facility

Production flowlines will be used to transport three-phase production from the production well pad to the Badami Main Production Facility for separation and processing prior to transfer to the common carrier pipeline. It is expected that produced gas and water will be returned to injection wells in flowlines for injection to enhance oil recovery. These flowlines will be elevated on vertical support members (VSMs) at least 5 feet above the tundra surface and will be insulated.

The Badami Main Production Facility will be located on a pad south and east of the well pad (Figure 3-2). This facilities pad will have approximate working surface



BP EXPLORATION (ALASKA) INC.		
BADAMI WELL PAD LAYOUT		
DATE: JAN. 1995	SCALE: 1" = 250'	FIGURE: 3 - 5



BP EXPLORATION (ALASKA) INC.

BADAMI
WELL PAD CROSS SECTIONS

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3-6

dimensions of 800 feet by 600 feet; pad side slopes will have a grade of 2:1. The gravel pad will extend a minimum of 5 feet above the existing tundra surface (Figures 3-7 and 3-8). The base of the facilities pad will be approximately 820 feet by 620 feet. With the flare pad and road to the flare pad, approximately 13.8 acres of tundra will be covered, and about 170,000 cubic yards of gravel used. The location was selected based on avoidance of wetter tundra, facilities layout requirements, and flare siting requirements.

Production facilities will include:

- Multi-stage oil, water, and gas separation;
- Crude oil chilling, pumping, and metering;
- Gas conditioning, compression, and reinjection;
- Flare and pressure relief systems;
- Produced water treatment and re-injection;
- Source water (Cretaceous) production and re-injection;
- Electrical power generation; and
- Utility provision.

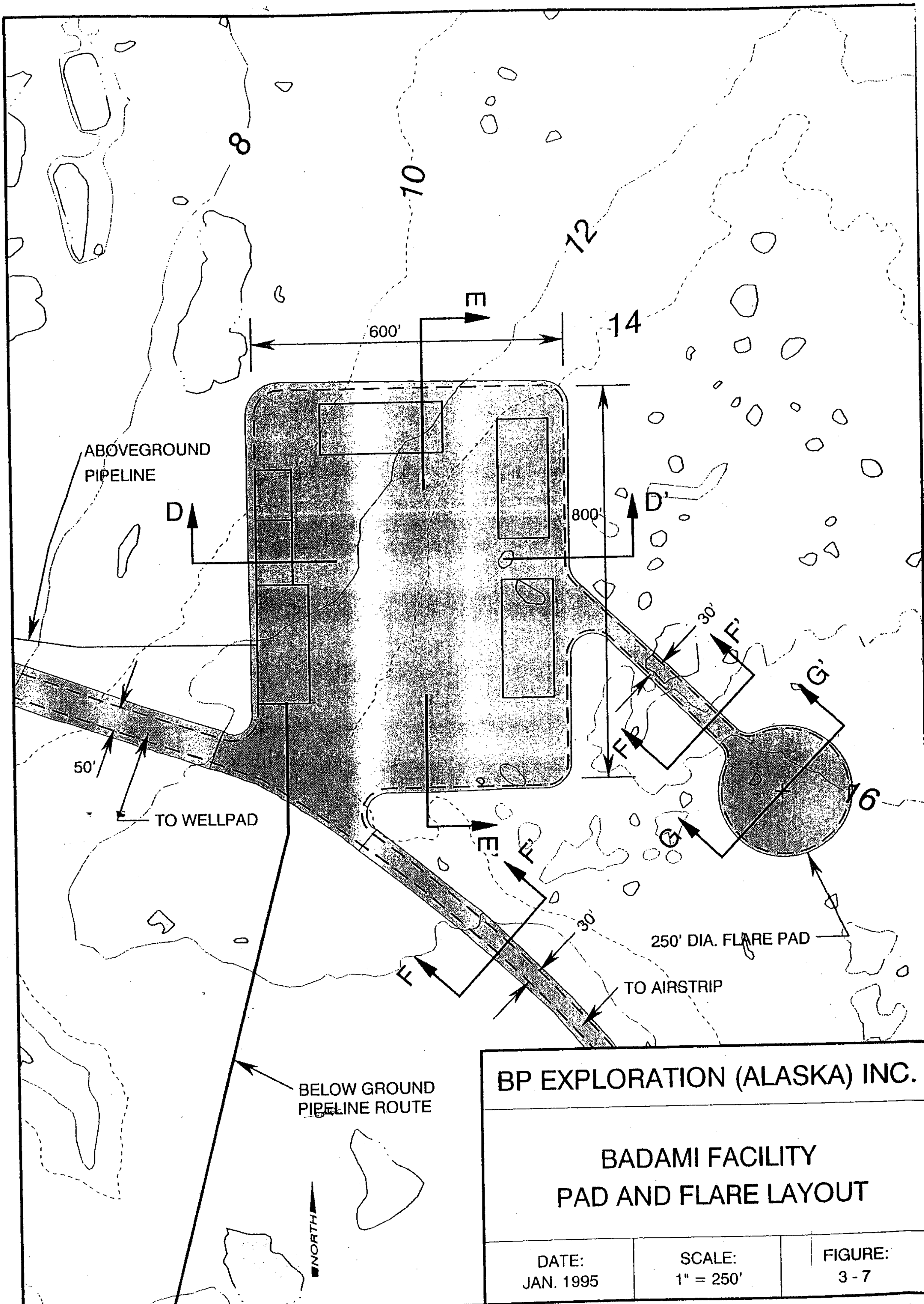
The process used to condition Badami crude oil for shipment will be similar to that used for most other North Slope facilities, except for chilling of the crude oil for pumping in a buried pipeline. A conceptual Badami process-flow schematic is shown in Figure 3-9.

Propane chillers will be used to refrigerate the treated Badami crude oil. Three chillers, each having the capacity to process 50 percent of the pipeline throughput, will be installed at this module. Two of these chillers will be operational at any given time, and the third will be on standby or being dewaxed. Dewaxing will be accomplished by circulating warm oil through the unit to melt and dissolve the wax. The redissolved wax will then be reinjected into the process stream upstream of the chillers.

Badami crude oil will be chilled from approximately 120°F to 30°F. The refrigeration unit will require about 4,000 horsepower (hp) of compression, to be provided by two 2,000-hp electric-drive screw compressors. Centrifugal compressors, gas engine drivers, and gas turbine drivers are being considered as options. A multi-stage centrifugal pump will be used to pressurize Badami oil before it is metered and passed through the inlet valve to the pipeline.

3.5 PIPELINE

This section describes basic information about the Badami Pipeline. More detailed information about design, construction, operation, and maintenance of the pipeline system is contained in the Application for Pipeline Right-of-Way Lease, including the Design Basis provided in Appendix A of the application.

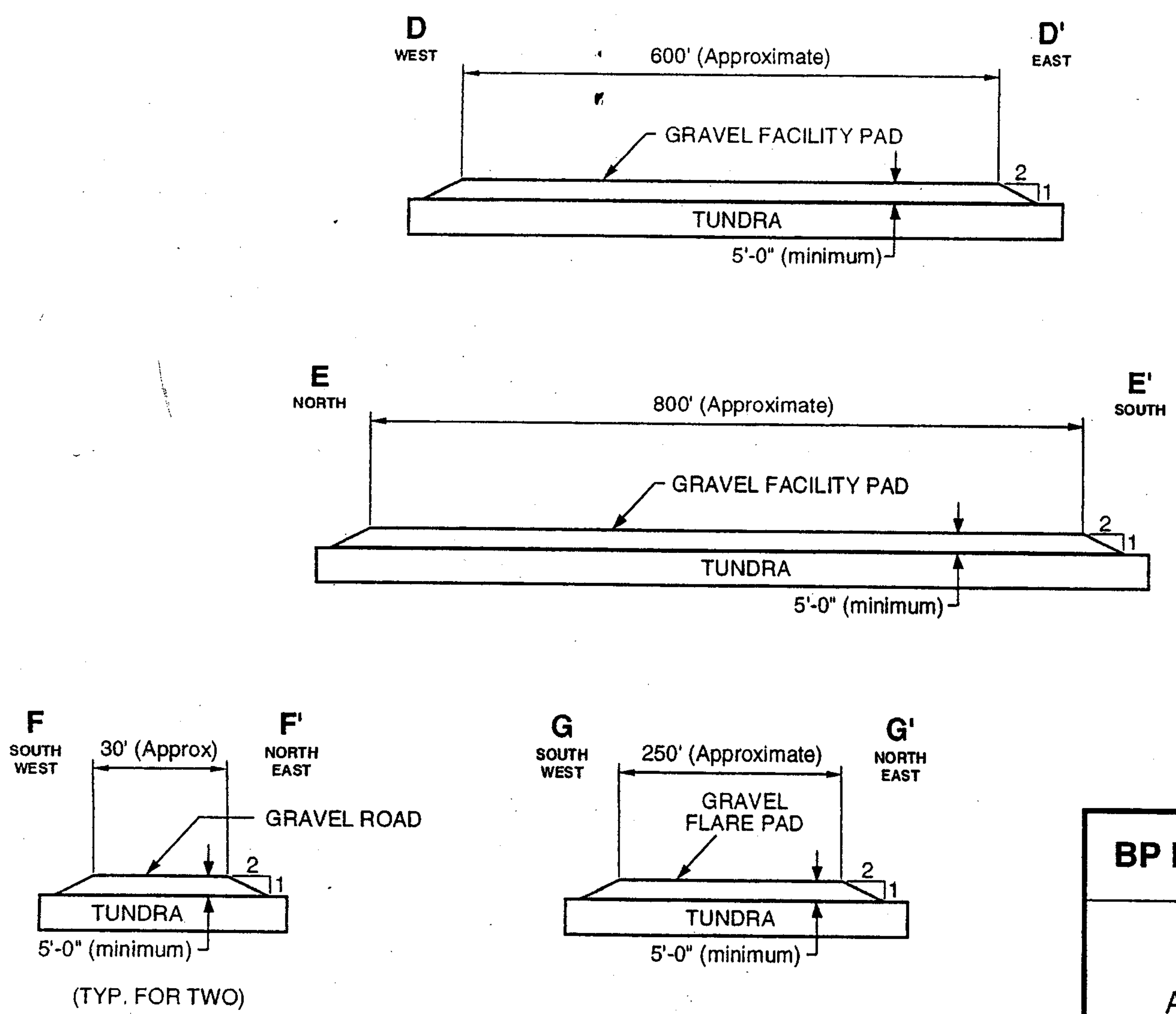


BP EXPLORATION (ALASKA) INC.

BADAMI FACILITY
PAD AND FLARE LAYOUT

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 250'	3 - 7

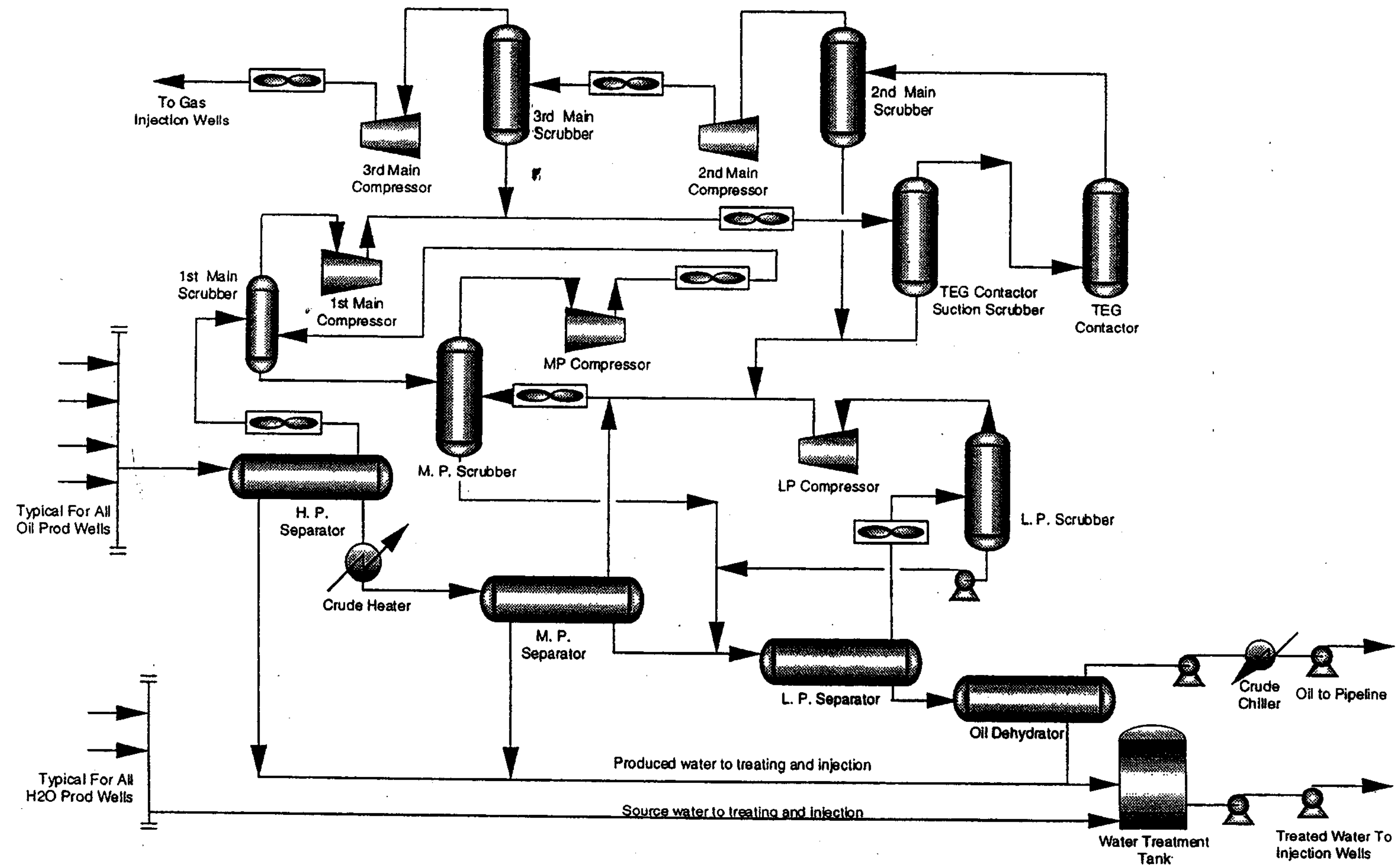
ex12466.dgn



BP EXPLORATION (ALASKA) INC.

BADAMI FACILITY PAD
AND FLARE CROSS SECTIONS

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3-8



BP EXPLORATION (ALASKA) INC.		
BADAMI DEVELOPMENT PROJECT BADAMI FACILITIES CONCEPTUAL PROCESS SCHEMATIC		
DATE: JAN. 1995	SCALE: NOT TO SCALE	FIGURE: 3-9

3.5.1 Route and Associated Facilities

Exhibit A shows the proposed centerline alignment of the pipeline route, proposed valve pads, proposed pipeline material sites, access routes to material sites, potential water sources, and access routes to the potential water sources. The route maps also illustrate the proposed planning, construction, and operational rights-of-way.

The pipeline route was selected based on a set of planning criteria. These criteria will continue to be used to refine the alignment as more detailed information about the pipeline corridor is available. Routing criteria included:

- Minimizing overall length,
- Minimizing excavation volumes at river crossings,
- Optimizing river crossing orientation,
- Avoiding known cultural resource sites,
- Avoiding higher-value habitats,
- Avoiding lakes,
- Avoiding areas with extensive ice-wedge polygons,
- Avoiding drained lake basins,
- Allowing low-maintenance operations,
- Maximizing safety and pipeline integrity, and
- Minimizing pipeline stress.

3.5.2 Pipeline Design Concept

Pipeline Trench

The entire Badami Pipeline will be buried in permafrost, except for some thawed sections at river crossings. The design of the buried system is intended to ensure safe and reliable pipeline operations. A combination of select and native trench backfill will be used to create a stable trench section. Select backfill (3/8-inch minus) gravel will be placed over and around the sides of the pipe, and native backfill will be placed over the select backfill.

The use of the select backfill has two primary functions: (1) the granular, ice-free, thaw-stable select backfill in the lower part of the pipe trench will reduce the amount of potential thaw settlement in the backfill, and (2) it will help limit the formation of a surface trough along the top of the pipe. The quantity of select backfill to be used is a function of the ice content of the spoil. Placing native material over select backfill will result in surplus material, creating a berm over the ditch at the beginning of the first summer season.

During the first summer, the native spoil will thaw, resulting in shrinkage as the ice in the spoil melts and water drains from the spoil, and creating a volumetric deficiency of backfill material. The amount of shrinkage will be a function of free ice content of the spoils, the amount of snow mixed into the spoils, and the thickness of the ice pad. As shown in Figures 3-10 through 3-13, as the berm settles, the excavation will typically remain full because sufficient select backfill has been used. The berm will necessarily be wider than the cut ditch, resulting in some material from the excavation being placed on top of the ice pad overlying undisturbed ground on either side of the ditch.

The berm has the potential to intercept or impound surface runoff. If surface runoff infiltrates the backfill, the ditch could become a potential watercourse. In order to minimize the disturbance of natural drainage patterns, a series of impermeable berm breaks and ditch plugs is planned for the full length of the line. Typical designs for these are shown on Figure 3-14.

The berm breaks will prevent accumulation of water on the south (upgradient) side of the berm. The breaks will be designed to provide an area of unobstructed cross-flow across the trench, to minimize erosion of the ditch backfill as flow crosses the pipeline trench, to minimize infiltration of flow into the ditch backfill, and to minimize the concentration of flow north of the right-of-way which could lead to thermal or hydraulic erosion.

Ditch plugs, which are impermeable barriers extending across the full width and depth of the trench, will be installed where the slope parallel to the ditch line is 1 percent or greater. The impermeable plugs will force water to the surface of the trench where it will flow across a berm break to a point downgradient of the pipeline trench. The plugs are designed to minimize flow parallel to the pipe which could lead to thermal degradation of the native material in the perimeter of the ditch, and consequently to pipe settlement.

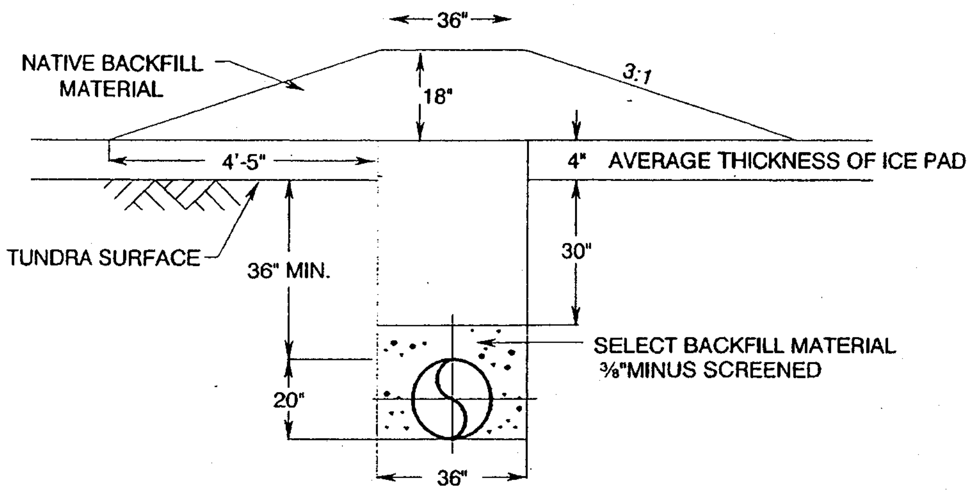
Pipe Design

In selection of the pipeline material grade and thickness, the primary criterion was containment of hazardous liquid under pressure. Secondary criteria included ease of welding, flexibility for bending, and cost. Existing design standards strictly govern the interrelationship among material strength, pressures, temperatures, and dimensions.

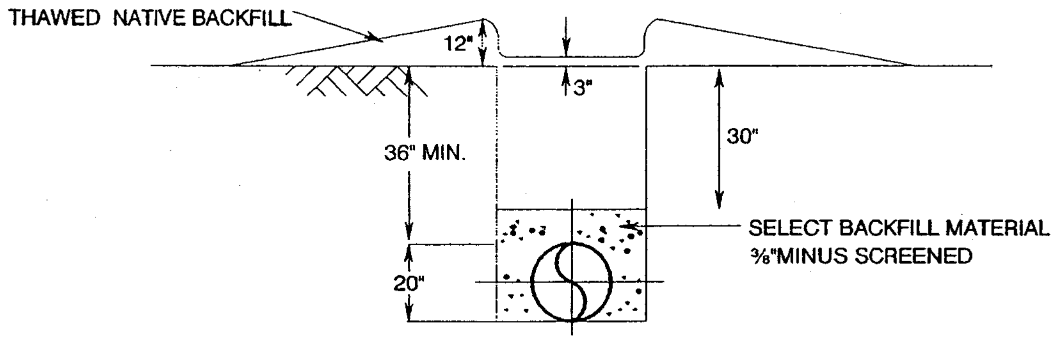
Relevant design standards/criteria include:

- **Federal and State Regulations**
  - 49 CFR 195, "Transportation of Hazardous Liquids by Pipeline"
  - 75 AAC 80, "Oil and Hazardous Substances Pollution Control"

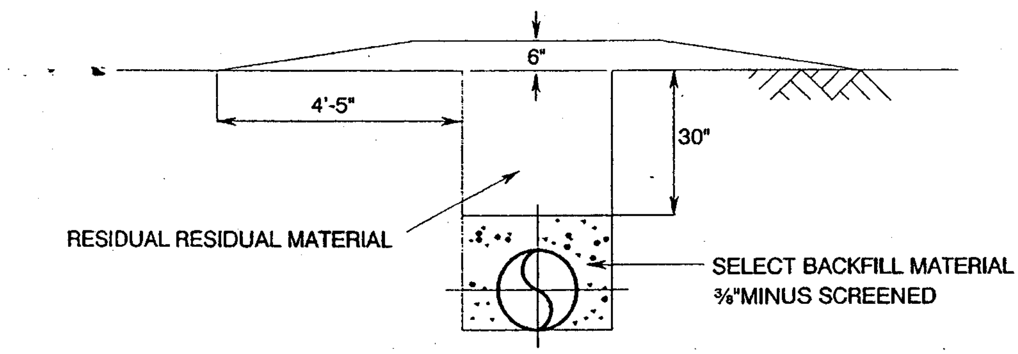
DITCH CONFIGURATION-10% (BY VOLUME) ICE CONTENT IN EXCAVATED MATERIAL



APPROXIMATE SHAPE AND CONTENT AFTER BACKFILLING



APPROXIMATE SHAPE OF DITCHLINE AFTER ONE THAW SEASON ASSUMING
NO LOSS OF RESIDUAL MATERIAL



APPROXIMATE SHAPE OF DITCHLINE AFTER THAW, SETTLEMENT,
& RESTORATION ASSUMING 30% LOSS OF RESIDUAL MATERIAL

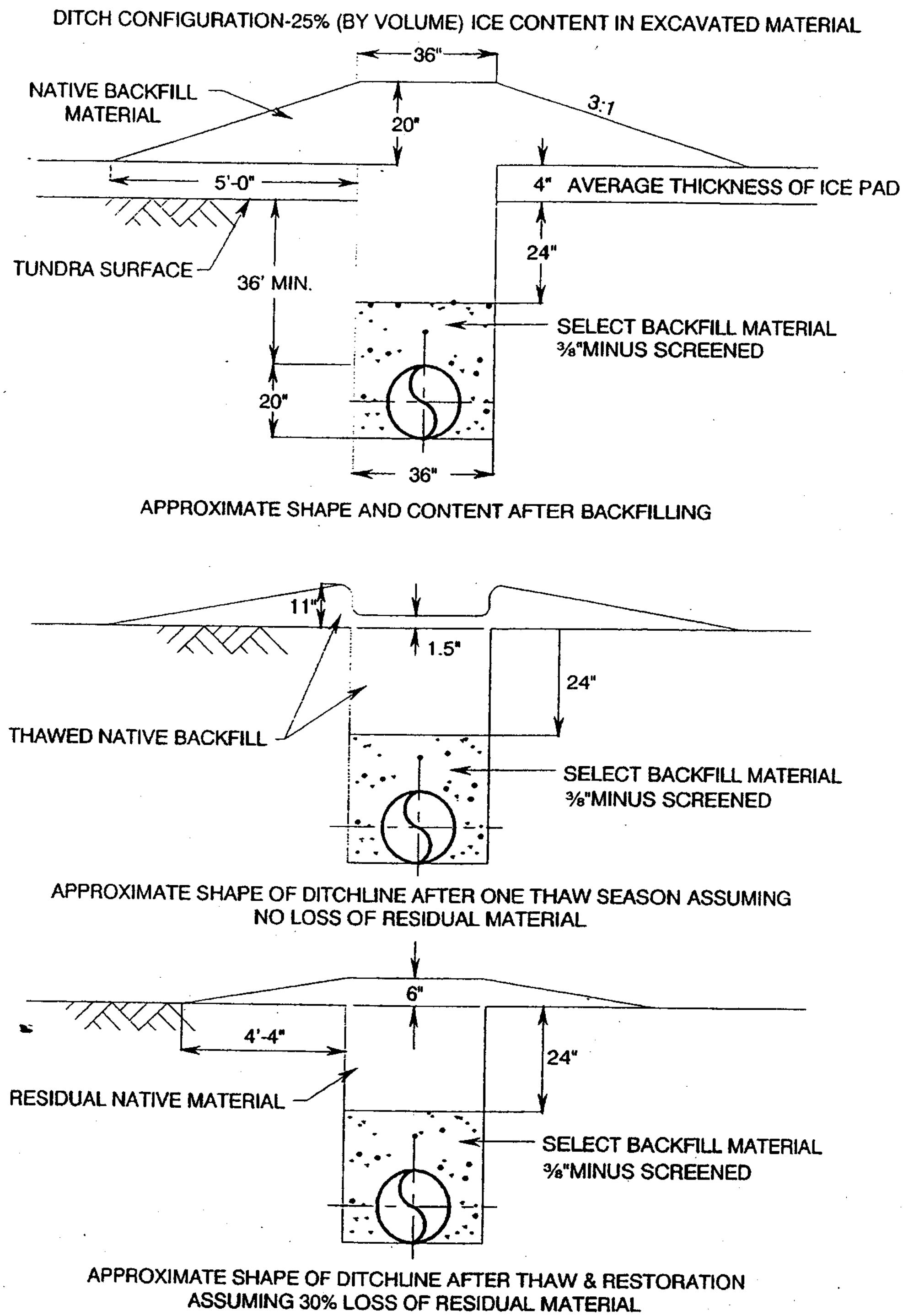
ASSUMPTIONS

1.) 30% BULKING IN EXCAVATED MATERIAL THAT WILL REMAIN AFTER BACKFILLING
2.) 90% OF BULKING WILL DISAPPEAR AFTER FIRST YEAR THAW
3.) 90% OF THAW SETTLEMENT WILL OCCUR AFTER FIRST THAW SEASON
4.) AVERAGE THICKNESS OF ICE PAD - 4"
5.) AVERAGE LOSS OF RESIDUAL MATERIAL AFTER THAW - 30% NOTE-THIS WILL BE DUE MAINLY TO MIXING WITH THE SURFACE VEGETATION NEAR THE DITCH

BP EXPLORATION (ALASKA) INC.

BADAMI PIPELINE DITCH
CROSS SECTION BEFORE AND AFTER
THAW AND BULK SETTLEMENT
(10% ICE CONTENT)

DATE:	SCALE:	SHEET:
JAN. 1995	NOT TO SCALE	3 - 10



ASSUMPTIONS

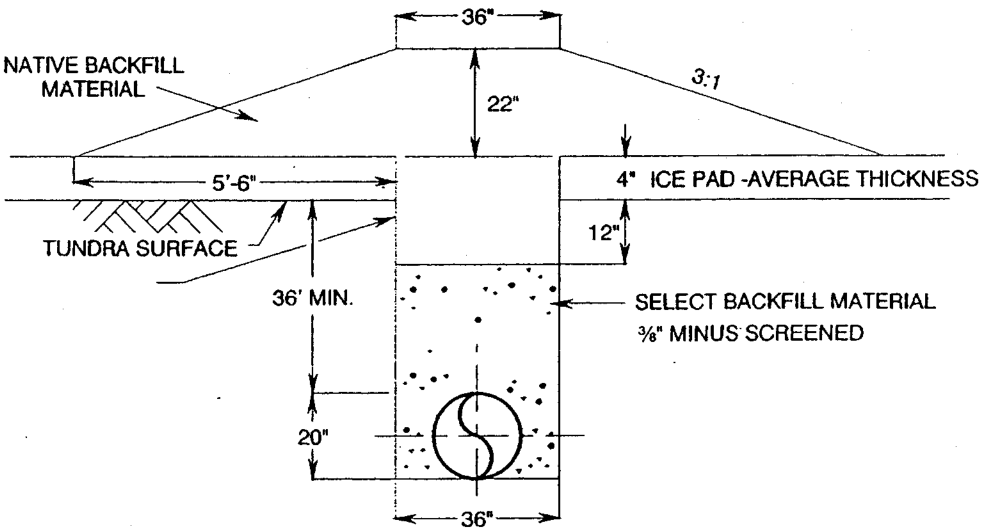
1.) 30% BULKING IN EXCAVATED MATERIAL THAT WILL REMAIN AFTER BACKFILLING
2.) 90% OF BULKING WILL DISAPPEAR AFTER FIRST YEAR THAW
3.) 90% OF THAW SETTLEMENT WILL OCCUR AFTER FIRST THAW SEASON
4.) AVERAGE THICKNESS OF ICE PAD - 4"
5.) AVERAGE LOSS OF RESIDUAL MATERIAL AFTER MATERIAL AFTER THAW-30%
NOTE-THIS WILL BE DUE MAINLY TO MIXING WITH THE SURFACE VEGETATION NEAR THE DITCH

BP EXPLORATION (ALASKA) INC.

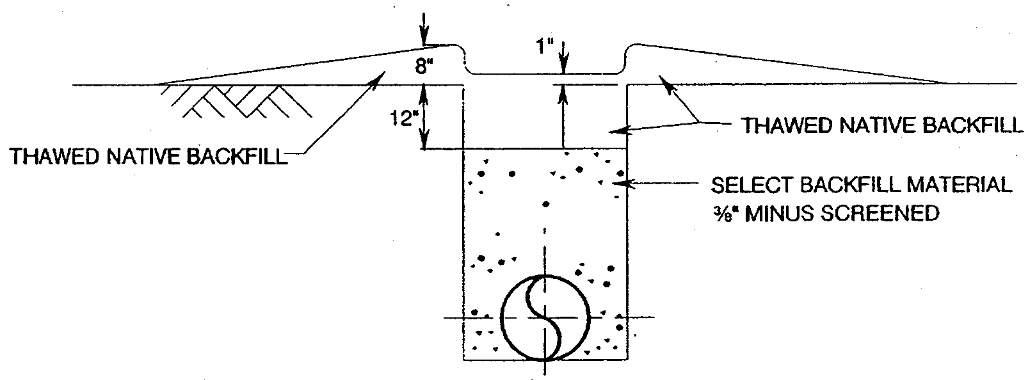
BADAMI PIPELINE DITCH CROSS SECTION BEFORE AND AFTER THAW AND BULK SETTLEMENT (25% ICE CONTENT)

DATE:	SCALE:	SHEET:
JAN. 1995	NOT TO SCALE	3 - 11

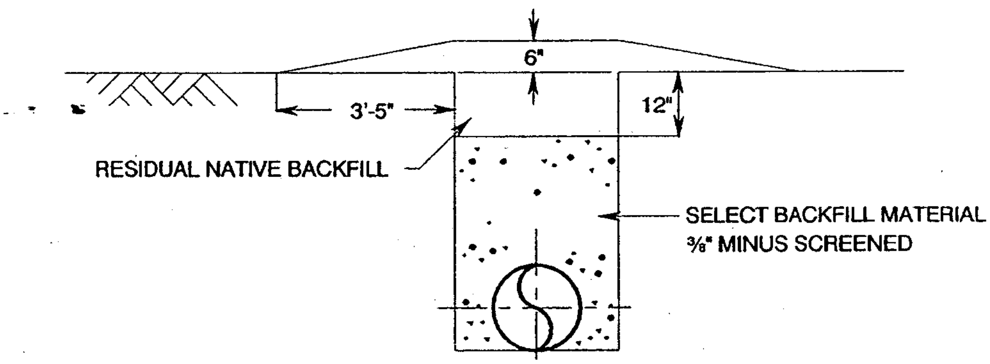
DITCH CONFIGURATION-50% (BY VOLUME) ICE CONTENT IN EXCAVATED MATERIAL



APPROXIMATE SHAPE AND CONTENT AFTER BACKFILLING



APPROXIMATE SHAPE OF DITCHLINE AFTER ONE THAW SEASON
ASSUMING NO LOSS OF RESIDUAL MATERIAL



APPROXIMATE SHAPE OF DITCHLINE AFTER
THAW SETTLEMENT AND RESTORATION
ASSUMING 30% LOSS OF RESIDUAL MATERIAL

ASSUMPTIONS

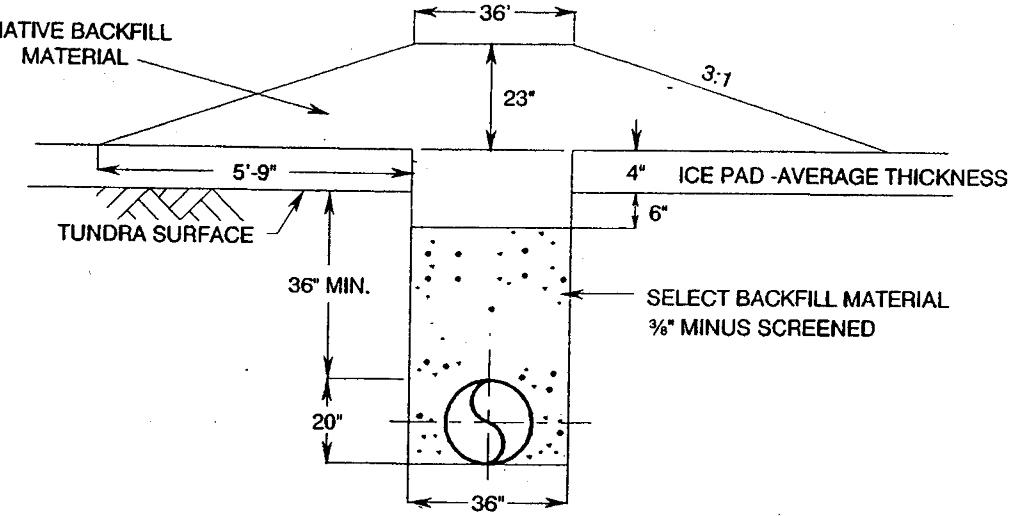
1.) 30% BULKING IN EXCAVATED MATERIAL THAT WILL REMAIN AFTER BACKFILLING
2.) 90% OF BULKING WILL DISAPPEAR AFTER FIRST YEAR THAW
3.) 90% OF THAW SETTLEMENT WILL OCCUR AFTER FIRST THAW SEASON
4.) AVERAGE THICKNESS OF ICE PAD - 4"
5.) AVERAGE LOSS OF RESIDUAL MATERIAL AFTER THAW - 30%
NOTE-THIS WILL BE DUE MAINLY TO MIXING WITH THE SURFACE VEGETATION NEAR THE DITCH

BP EXPLORATION (ALASKA) INC.

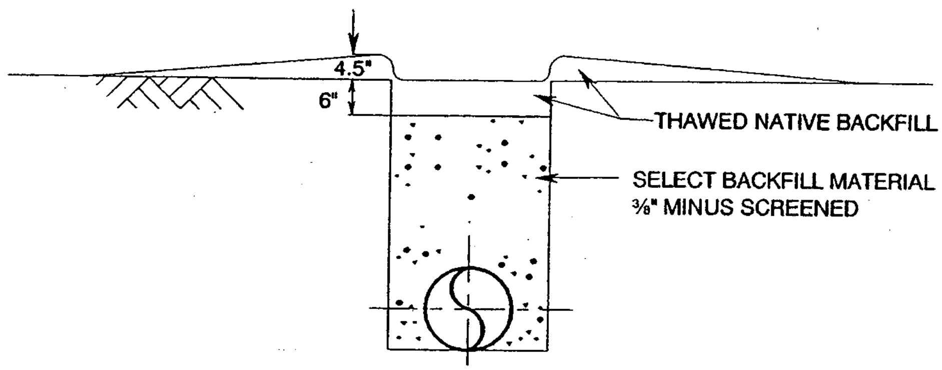
BADAMI PIPELINE DITCH
CROSS SECTION BEFORE AND AFTER
THAW AND BULK SETTLEMENT
(50% ICE CONTENT)

DATE:	SCALE:	SHEET:
JAN. 1995	NOT TO SCALE	3 - 12

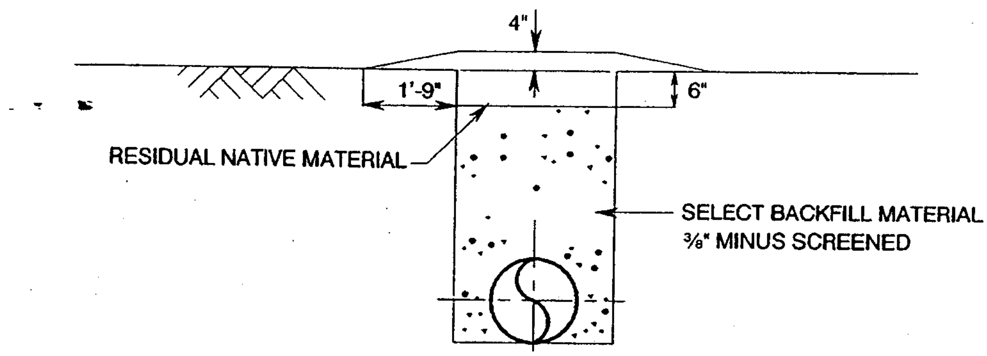
DITCH CONFIGURATION-75% (BY VOLUME) ICE CONTENT IN EXCAVATED MATERIAL



APPROXIMATE SHAPE AND CONTENT AFTER BACKFILLING



APPROXIMATE SHAPE OF DITCHLINE AFTER ONE THAW SEASON
ASSUMING NO LOSS OF RESIDUAL MATERIAL

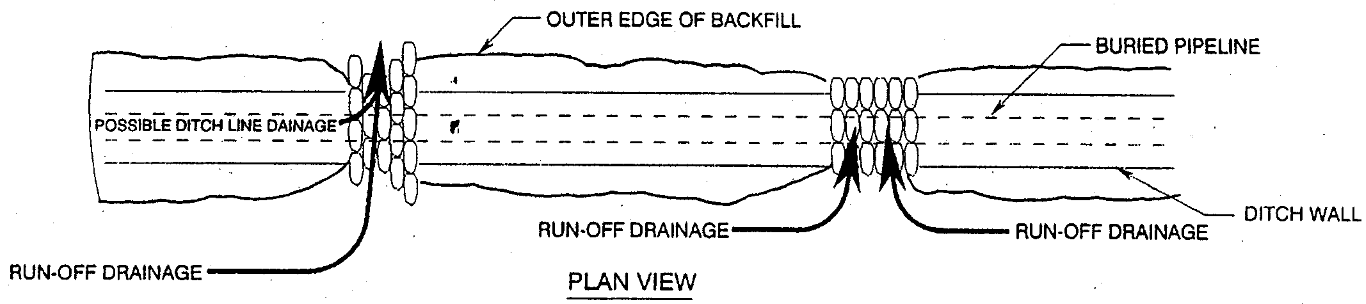


APPROXIMATE SHAPE OF DITCHLINE AFTER THAW SETTLEMENT
AND RESTORATION ASSUMING 30% LOSS OF RESIDUAL MATERIAL

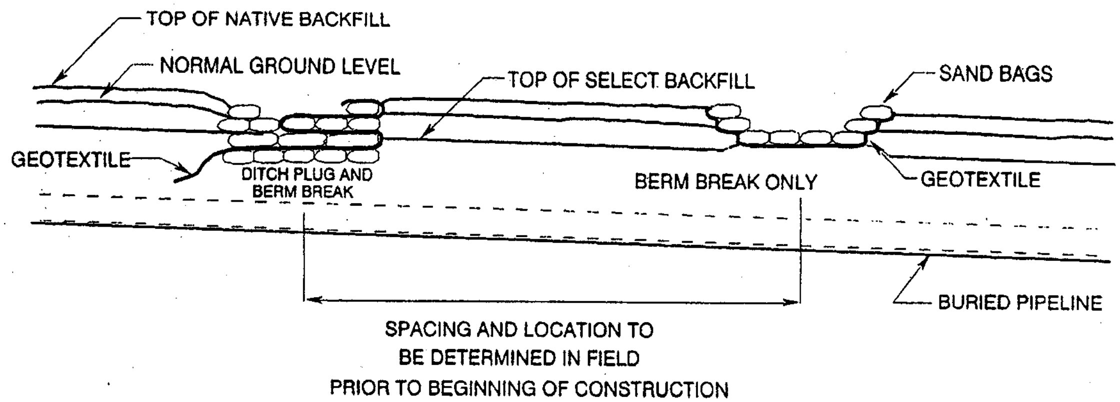
ASSUMPTIONS

1.) 30% BULKING IN EXCAVATED MATERIAL THAT WILL REMAIN AFTER BACKFILLING
2.) 90% OF BULKING WILL DISAPPEAR AFTER FIRST YEAR THAW
3.) 90% OF THAW SETTLEMENT WILL OCCUR AFTER FIRST THAW SEASON
4.) AVERAGE THICKNESS OF ICE PAD - 4"
5.) AVERAGE LOSS OF RESIDUAL MATERIAL AFTER THAW - 30% NOTE-THIS WILL BE DUE MAINLY TO MIXING WITH THE SURFACE VEGETATION NEAR THE DITCH

BP EXPLORATION (ALASKA) INC.		
BADAMI PIPELINE DITCH CROSS SECTION BEFORE AND AFTER THAW AND BULK SETTLEMENT (75% ICE CONTENT)		
DATE: JAN. 1995	SCALE: NOT TO SCALE	SHEET: 3 - 13



PLAN VIEW



CROSS SECTION

NOTES:

1. TYPICALLY DITCH PLUGS WILL BE AS FREQUENT AS EVERY 300' WHERE GRADE EXCEEDS 1%.
2. BERM BREAKS PLACED AT ABOUT 100' SPACING.
3. USE OF MOLDED PLASTIC FOAM DITCH PLUG IS BEING CONSIDERED AS AN OPTION TO SANDBAGS/GEOTEXTILE PLUGS

BP EXPLORATION (ALASKA) INC.		
BADAMI AREA DITCH PLUG AND BERM OPENING SCHEMATIC		
DATE: JAN. 1995	SCALE: NOT TO SCALE	FIGURE: 3 - 14

ex12468.dgn

- **Industry Standards (Codes)**
  - ANSI B 31.4 - 1992, "Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia and Alcohol"

Table 3-1 summarizes pipeline design characteristics for the cross-country pipeline segments and for the four major river crossings.

The 20-inch pipeline will be buried in permafrost and will transport crude oil that has been chilled to inlet temperature of 30°F. Soils around the pipe are expected to remain frozen. Since the soil surrounding the pipe will be imported select backfill, which is relatively unsusceptible to thaw settlement or frost heave, there should be no threat to pipeline integrity.

The proposed pipeline will transport chilled crude oil and natural gas liquids. Modeling was conducted to determine that 30°F is the optimum inlet temperature for this oil in a chilled, buried system. Tests have also been conducted to determine the waxing properties of Badami crude oil. When the oil is chilled, the waxy fraction of the petroleum becomes suspended in granular form within the crude stream. Since the density of this solid wax is very similar to the density of the parent oil, it can be transported within the pipeline with minimal deposition.

Eleven isolation valves will be installed in this pipeline system. These valves will be located at the pipeline inlet, the pipeline outlet, on either side of the four major river crossings, and on the west side of West Badami Creek (Exhibit A). The typical pad layout and cross section are shown in Figures 3-15 and 3-16. Automated valves will be installed at the pipeline inlet and outlet, and on both sides of the Shaviovik and Sagavanirktok rivers. Manual block valves will be used on both sides of the No Name and Kadleroshilik rivers and on the west side of West Badami Creek.

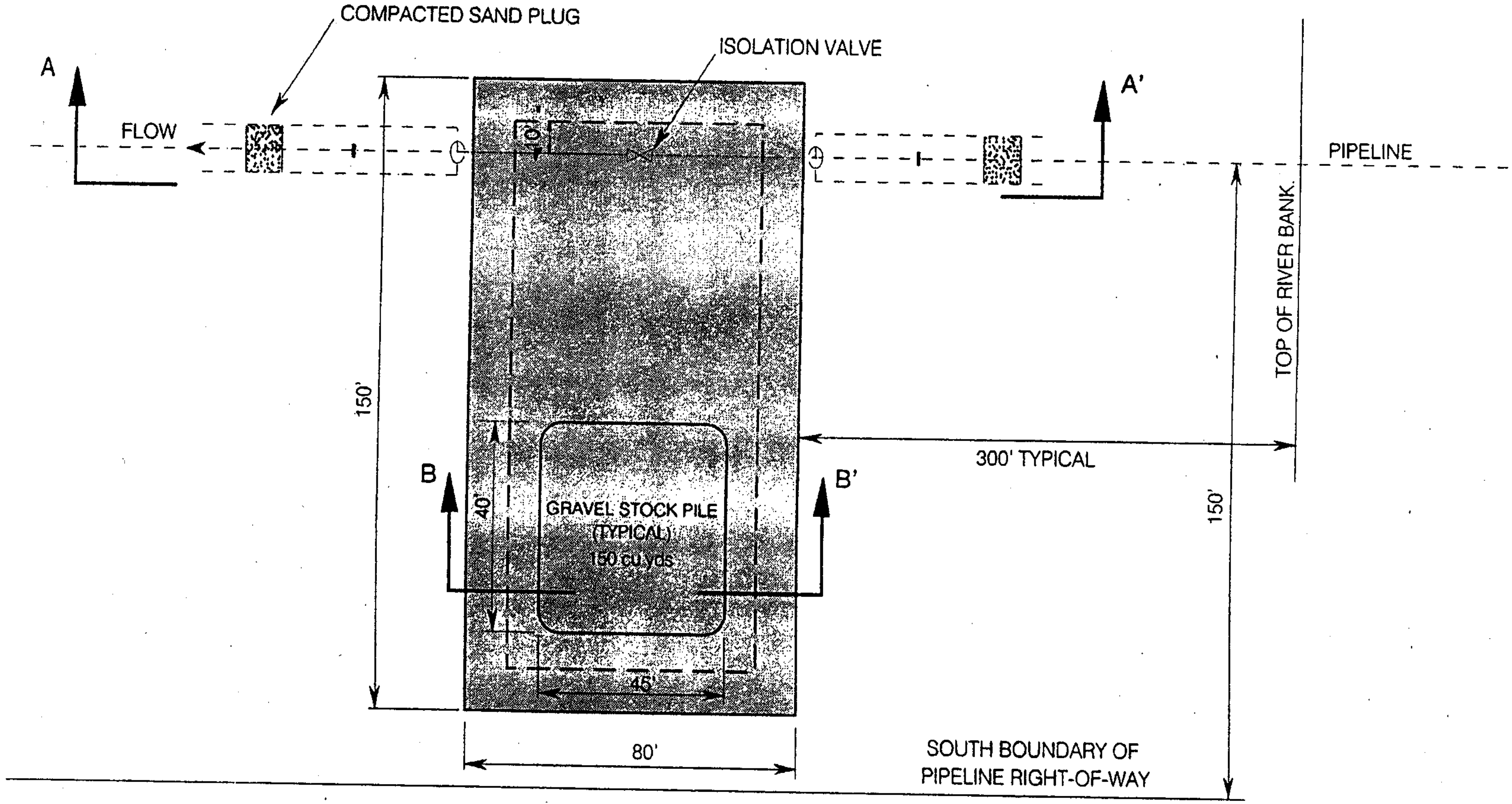
To protect the exterior of the pipe from corrosion, a flexible coating of fusion-bonded epoxy will be used. This coating will withstand expected soil and air temperatures encountered during transportation and construction, and will protect the pipe from damage during installation and operation. Cathodic protection will be provided through an impressed current system.

Mass flow meters will be installed at the inlet and outlet of the pipeline. These meters will provide extremely accurate measurements of the volume of throughput and of the quantity of product in the pipeline at any given time, and will be the primary component of the leak detection system.

Operation of the Badami Pipeline will require construction of one refrigeration and pumping station at the Badami Main Production Facility, and construction of a heater station at the tie-in with the Endicott Pipeline (Figures 3-17 and 3-18).

TABLE 3-1
BADAMI PIPELINE DESIGN CHARACTERISTICS

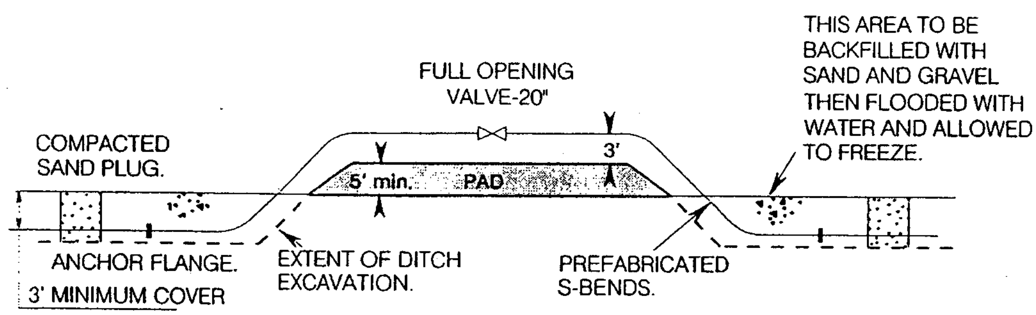
DESIGN FACTOR	CROSS-COUNTRY SEGMENTS	RIVER CROSSINGS
Pipeline outside diameter	20 inches	20 inches
Grade (API 5L)	X65	X65
Design pressure (psi)	1480	1480
Design temperature	-20°F	-50°F
Corrosion allowance	0.125 inches	0.121 inches
Maximum design stress	0.72	0.60
Wall thickness	0.469 inches	0.500 inches
External coating	Fusion-bonded epoxy	Fusion-bonded epoxy plus concrete



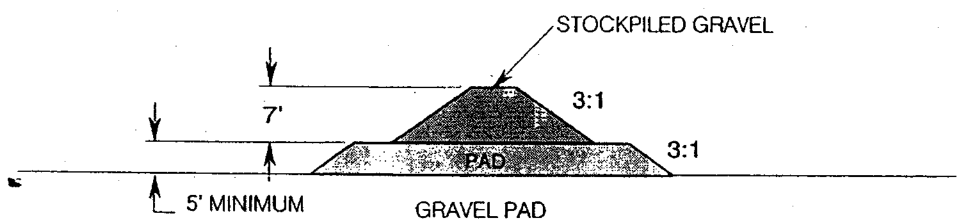
PLAN VIEW

NOTE:
AUTOMATED VALVES ARE PLANNED FOR THE INLET, OUTLET AND EACH SIDE OF THE SAGAVANIRKTOK AND SHAVIOVIK RIVERS. FIVE OTHER VALVES AT RIVER CROSSINGS WILL BE MANUALLY OPERATED.

BP EXPLORATION (ALASKA) INC.		
BADAMI AREA ISOLATION VALVES AT RIVER CROSSINGS - TYPICAL LAYOUT		
DATE: JAN. 1995	SCALE: NOT TO SCALE	FIGURE: 3 - 15

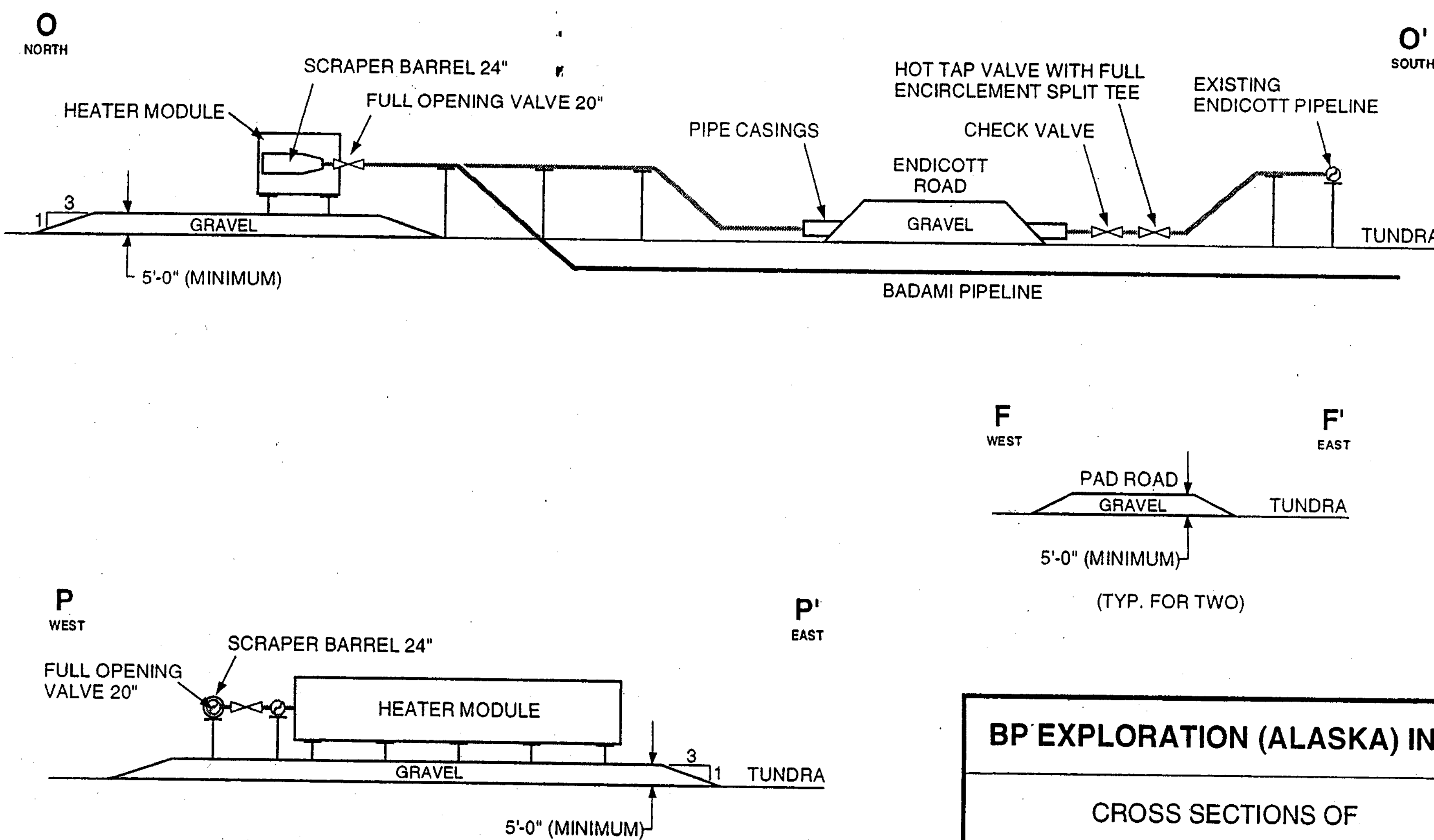


SECTION A - A'



SECTION B - B'

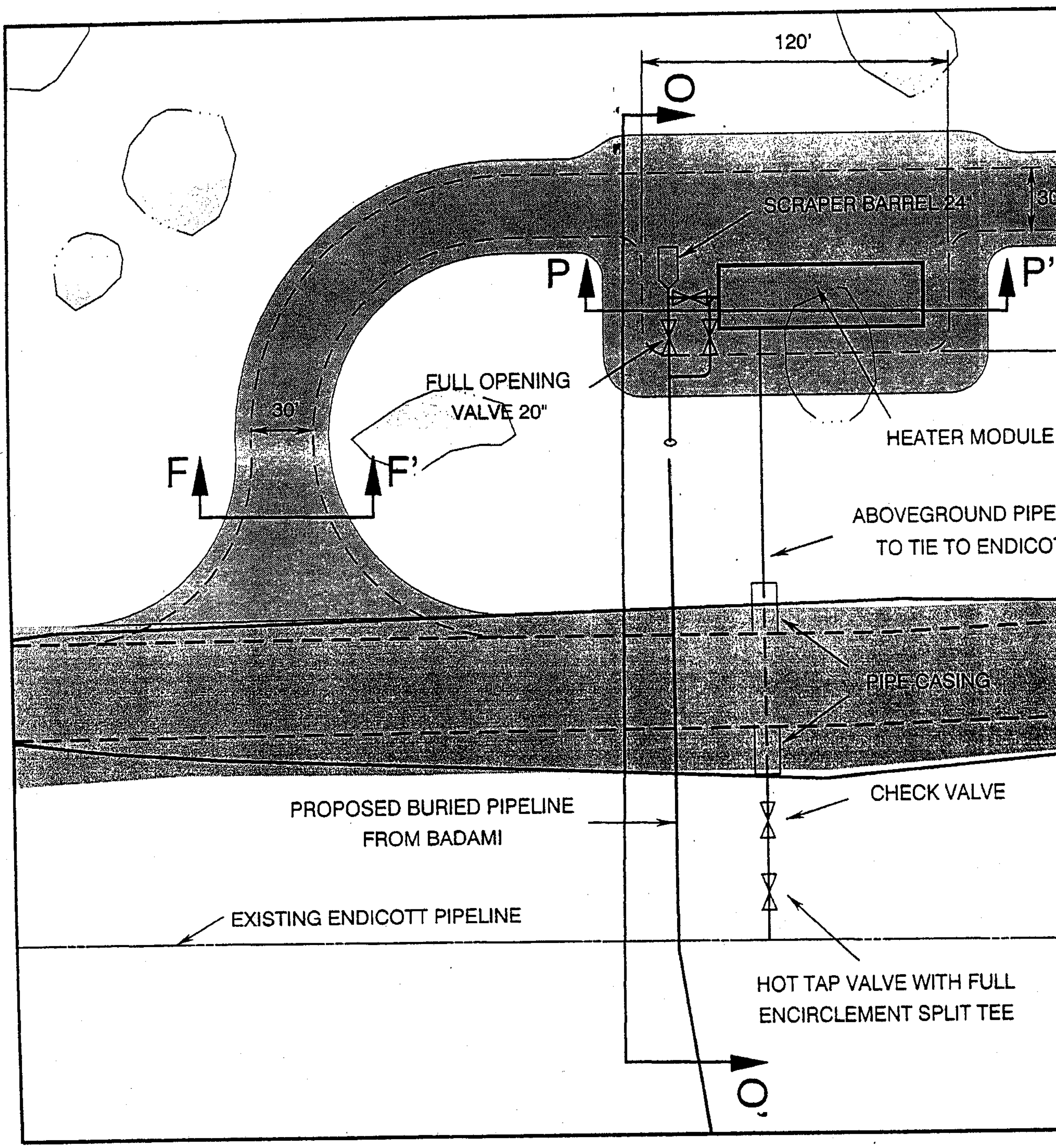
BP EXPLORATION (ALASKA) INC.		
BADAMI AREA ISOLATION VALVES AT RIVER CROSSINGS - TYPICAL CROSS SECTION		
DATE: JAN. 1995	SCALE: NOT TO SCALE	FIGURE: 3 - 16



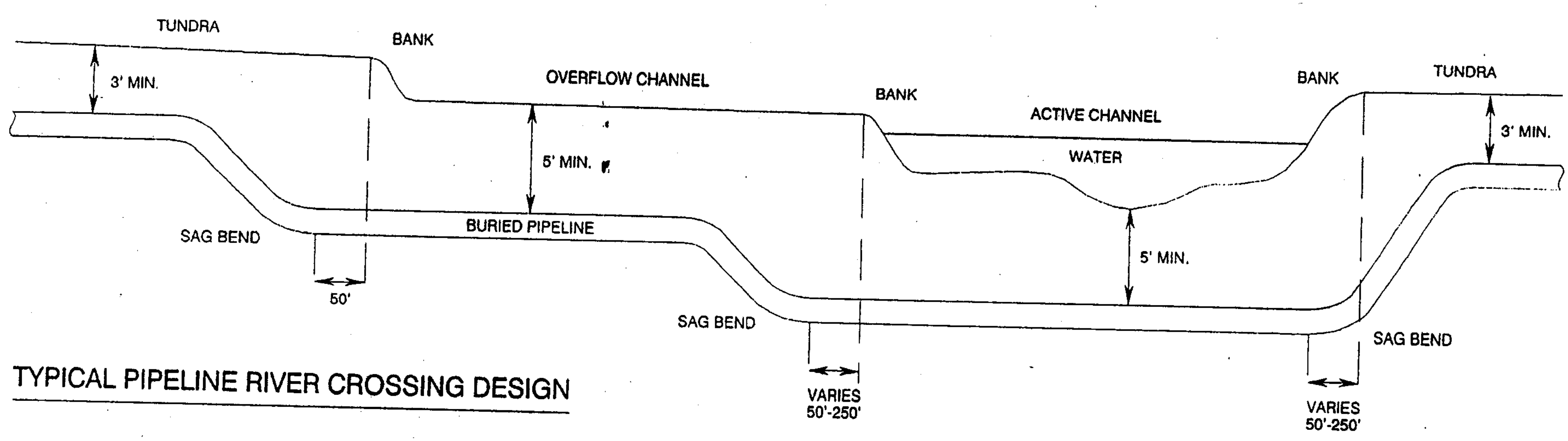
BP EXPLORATION (ALASKA) INC.

CROSS SECTIONS OF
TIE-IN FACILITIES
AT THE ENDICOTT PIPELINE

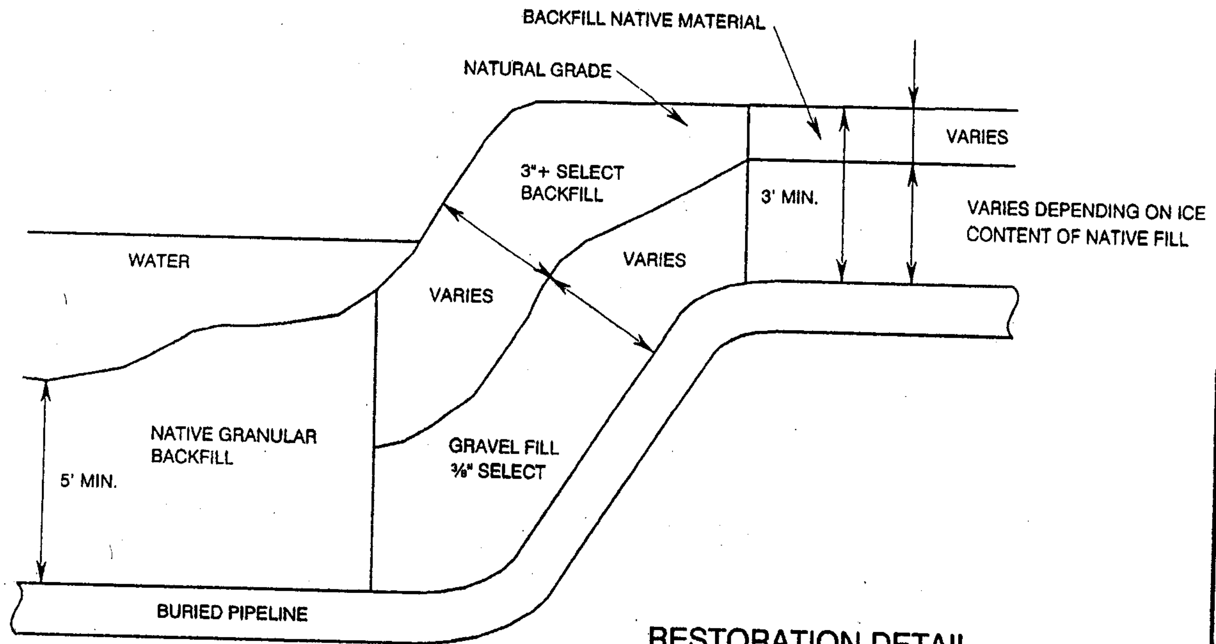
DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3-18



BP EXPLORATION (ALASKA) INC.		
TIE-IN FACILITIES AT THE ENDICOTT PIPELINE		
DATE: JAN. 1995	SCALE: 1" = 60'	FIGURE: 3 - 17



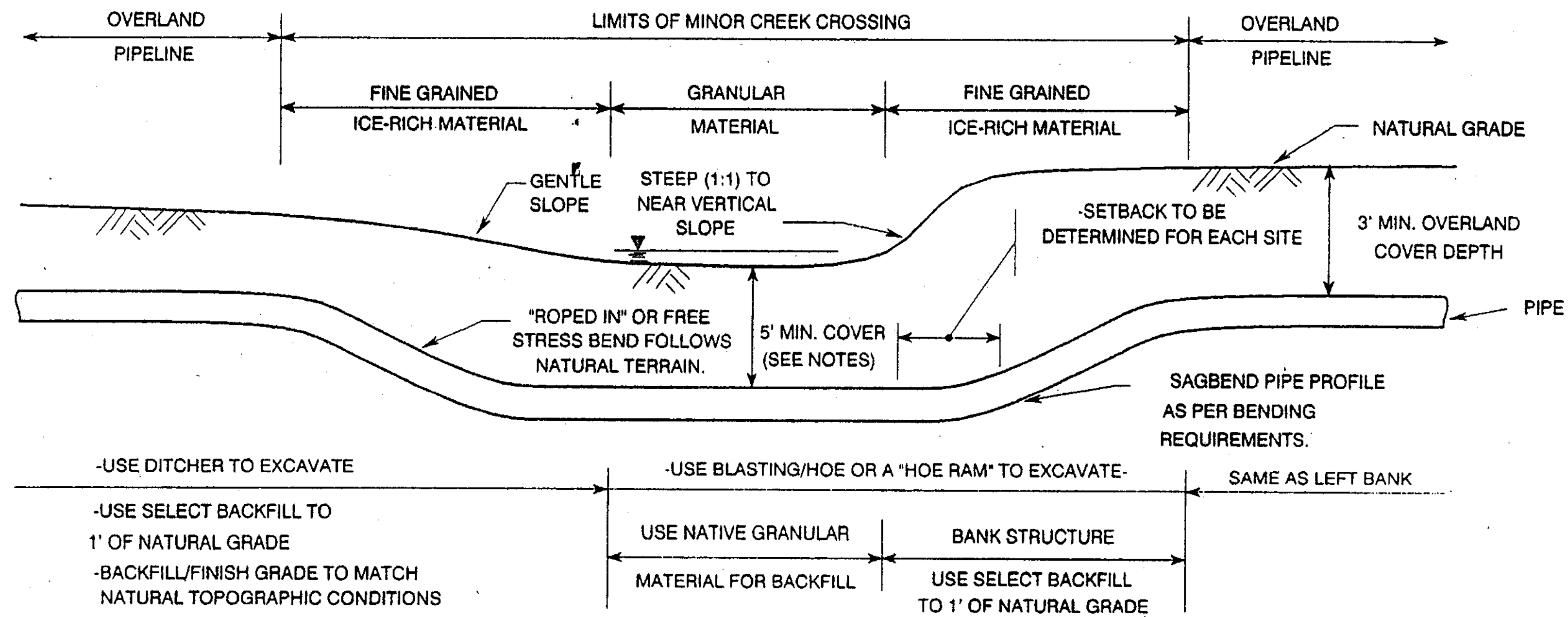
TYPICAL PIPELINE RIVER CROSSING DESIGN



RESTORATION DETAIL

BP EXPLORATION (ALASKA) INC.		
BADAMI AREA TYPICAL PIPELINE RIVER CROSSING DESIGN AND RESTORATION		
DATE: JAN. 1995	SCALE: NOT TO SCALE	FIGURE: 3 - 19

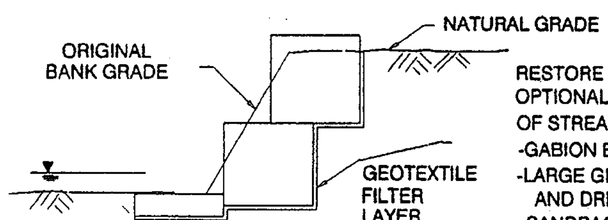
ax12472.dgn



CROSSING PROFILE

NOTES:

1. MINOR CREEK CROSSING DEFINED AS GREATER THAN 10' WIDE
2. CREEKS TO BE SURVEYED AND CLEARLY MARKED PRIOR TO FREEZE-UP.
3. COVER DEPTHS TO BE MEASURED FROM LOWEST POINT IN STREAM.



RESTORE BANK TO MATCH EXISTING GRADE. OPTIONAL TECHNIQUES, DEPENDING ON SIZE OF STREAM, VELOCITY, AND EROSION POTENTIAL ARE:
- -GABION BASKETS (AS SHOWN)
- -LARGE GRAVEL BAGS (AS USED ON ENDICOTT AND DRILLING ISLANDS)
- -SANDBAGS
- - USE COBBLES TO RESTORE SLOPE.

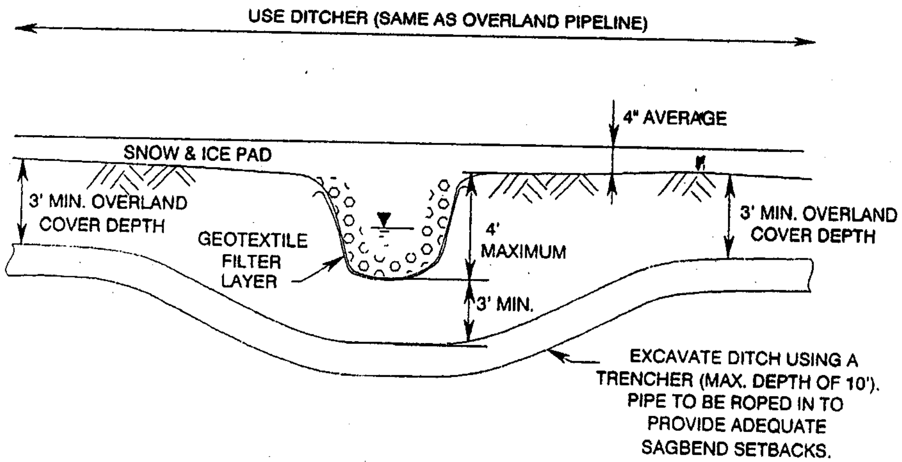
RESTORATION OF STEEP RIGHT BANK

BP EXPLORATION (ALASKA) INC.

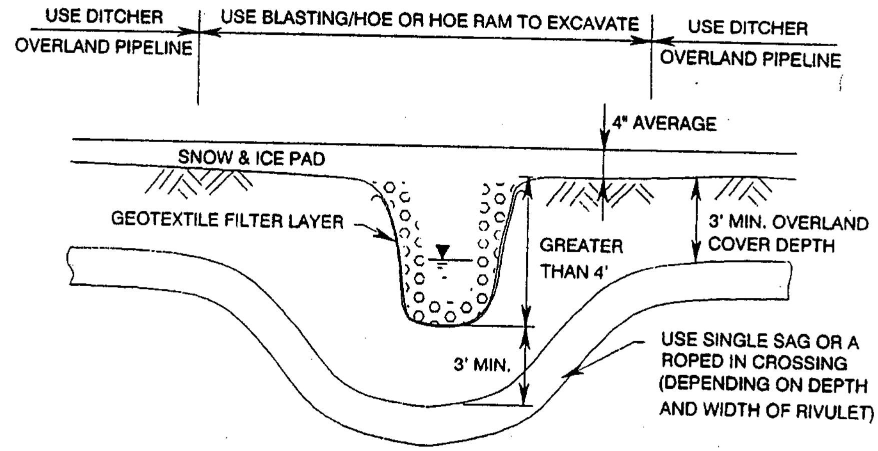
BADAMI AREA
MINOR CREEK CROSSING
DESIGN AND RESTORATION

DATE:	SCALE:	FIGURE:
JAN.1995	NOT TO SCALE	3 - 20

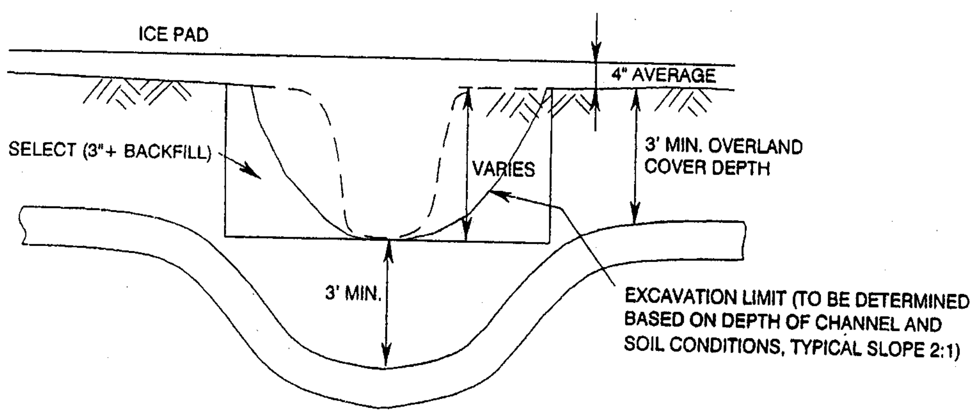
ex12473.dgn



CASE A- CROSSING PROFILE- RIVULET < 4' DEEP



CASE B- CROSSING PROFILE- RIVULET > 4' DEEP



ALTERNATE RESTORATION PLAN

DESIGN AND CONSTRUCTION NOTES

1. RIVULETS TO BE SURVEYED AND CLEARLY MARKED PRIOR TO FREEZE-UP. NATURAL BOTTOM ELEVATION, TOP WIDTH AND SIDE SLOPES TO BE DOCUMENTED AND PHOTOGRAPHED TO PROVIDE INFORMATION FOR:
   - DITCH DEPTH AND PIPELINE PROFILE
   - BANK RESTORATION DETAILS
2. FOR CASE "B" RIVULETS:
   - MINIMIZE DITCH WIDTH AND ZONE OF DISTRIBUTION BY CAREFUL BLASTING AND/OR USE OF HOE RAM.
3. PLACE SELECT GRANULAR BACKFILL TO WITHIN 1' OF NATURAL GRADE.
4. USE SANDBAGS FOR BANK RESTORATIONS FOR CASE "A" RIVULETS. FOR CASE "B" CROSSINGS, USE SANDBAGS OR GABIONS DEPENDING ON DEPTH OF RIVULET AND EXTENT OF DISTURBANCE. RESTORED BANKS TO BE SMOOTHLY CONTOURED INTO THE NATURAL BANKS.

BP EXPLORATION (ALASKA) INC.

BADAMI AREA
BEADED STREAM
DESIGN AND RESTORATION

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3 - 21

3.6.2 Pipeline

Cross Country Segments

The pipeline will be constructed during the winter of 1996-1997, and all work will be conducted from ice pads/roads in order to protect the tundra from possible damage. As shown in Figure 3-22, an ice pad will be built to support numerous passes of heavy construction equipment. The trench will be excavated through the pad. If necessary, a temporary snow fence will be placed at the northern boundary of the construction right-of-way to minimize snow accumulation in the construction area. Construction will proceed from west to east along the right-of-way.

After construction, the ice structures will be breached or fractured before spring breakup in order to allow these constructed ice features to break up at a rate similar to the naturally occurring ice.

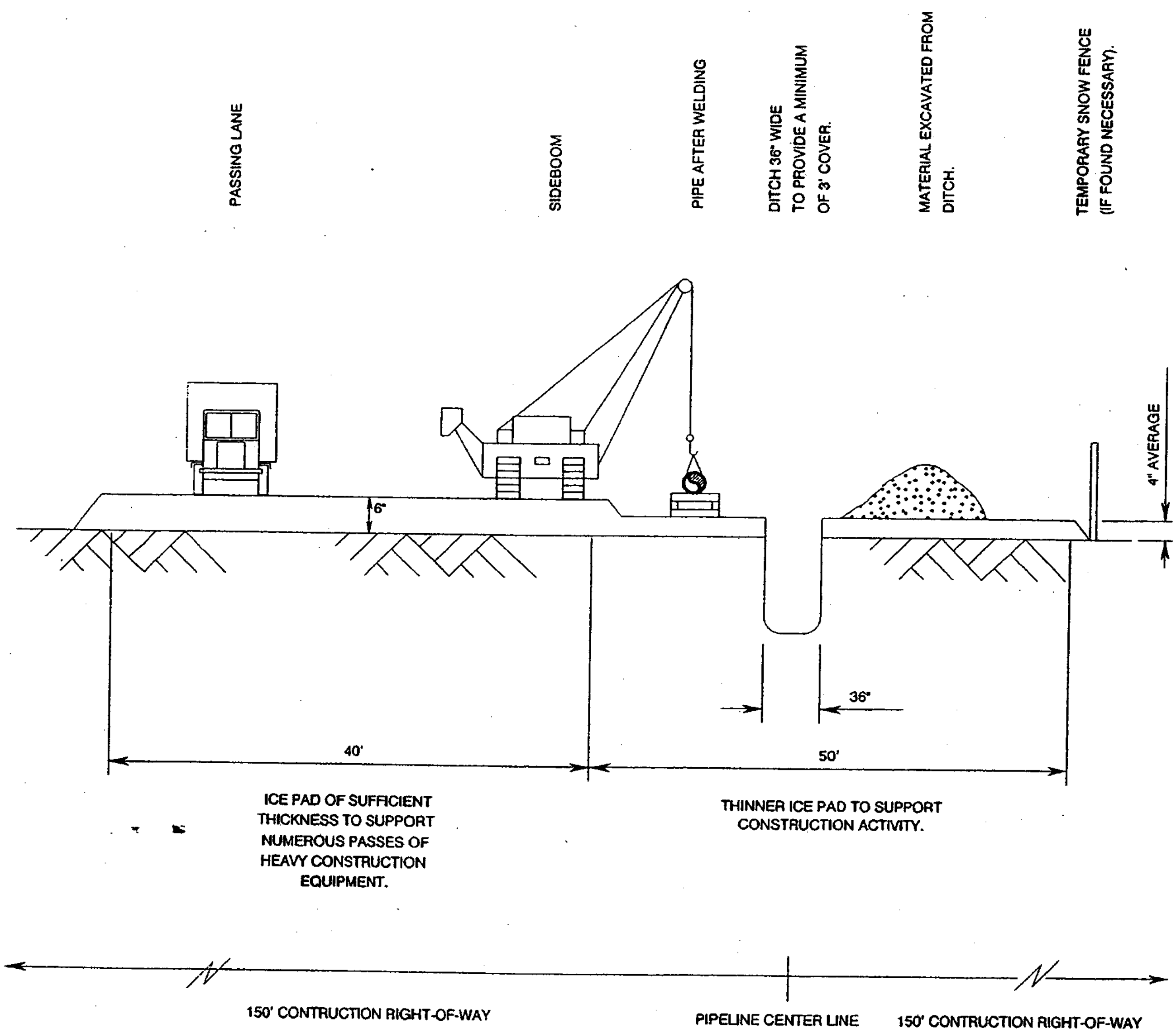
An arctic wheel trencher capable of excavating to a maximum depth of 10 feet in a single pass will excavate the ditch for the 20-inch-diameter pipeline. The ditching machine will produce a finely cut, homogenized mixture of ice, organic matter, and inorganic soil. By the time backfilling has occurred, there will be a certain amount of snow mixed in as well. The spoils will be stacked on the ice pad on the north side of the trench. The ditch will be excavated to a typical depth of 5 feet beneath the top of the ice pad in order to achieve a minimum 3-foot cover over the pipe. The pipe will be laid directly on the floor of the trench; no bedding material will be used.

To ensure that only line pipe of the highest quality goes into the Badami Pipeline, all pipe will be inspected by an independent contractor at the pipe mill under the direction of the project's quality assurance coordinator. All other purchased materials will be similarly inspected.

All welds on the pipeline will be fully inspected radiographically during construction. Throughout construction, inspectors will be employed to ensure that the approved welding procedures are followed, including preheat and cool down. Welds on the river crossing sections will be ultrasonically inspected to ensure that cold cracking does not occur. The cross-country segments of the pipeline will be hydrostatically tested following construction; segments at river crossings will be pressure tested prior to lowering-in. Hydrotest fluids will be disposed of through injection into an approved well.

River and Stream Crossings

The pipeline trench crossing of the four major rivers, minor creeks (those with a bank height greater than 4 feet), and any other crossing with coarse, granular bed material will be excavated by blasting and a backhoe. The trenching machine cannot be used at these crossings due to the required ditch depth and the machine's limitations for excavation of coarse granular material. Wherever possible, a jackhammer on a backhoe (a



BP EXPLORATION (ALASKA) INC.

BADAMI AREA
CROSS SECTION OF PIPELINE
RIGHT OF WAY DURING
CONSTRUCTION

DATE:	SCALE:	FIGURE:
JAN. 1995	NOT TO SCALE	3 - 22

hoe ram) will be used as an alternative to blasting to minimize the width of the ditch and the extent of disturbance.

The method of construction to be used at any individual river, creek, or stream crossing will be determined based on the absence or presence of water in the channel and its depth. Based on general knowledge of the area and on observations of pre-breakup icing conditions, surface and subsurface water are likely to be encountered across a portion of the East Channel of the Sagavanirktok River crossing during the February-to-April construction window. Other crossings are expected to be dry.

The crossing of the East Channel of the Sagavanirktok River will be excavated in three sections: the expected wet channel sections at the east and west banks, and the dry section in the middle. Snow and ice will be removed, the wet areas excavated by backhoe, and the dry areas excavated by blasting and backhoe. Depending on the side slopes of the excavations and the number and sizes of sidebooms available, the pipe will either be welded alongside the trench and lowered in by sideboom tractor, or welded alongside the trench centerline on one side of the river and pulled into place. Following pipe placement, the granular excavated material will be placed back in the ditch using a backhoe. To minimize disruption of natural flow, the trench will be backfilled to original grade using the native spoil. Bulking is estimated to be 40 percent. The surplus material will be graded out upstream and downstream along the riverbed. Voidage created by the subsequent settlement of the backfill will be filled by the natural downstream movement of riverbed materials during the first year following construction.

The remainder of the river crossings will be dry-excavated by blasting and backhoe excavation or through the use of the hoe ram. The concrete-coated pipe will be placed by lowering it in with sidebooms. Excavated granular material will be placed back in the ditch and riverbeds restored to pre-construction contours.

3.6.3 Pipeline Construction Rehabilitation

After thaw settlement of the trench backfill has occurred in the summer of the first year after construction, there will be a small mound of excavation spoil on top of the tundra on each side of the ditch, and the area directly over the ditch will be lower than the adjacent berm edges. The berm will therefore have to be regraded by hand late in the first summer after construction to restore the geometry of the spoil over the ditch. This regrading is important in order to avoid trapping water in the ditch.

After the trench backfill mound has been stabilized, revegetation will begin. The general approach will be to create conditions that promote establishment of native vegetation on the site. This will involve applying phosphorus fertilizer to the disturbed area at a rate of about 5 to 10 pounds/acre and seeding lightly (approximately 100 pure live seed/square foot) with a native species such as *Puccinellia arctica*. *Puccinellia* readily establishes on disturbed sites, but does not persist. These characteristics are considered advantageous because the *Puccinellia* will help stabilize the site initially, but will allow other native species to colonize and become established on the trench cap.

River banks will be restored to their pre-construction slope and shape using ice-free granular fill. Oversized material obtained from the proposed river floodplain borrow sites will be placed over the disturbed bank area to ensure that little erosion occurs prior to re-stabilization of the bank area. At minor creek crossings, steep and vertical banks will be restored using ice-free granular fill or gabions. Two restoration techniques could be used for crossings of beaded tundra streams, depending on the characteristics of each crossing. One option would be to restore these narrow, nearly vertical-walled drainages by using sandbags or gabions. As an alternative, the banks could be restored to a stable slope using granular fill. Thermal degradation of the fill/natural material interface would be allowed to develop into a bead formation in the stream. Possible failure of a vertical bank section and resultant blockage of the watercourse is the scenario that would favor the approach to simply let a bead form. In all cases, river and stream crossings will be designed to allow unrestricted fish passage.

3.7 GRAVEL SOURCES

Estimated quantities of gravel required for construction of each facility are listed in Table 3-2. Gravel for the well pad, facilities pad, dock, in-field road system, and airstrip will be obtained from the new East Badami Gravel Mine Site, located south of the facilities pad (Figure 3-2). A 5.7-acre cell at this mine site will be reserved for field operations and maintenance. In addition, a 35.4-acre site is being permitted for future use but will not be constructed at this time.

The mining plan and reclamation plan for the East Badami Gravel Mine Site have been developed in close coordination with the Alaska Department of Fish and Game (ADF&G), the Alaska Department of Natural Resources (ADNR), and other interested agencies. The construction mine site will be about 72.1 acres in size. Overburden will be stripped and stockpiled in berms along the western and northern boundaries of the site. In order to excavate the nearly 2.2 million cubic yards needed to construct field facilities, the mine will be excavated to an average depth of 20 feet. After construction is complete, the mine site will be allowed to flood. The planned excavation is designed to create fish overwintering habitat when flooded.

Final geotechnical investigations to confirm the potential of this source are scheduled for winter 1995. If these investigations show that there is not adequate material at this site, an alternate site at the Shaviovik River will be developed (Exhibit A). Only one of these two sources would be used.

Two mine sites are also proposed to supply gravel needed for pipeline construction. These mine sites will be located in the floodplains of the Shaviovik and Kadleroshilik rivers (Exhibit A). The mining and reclamation plans for these sources are

TABLE 3-2
BADAMI GRAVEL FILL AND EXCAVATION REQUIREMENTS

FACILITY	CUBIC YARDS	ACRES AFFECTED
Field Development		
Well Pad	270,000	23.2
Facilities Pad	149,000	12.1
Airstrip and Apron	792,000	40.0
Dock	741,000	23.8
Flare Pad	15,000	1.2
Road from Dock to Well Pad	11,000	1.1
Road from Well Pad to Facilities Pad	18,000	2.5
Road from Facilities Pad to Flare Pad	6,000	0.5
Road from Facilities Pad to Airstrip	36,000	3.5
Road from Airstrip to Mine Site	13,000	1.6
Subtotal Facilities Construction	2,051,000	109.5
East Badami Mine Site Pit Excavation	(2,051,000)	72.1
East Badami Maintenance Pit Excavation	(200,000)	5.7
East Badami Mine Site and Maintenance Pit Overburden Placement	660,000	12.2
Future Use Excavation	(1,400,000)	35.4[1]
Future Use Pit Overburden Placement	300,000	
Subtotal Mine Site Development	960,000[2]	125.4
Total Field Development	**3,011,000[2]**	**234.9**
Pipeline		
Trench Excavation - River Crossings	(37,000)	—
Trench Backfill - River Crossings	37,000	4.7
Trench Excavation - Cross Country	(71,000)	—
Trench Backfill - Cross Country Native Backfill over Select Backfill[3]	71,000	45.5
Trench Backfill - Cross Country Select Backfill[3,4]	70,000	—
Valve Pads	18,000	2.5
Endicott Tie-In Pad	16,000	0.9
Subtotal Pipeline Construction	104,000	53.6
Shaviovik Mine Site Excavation	(60,000)	6.5
Kadleroshilik Mine Site Excavation[5]	(60,000)	9.0
Subtotal Mine Site Excavation	(120,000)	15.5
Subtotal Pipeline System	**104,000[2]**	**69.1**
PROJECT TOTAL	**3,065,000**	**304.0**

[1] Affected acreage includes area for overburden placement
[2] Total cubic yards required for construction, does not include quantity excavated
[3] Estimated maximum quantity assuming 75% ice content in excavated material
[4] Includes river crossing bank restoration
[5] Includes source reserved for future maintenance use

similar to the plans developed for the East Badami Mine Site. The sites will be operated only during pipeline construction and will be reclaimed to provide fish overwintering habitat.

More information about development of these gravel mine sites is contained in gravel mining and reclamation plans submitted to ADNR with the Competitive Material Sales applications.

3.8 SPILL PREVENTION AND RESPONSE

An Oil Discharge Prevention and Contingency Plan (ODPCP) was approved by ADEC on November 4, 1993 for BPXA's Badami area exploratory drilling operations. This plan has been amended and approved to cover field appraisal operations. Appendix A of this Environmental Assessment contains a draft of the type of plan that will be prepared for Badami production operations.

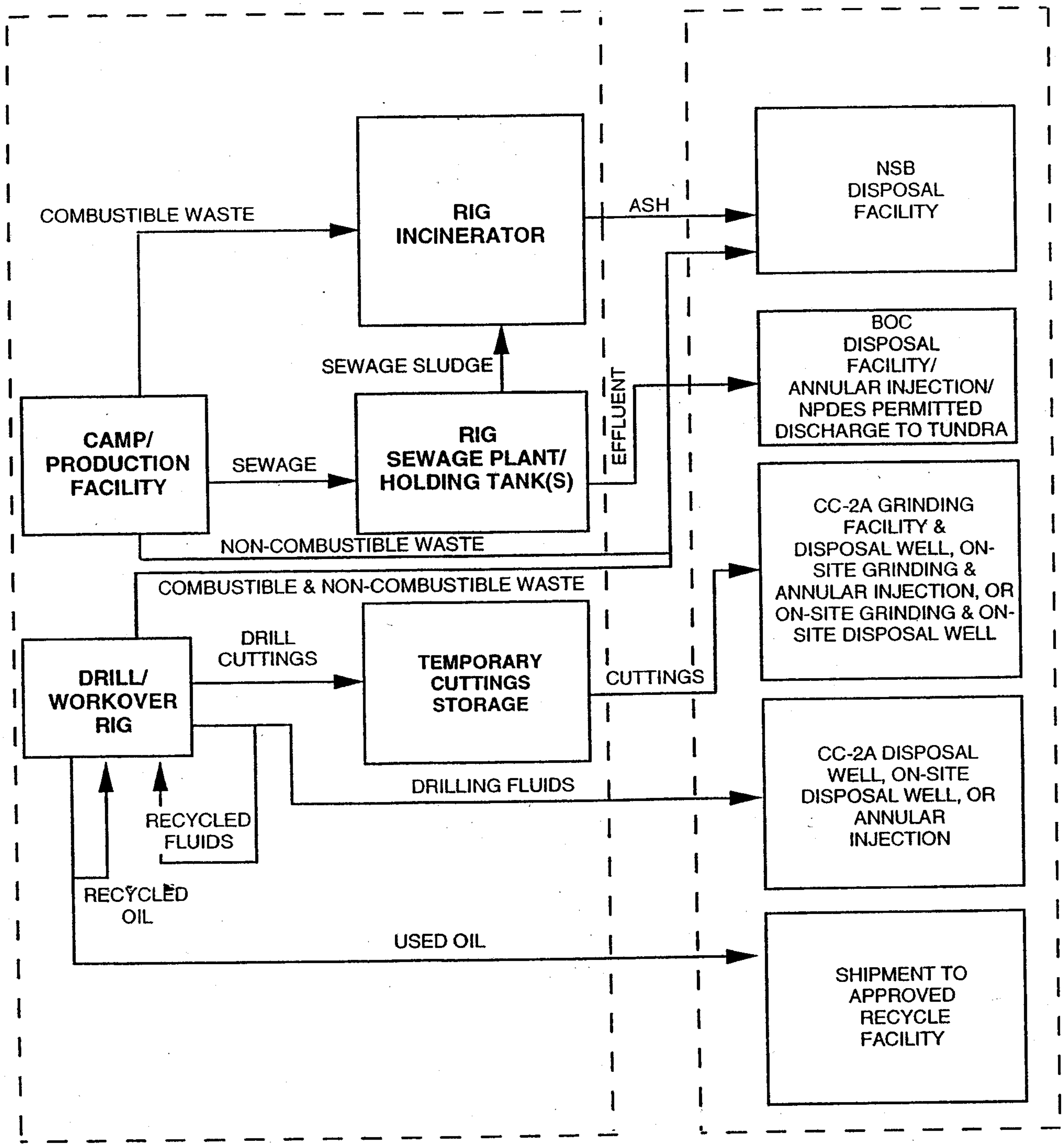
The Badami Area ODPCP will be amended again to incorporate Badami operations and spill response considerations. Amendments to the Plan will include: revision of the spill prevention section to cover facility and pipeline operations; identification of spill response equipment to be staged and/or deployed at sensitive areas along the pipeline route (primarily river crossings); equipment to be staged at the facility; and spill prevention and response considerations specific to a facility with limited access. Operations cannot commence until the Badami Area ODPCP amendment is approved.

While it will be some time before amendments to the Badami Area ODPCP are submitted for agency approval, spill prevention and general spill response information is required by review agencies to evaluate the currently submitted permit applications. This spill prevention and response information is provided in Appendix A and includes: a general description of the Badami drillsite, Main Production, and pipeline facilities; fuel transfer procedures and secondary containment considerations for the drillsite and Main Production facilities; corrosion control and discharge detection associated with the Badami Pipeline; a potential discharge analysis for the pipeline; a review of comparable discharge histories; an evaluation of increased risks of discharges; and a general discussion of pre-staged spill response equipment and spill prevention.

3.9 WASTE MANAGEMENT

All waste disposal procedures will conform with Alaska Department of Environmental Conservation (ADEC) and U.S. Environmental Protection Agency (EPA) requirements. Figure 3-23 is a schematic plan for waste management during the project.

The majority of wastes generated during project construction will consist of drill cuttings and spent muds. Some drilling waste will also be generated during operation



BP EXPLORATION (ALASKA) INC.

BADAMI DEVELOPMENT PROJECT

WASTE MANAGEMENT PLAN

DATE:	SCALE:	FIGURE:
JAN. 1995	NONE	3-23

from well workover rigs. No reserve pit will be constructed. Drilling fluids will be disposed of through annular injection on-site, injection into an on-site permitted disposal well, or transportation off-site to permitted disposal wells. Cuttings will either be disposed of on-site or transported off-site for disposal. For on-site disposal, cuttings will be treated by a portable grinding unit and disposed of through annular injection or into a permitted on-site disposal well along with spent muds. Alternatively, cuttings will be transported off-site to the CC-2A grinding facility and disposal well at Prudhoe Bay. Space for temporary storage of drilling wastes will be provided on the site.

In addition to drilling wastes, domestic wastewater and solid waste will be generated during the project. Solid wastes including scrap metal, timber, garbage, etc. will be hauled off-site for disposal at the North Slope Borough landfill. Combustible wastes will be taken to the North Slope Borough incinerator or incinerated on-site at the drill rig camp incinerator. Waste lubricating oil will be packaged in drums for shipment to an approved recycling facility.

An approved treatment unit at the rig camp, and subsequently at the field facilities, will treat sanitary wastes. Effluent from the unit will be chlorinated, and the treated effluent will either be discharged to the tundra in accordance with an NPDES permit, be hauled to BPXA's Base Operations Center waste disposal facility, disposed of through annular injection, or used to support drilling operations. Evaporation is being considered as a means to reduce waste volumes.

The estimated peak quantity of domestic wastewater generated during construction is approximately 13,000 gallons per day; the expected average effluent flow during operations is 1,500 gallons per day. Sewage sludge will be incinerated at the on-site facility, and incinerator ash and all other innocuous waste will be hauled to the North Slope Borough waste disposal facility.

Wastes shipped off-site will be transported via winter ice roads or summer barges. Any wastes generated during spring and fall (when both ice road and barge travel are interrupted by breakup and freeze-up) which must be transported off-site for disposal will be stored on-site in holding tanks until they can be transported to the Prudhoe Bay oil fields for disposal.

3.10 ENDICOTT FACILITIES

The Badami pipeline right-of-way will terminate at the tie-in with the Endicott Pipeline. Before entering the Endicott Pipeline, the Badami crude oil will be reheated to a temperature of up to 120°F.

A heater station will be constructed at the Endicott Pipeline tie-in. This pad will be approximately 150 feet by 100 feet (Figure 3-17). The pad will contain a module with facilities to reheat Badami crude oil, including two 16 million Btu/hr heaters. Other facilities located at the tie-in would include a pig receiver and metering unit and associated controls.

Since Badami oil will be added to the Endicott Pipeline at a time when Endicott production is declining, adequate capacity will be available to transport production from both fields.

3.11 SUPPORT FACILITIES

3.11.1 Camp

A camp to support construction of gravel facilities will be established in the Badami area in the winter of 1995-1996. A camp will also be operational in the summer of 1997, when installation of facility modules and pipeline tie-in construction occur. At peak occupancy, this camp will house 130 workers. As is standard arctic drilling practice, the drilling rig crew will be housed in temporary, self-contained quarters located on the wellsite during drilling. It is anticipated that minor equipment maintenance will occur at the construction sites, with major repairs being undertaken at permanent repair facilities at Prudhoe Bay.

3.11.2 Water Sources

Fresh water will be needed for ice road construction, hydrotesting the pipeline, drilling operations, and domestic use. During field operations, up to 1,500 gallons of water per day will be needed for domestic use. Much higher water consumption and wastewater generation will occur during field construction and development drilling. The maximum rate will occur during 1996, when up to 13,000 gallons of water per day could be required during gravel construction.

Domestic water will be obtained from a local permitted source (see Exhibit A). Possible sources include water from the East Badami Mine Site (if not brackish) or from nearby deep lakes. Wastewater will either be treated on-site and discharged or hauled back to the Prudhoe Bay Unit for treatment and disposal (see Section 3.10).

Drilling of each Badami well will require about 1.8 million gallons, at a rate of 20,000 gallons per day, for a total maximum water consumption of 108 million gallons. Annual construction of a sea ice road construction would require up to 20 million gallons of water, and ice road construction along the pipeline corridor would also require up to 20 million gallons. Drilling make-up water will be obtained from a nearby lake or the East Badami Mine Site. Hydrotesting of the multi-phase pipeline will require approximately 2 million gallons at a rate of about 250,000 gallons per day. Water for ice road construction and hydrotesting will come from existing or new permitted sources in the pipeline corridor (Exhibit A). Planned access routes to possible water sources are shown on Exhibit A.

3.11.3 Power

Electrical power for field operations will be generated on-site using Badami gas.

3.11.4 Communications

Voice and data links will be established between Badami and the Prudhoe Bay and Duck Island units. A supervisory control and data acquisition (SCADA) control system will also be installed for operation of the Badami Pipeline. A data communication system will be installed between the endpoints of the pipeline.

3.12 OPERATIONS AND MAINTENANCE

The Badami field will be a minimally staffed facility. Use of simple-to-operate facilities was a basic design concept in planning this field. Much of the operation will be automated, reducing the need for extensive personnel on-site. At this point in facilities design, it is estimated that up to 15 full-time personnel will be required to operate the field and the pipeline.

A safety program will be implemented for this project, including such measures as safety briefings, a safety officer, identification and correction of potential work hazards, environmental awareness, polar bear training, contingency plans for medical evacuations, first-aid training, and screening of workers for remote construction. All employees and contractors on the project will be required to attend regularly scheduled safety meetings. Any condition that could cause a hazard to the safety of the workers on the pipeline will be reported to the responsible supervisor so that immediate action can be taken.

BPXA will also implement a program to ensure that construction, operation, and maintenance of project facilities are conducted in full compliance with relevant federal, state, and local regulations and permit conditions. One key objective of this program will be to ensure pipeline integrity, prevent spills or leaks, and establish procedures for performance monitoring to ensure continued integrity and for response planning.

After construction, a pipeline inspection and maintenance program will be implemented. The goals of this program will not only be to ensure pipeline operating integrity and safety, but also to prevent, identify, and respond to any situations that could cause significant damage to the environment. The pipeline will be regularly inspected by electronic internal inspection devices (pigs) to detect any pipeline movement, corrosion, or other potential problem.

The ongoing pipeline inspection and maintenance program will address potential adverse habitat or water quality impacts resulting from unplanned problems with pipeline performance, including possible thermokarsting, hydraulic erosion, or creation of impoundments by the trench backfill. Table 3-3 provides a summary of possible response actions to pipeline drainage and erosion problems. These measures have been formulated in cooperation with state and federal resource and regulatory agencies.

No harm to vegetation is anticipated due to routine operation and maintenance of the pipeline. Access for minor repairs will be via either rollagons or helicopters. The design plan for rehabilitation of the trench backfill is intended to eliminate the need for heavy equipment or significant volumes of additional backfill. Most of this work can be done by hand. Some ongoing restoration of the trench backfill will be required, particularly after the first summer thaw, and will mainly take place in August and September. Adjustments to the berm breaks, if required, will also be made at this time. This work, as well as work in subsequent years, will be performed when rollagon support can be used without harm to vegetation.

All pipeline isolation valves will have an adjacent gravel pad to allow for valve maintenance without harm to tundra. Any heavy equipment that might be needed for valve repairs could be transported using rollagons or be slung to the site with a heavy-lift helicopter.

Any planned pipeline repairs will be completed in winter from ice pads, if possible. Two options exist for repairs that are required at other times of year. During times when travel over the tundra is permitted, repairs would be supported by rollagons. Typical equipment for pipeline repairs include backhoes, a welding unit, short pipe sections, joint coating equipment, tools, and consumables. The backhoes could either be permanently welded to special rollagons or loaded onto the rollagon deck. Outriggers would need to be fitted onto the rollagons to support them for backhoe work. Wooden mats (40 feet by 8 feet) would be pinned together and laid on the tundra to minimize environmental disturbance. Any excavation would be performed with a hydraulic hoe ram in combination with a bucket hoe. These two hoes would be capable of any required work that could otherwise be done with a sideboom tractor. At times when tundra travel is prohibited, heavy-lift helicopters would be used to support repair work.

Minimal maintenance of river and stream crossings is expected. Gravel will be stockpiled on the valve pads in the event material is required for bank maintenance. Routine maintenance will be accomplished using small backhoes either mounted on or transported by rollagons. During breakup, equipment could be mobilized to the work area using heavy-lift helicopters. In a worst-case scenario, a temporary pipeline shutdown might be required until repairs could be performed.

TABLE 3-3
RESPONSE OPTIONS TO DRAINAGE CONTROL ALONG BADAMI PIPELINE TRENCH

CONDITION	METHOD	ACTIVITY	TIMING
Berm Break Fails			
Structure subsides	HL	Monitor; remove bags; add fill; replace/add bags	2
Structure perched - ponding	HL	Monitor; remove bags; remove fill; replace/add bags	3
Structure shifts-bag washout	HL	Monitor; recover washed out fill and replace; recover, replace and realign bags	3
Structure blocked - ponding	HL	Monitor; remove blockage (ice, fill, bags, etc.)	1
Berm Fails			
Washout	C	Monitor; recover washed out fill and replace, if necessary; evaluate need for berm break and install if necessary	3
Subsidence of berm - below tundra plane (ponding)	C	Monitor; add material to slightly above tundra plane; add sand bags if necessary	2
Subsidence of berm - below tundra plane (no ponding)	C	Monitor; add material to slightly above tundra plane	2
Subsidence of berm above tundra plane (ponding)	C	Monitor; remove material to other needed areas of trench	2
Subsidence of berm above tundra plane (no ponding)	C	Monitor; remove material to other needed areas of trench	2
Subsidence of berm - below tundra plane (flowing water within trench but thaw stable)	C	Monitor; evaluate; add sand bags to divert flow across trench if necessary; add material slightly above tundra plane	2
Subsidence of berm - below tundra plane (flowing water within trench and thaw instability results)	C	Monitor; evaluate; initiate repairs to replace select backfill and stabilize; replace backfill for revegetation	1
Berm Blocks Natural Drainage			
Ponding - no flow	C	Monitor; evaluate; add berm break, if necessary	3
Ponding - lateral flow (no erosion)	C	Monitor; evaluate; add berm break, if necessary	3
Ponding - lateral flow (erosion)	C	Monitor; evaluate; remove material to other needed areas of trench	2
Erosion			
Erosion downstream of berm break	C	Monitor; evaluate; monitor; restore and add material to area if necessary	3
Erosion along berm	C	Monitor; evaluate; monitor; restore and add material to area if necessary	3

HL: Hand labor (rakes, shovels, wheel barrows).
C: Combination of hand labor and light mechanized equipment.

1. Immediate
2. When accessible
3. When dry

4. AFFECTED ENVIRONMENT

The study area for the environmental assessment of the proposed Badami Development Project is located between the Endicott Access Road on the west side of the east channel of the Sagavanirktok River, and Bullen Point on the east side of Mikkelsen Bay (Figure 1-1). It extends from several miles offshore in Mikkelsen Bay to approximately 15 miles south of the coast.

4.1 CLIMATE

The study area is located in the arctic climatic zone, which has extremely cold winters and cool summers. Long-term National Weather Service climatological data are available for Barter Island (approximately 85 miles east of Badami) and for Point Barrow (about 200 miles west of Deadhorse). The mean annual temperature is 9.8°F at Barter Island, where it ranges from a mean maximum of 45.1°F during summer months to a mean minimum of -26.5°F during winter months. The prevailing wind direction is east-northeast, but winds at Barter Island have an east/west bimodal distribution. Annual wind speed averages 10 to 15 miles per hour (mph), but speeds ranging from 30 to 50 mph are common during winter storms. Fog occurs an average of 76 days annually at Barter Island, and occurs in the form of ice fog at temperatures below -20.4°F (U.S. Army Corps of Engineers, Alaska District and Environmental Research and Technology, Inc. 1984).

Summer weather data were collected at a nearshore coastal site as part of the Endicott Monitoring Program from 1985 through 1990 (Envirosphere 1987, 1990, 1992; SAIC 1993a, b, 1994). Sampling generally included the period from June through September, although additional data were collected during October in some years. Weather conditions at Endicott are similar to those for Barter Island and other sites along the Beaufort Sea coast. Winds are generally from the east or northeast, but shifts to west or northwest are common throughout the summer. Wind speed and direction at coastal sites were highly variable but not significantly different from that at a more inland site (i.e., Deadhorse airport). Temperatures during summer are also highly variable and tend to be higher inland than at coastal locations.

Weather data derived for BPXA's experimental ice pad at the Yukon Gold No. 1 wellsite (Hazen et al. 1993) about 20 miles southeast of Badami are representative of conditions that can be expected south of the coast, and data recorded at Barter Island are representative of conditions along the coast (Table 4-1). Since inland areas are warmer than coastal areas, the calculated mean maximum summer and winter temperatures are higher inland, and there is a longer thawing period.

Table 4-2 contains the estimated average monthly precipitation at Prudhoe Bay. Storm rainfall intensities are relatively low, primarily because thunderstorms are rare. The most severe rainfall has been associated with fall frontal-system storms originating in the Pacific and tracking north of the Aleutians. These storms are associated with winds from the southwest. Two-thirds of the annual precipitation falls as snow, and the 0.9-foot average snow depth recorded at Barter Island (Table 4-1) is representative of the study area.

4.2 GEOMORPHOLOGY

The study area is located within the physiographic province known as the Arctic Coastal Plain (Wahrhaftig 1965), except for the nearshore area in the immediate vicinity of the proposed dock, which would extend a short distance into the Littoral Zone. The Arctic Coastal Plain is typified by gentle topography, ice-bonded permafrost soils, wet tundra, and wind-oriented thaw lakes. The dominant feature of the onshore region is the perennially frozen ground known as permafrost. Permafrost extends almost to the ground surface except for thaw pockets, which are typically located beneath deep lakes and large river channels. Thaw depths under the tundra areas are commonly 1 to 2 feet at the end of the summer.

The temperature of the permafrost depends primarily on the depth below ground surface, the time of the year, the moisture content in the thawing or freezing active layer, the solar gain of the ground surface in the summer, and the thickness of insulating snow layers in the winter. Typical ground temperatures at depths of 25 feet vary from 10°F to 20°F. Temperature profiles available for Bullen Point, at the eastern side of Mikkelsen Bay about 6 miles from Badami, indicate that mid-November surface temperatures are approximately 15°F. Between the surface and 1 foot depth, the temperature may increase to more that 25°F, while below 1 foot the temperature declines and stabilizes at 15°F in the 4- to 5-foot-depth region (Shannon and Wilson 1991).

Because of the impermeable nature of the shallow permafrost table, drainage of the onshore region is poor. All water derived from rain and snow and from summer thaw of the near-surface soils accumulates above the permafrost table, resulting in formation of permafrost wetlands characteristic of the North Slope.

Wind-oriented thaw lakes dominate the landscape in the area west of the ancient Canning River alluvial fan, which starts at the southern limit of Mikkelsen Bay. The thaw-lake basins originate in areas of restricted drainage, where shallow ponding results in a warmer surface temperature that causes the underlying ground ice to thaw, resulting in subsidence. Most of the ponds and lakes are relatively shallow (less than 4 feet deep).

TABLE 4-1
CLIMATE DATA FOR YUKON GOLD ICE PAD AREA (INLAND) AND BARTER ISLAND (COASTAL)

	DERIVED YUKON GOLD ICE PAD AREA CLIMATE DATA*	RECORDED BARTER ISLAND CLIMATE DATA**
Average Air Temperature	11.0°F	14.2°F
Mean Maximum Air Temperature	46.5°F	45.1°F
Mean Minimum Air Temperature	-19.1°F	-26.5°F
Thawing Index	1025 F-days	570 F-days
Freezing Index	8620 °F-days	8400 °F-days
Length of Thawing Season	92 days	92 days
Average Snow Depth	0.5 feet	0.9 feet
Average Wind Speed	13.5 mph	13.3 mph

F-day: degree day above 32°F

°F-day: degree day below 32°F

*Hazen et al. 1993

**U.S. Army Corps of Engineers, Alaska District and Environmental Research and Technology, Inc., 1984

TABLE 4-2
ESTIMATED AVERAGE MONTHLY PRECIPITATION AT PRUDHOE BAY, ALASKA
(INCHES OF WATER)

MONTH	PRECIPITATION (INCHES OF WATER)
January	0.5
February	0.5
March	0.4
April	0.5
May	0.4
June	0.8
July	2.0
August	2.3
September	1.3
October	1.2
November	0.7
December	0.4
ANNUAL	11.0

Note: The most reliable measurements of precipitation are those made near Deadhorse by the U.S. Soil Conservation Service (SCS) with a Wyoming-type gauge, which enables measurement of blowing snow. The catch of precipitation by this gauge is roughly double the catch recorded by conventional rain gauges, due to the inability of the conventional gauges to measure snowfall in windy environments. The data presented in this table were derived by correlating the average monthly precipitation measured at the SCS gauge with the long-term monthly distribution of annual precipitation measured at Barrow.

The thaw lakes go through a cycle of development, expansion, drainage, and revegetation. Thaw lakes are uncommon on the Canning River fan east of the study area. Small beaded drainages that cross the alluvial fan indicate that ground ice is present, but the lack of thaw lakes suggests that the dominant soil type is coarser than the soils to the west.

Of the rivers crossing the study area, only the Sagavanirktok River appears to be large enough to have a significant thaw bulb beneath its channel. Brewer (1987) reported that temperature measurements beneath the Shaviovik River did not indicate any unfrozen zones, although the temperatures were about 5°F warmer than beneath adjacent well-drained tundra.

Soils beneath the tundra areas are expected to consist of a surficial layer of organic soil and silt, with sand and gravel at depth. The base of the silt is expected to be on the order of 10 to 15 feet below the tundra surface in the thaw lake areas and thinner in the Canning River fan. Large amounts of ground ice are expected from the permafrost table to the base of the siltier soils. The ground ice is predominantly wedge ice formed at the perimeters of polygons. The rivers are generally gravel-bottomed.

The Arctic Coastal Plain grades gently into the continental shelf of the Beaufort Sea. The average depth of the shelf is only 120 feet, and its width averages 44 miles (Sharma 1979). Waters of the continental shelf are ice-covered for about nine months of the year, with the ice-free period generally extending from mid-July until September. The nearshore zone lies between the beach and the offshore barrier islands and is typified by subtle seabed topography with gentle slopes. It is made up of a series of bays, lagoons, deltaic mudflats, and narrow barrier islands. Lunar tides are less than 1 foot. Because the water is shallow and there is little tidal amplitude, the movement of water in the coastal Beaufort Sea is predominantly wind-driven. Summer winds are typically easterly, but are variable and can change quickly. The largest water level variations are due to wind-driven surges originating from westerly storms during the end of the open-water season. The beach line is generally retreating due to the effects of storm surges and associated erosion of the onshore permafrost.

To develop an historical perspective on the dynamics of coastal processes in Mikkelsen Bay, aerial photographs of the shoreline taken from 1948 to 1993 were examined. The shoreline geomorphology is remarkably stable for a coastline that is typically characterized as erosional. Observations from the last 40 years indicate that there are no significant geomorphological changes in the shoreline at the site of the proposed docking structure. Immediately to the west, an accretionary spit has slowly lengthened during the period, and the exposed waveforms at the tip of the spit suggest the accretion is generated by storm activity. The growth of the spit indicates sediment transport is from the east to the west, which corresponds to the prevailing sediment drift observed at many locations along this coastline (e.g., Hearn and Robb, 1991). The accretionary spit growth is quite slow and presently is at or near equilibrium. This indicates that there is only a small volume of sediment being moved along the shore. The shoreline at the proposed site is tundra with a narrow sand beach separating the 3-foot-high tundra bluff from the water. Log drift debris found on the top of the bluff indicates that the bluff is exposed to storm action.

Reimnitz and Maurer (1979) mapped the driftwood strand lines from a 1970 storm and concluded that the storm surge reached levels of 5 to 11 feet above mean sea level and exceeded any prior levels that had occurred in the previous 90 to 100 years. The highest levels of storm surge occurred at the end of shallow embayments that were open to the westerly winds.

The Littoral Zone is underlain by relict permafrost that remains after the retreat of the coastline. The offshore permafrost can contain ice-bonded sediments beneath the surface mantle of Holocene deltaic and lagoonal sediments.

4.3 OCEANOGRAPHY OF MIKKELSEN BAY

The proposed dock would originate onshore at the proposed Badami Development wellsite and extend north approximately 2,400 feet into Mikkelsen Bay. The dock terminus would be near the 3- to 4-meter (~10 to 12-foot) isobath.

Mikkelsen Bay is a 6.6-mile-long embayment on the Beaufort coast, flanked on the west by Tigvariak Island and on the east by Bullen Point (Figure 1-1). The seaward limit of the bay is marked approximately by the 5-meter (~17-foot) isobath, which lies about 3 miles from the shore for much of the bay. In the eastern half of the bay, the sea floor near shore is relatively steep, such that the 3-meter (~10-foot) isobath is less than about one-half mile from shore. Northward from that depth, the sea floor is generally flat and slopes gradually to the bay mouth. The sea floor in the western half of the bay is somewhat irregular, with steepest bottom slopes between the 2- and 3-meter (~6.6- to 10-foot) isobaths. At the west end of the bay, a half-mile-wide, but shallow (<1 meter [<~3.3 feet]), channel separates Tigvariak Island from the mainland. Distributaries of the Shaviovik River appear to discharge mostly to the west of this channel. The discharge of the Shaviovik River is seasonal, annually averaging 800 cubic feet per second, with discharge ceasing in late fall as the river freezes (AEIDC 1974).

Very little information is available on oceanography specific to Mikkelsen Bay or adjacent waters (AOGA 1988). During 1985–1989, the oceanography component of the Endicott Environmental Monitoring Program included periodic hydrographic transects as far east as the middle of Foggy Island Bay, approximately 12 miles west of the proposed Badami dock (Envirosphere 1987, 1990, 1991; SAIC 1993a, b). These data can be used for deducing the oceanographic conditions in Mikkelsen Bay, which, because of its setting, is somewhat analogous to Foggy Island Bay. A single hydrographic transect across Foggy Island Bay obtained by Thorsteinson et al. (1991) in August 1990 provides limited data for the area.

As with most locations along the Beaufort coast, the hydrography of Mikkelsen Bay at any time during the open-water season is a function of recent wind history, regional oceanographic processes, and the freshwater input from nearby rivers and streams (Barnes et al. 1984, Colonell and Niedoroda 1993). The major fresh water input to the Beaufort Sea coastal region occurs when the rivers break up and begin to overflow the sea ice (late May to early June). By mid-July, when the sea ice breaks up and withdraws from coastal waters, large volumes of river water remain in coastal areas adjacent to the river mouths. Melting of the sea ice provides a very large influx of nearly fresh water along the entire coastline.

In addition to sea ice melt, sources of fresh water that directly influence the hydrography of Mikkelsen Bay include two or three small tundra streams that drain into the bay, and the Shaviovik River at the west end of the bay. Winds tend to be either easterly or westerly for 80 to 90 percent of the time. Under westerly winds, some influx of fresh water to Mikkelsen Bay from the Shaviovik River might be expected but, because the delta area between the mainland and the south shore of Tigvariak Island is so shallow (<1 meter [<~3.3 feet]), it is unlikely that any significant portion of the Shaviovik River flow actually enters Mikkelsen Bay. In fact, Tigvariak Island might more appropriately be termed a peninsula, because of its probable effectiveness in blocking alongshore movements of water and sediment. The small tundra streams, although usually benign, occasionally become swollen with runoff due to intense summer rainstorms that can occur at virtually any time during the summer. When this happens, these streams can contribute large but fairly transient quantities of fresh water to the bay.

Beyond the limits of Mikkelsen Bay, the Sagavanirktok River, some 18 miles to the west, and the Canning River, about 24 miles to the east, are possible sources of fresh water for the bay. The Sagavanirktok, which is closer and has an annual average flow more than twice that of the Canning, is the more likely to have an effect on Mikkelsen Bay. Persistent westerly or northwesterly winds can transport Sagavanirktok River water as far east as Tigvariak Island and beyond; however, dilution by marine water will reduce significantly the effect of any such transport on Mikkelsen Bay. Under easterly winds, Canning River water will be so diluted by marine water that its influence on Mikkelsen Bay salinity will not likely be measurable.

The early-summer salinity of the bay probably depends only on the salinity and thickness of the sea ice just melted and the winter salinity of nearshore Beaufort Sea water (~34 parts per thousand, ppt). Assuming that the bay is virtually isolated from the adjacent Beaufort Sea at the 5-meter (~17-foot) isobath by the combined effects of Tigvariak Island and Bullen Point, the volume and surface area of the bay are approximately 137 million cubic meters (~4.8 billion cubic feet) and 55 million square meters (~592 million square feet, or 13,580 acres), respectively. For an average sea ice thickness of 5 feet and salinity of 5 ppt (Michel 1978), the early-summer salinity of the bay can be estimated as approximately 19 ppt.

Light to brisk variable winds will serve to thoroughly mix the shallow water column. Persistent west winds could serve to freshen coastal waters around Mikkelsen Bay as much as 5 to 10 ppt if they coincided with a period of high Sagavanirktok River flows. Otherwise, westerly winds are likely to make Mikkelsen Bay water saltier. Winds from the west, northwest, and north will transport surface waters onshore in the vicinity of Mikkelsen Bay, causing nearshore areas to have salinities typical of those offshore, which are generally greater than 25 ppt by mid-summer. Strong northeast and east to southeast winds will produce upwelling of bottom water that is relatively cold (<2°C [<35.6°F]) and saline (>32 ppt). If winds are sufficiently strong and persistent, this upwelling can surface in depths as shallow as 1 to 2 meters (<~3.3 to 6.6 feet) (Colonell and Niedoroda 1993). When such upwelling events occur, embayments that have little fresh water influx can become virtually marine for the rest of the open-water season.

Thus, the single most important factor in determining the hydrographic character of Mikkelsen Bay (and most other locations on the Beaufort Sea coast) is the wind history for the summer season. Early to mid-summer winds are typically light to brisk easterlies, with occasional brief reversals to light winds from other directions. Strong westerlies early in the season are unusual, making the coincidence of high Sagavanirktok River discharge with west winds an uncommon event. It is reasonable to expect that salinities in Mikkelsen Bay will be about 20 ppt in early summer, increasing gradually to fully marine salinities (30 to 34 ppt) by the end of summer. Occasional freshening of surface waters will occur due to occasional rainstorms and brisk west winds driving small amounts of Shaviovik River water into the west end of the bay. If strong east winds occur before the end of summer, the salinity of the bay might rise abruptly to nearly marine levels, where it would likely remain for the rest of the summer. If the open-water season is unusually calm, with no major wind events, the bay salinity is likely to hover about its initial value until late summer (late August - early September), when there is almost always a period of high winds. Late-season high wind events are generally responsible for making the nearshore Beaufort Sea fully marine.

In the summer of 1994, six hydrographic surveys were conducted in Mikkelsen Bay at approximately weekly intervals from 21 July through 26 August (Woodward-Clyde Consultants 1994). Each of these surveys consisted of the measurement of vertical profiles of temperature and salinity at four or five stations along at least four north-south transects parallel to the proposed dock alignment. Table 4-3 provides a summary of the data, which support the above discussion of the hydrography of Mikkelsen Bay.

The most notable characteristic of the data set from the surveys is its indication of a remarkable uniformity of hydrographic conditions. Vertical profiles of both temperature and salinity were generally uniform, with variations within the water column rarely being more than 0.5°C to 1.0°C (0.9°F to 1.8°F) or 1 to 2 ppt, respectively. Such variations are not large for Beaufort Sea coastal waters, where variations of 2°C to 4°C (3.6°F to 7.2°F) and 5 to 10 ppt are often observed in depths as shallow as 2 to 3 meters (~6.6 to

TABLE 4-3
SUMMARY OF TEMPERATURE AND SALINITY MEASUREMENTS FROM 1994 HYDROGRAPHIC SURVEYS IN MIKKELSEN BAY

			TEMPERATURE (°C)				SALINITY (PPT)			
SURVEY DATE	# STATIONS	# T/S OBS.	MAX.	MIN.	AVG.	STD. DEV.	MAX.	MIN.	AVG.	STD. DEV.
21 July	22	138	8.5	4.0	5.8	1.2	20.0	16.0	18.4	0.8
29 July	18	111	10.5	6.0	8.1	1.2	19.5	18.0	18.5	0.4
5 Aug	18	107	9.0	4.3	5.9	1.2	24.8	20.5	22.7	0.9
12 Aug	18	118	12.0	7.3	9.5	1.1	24.0	17.5	21.5	1.1
20 Aug	18	118	10.0	8.0	9.6	0.5	24.0	20.0	22.0	0.6
26 Aug	18	111	8.5	6.0	7.5	0.6	20.0	12.0	16.9	1.8

Source: Woodward-Clyde Consultants 1994

10 feet) (e.g., Mangarella et al. 1982; Savoie and Wilson 1983, 1984, 1986; Hale 1990; SAIC 1993a, b; Colonell and Niedoroda 1993).

Proceeding offshore along the individual transects, there was the expected decrease in water temperature as depth increased; however, salinities tended to be horizontally uniform along each transect, within 1 to 2 ppt, even to distances of a mile or more from shore. In directions roughly parallel to the shoreline, and along isobaths, there were no evident gradients of temperature or salinity that would indicate the presence of significant localized sources of fresh or marine water.

The uniformity of the hydrographic data set is further illustrated in Table 4-3. While the maximum and minimum values of temperature and salinity occasionally differed by as much as 5°C (9°F) and 8 ppt within a single survey, the standard deviations about the means were rather small, ranging from 0.5 to 1.2°C (0.9°F to 2.2°F) and 0.4 to 1.8 ppt, respectively.

Exceptions to these general observations occurred during the final survey (26 August) for which the average salinity (16.9 ppt) was lower by 2 to 5 ppt than that for all five prior surveys. Also, the largest standard deviation in the salinity data (1.8 ppt) was observed during this survey. This "freshening" of Mikkelsen Bay is believed to reflect the influx of runoff from a rainstorm that occurred several days prior to the survey.

Significant wind events are required to promote the mid- to late-summer mixing of marine water into the coastal zone (Colonell and Niedoroda 1993). The lack of trends in the temperature and salinity data from the surveys suggests that during the six-week surveillance of Mikkelsen Bay, the climatic factors that produce the usual patterns were absent; that is, the weather remained unseasonably warm through August, and the major wind events that usually serve to mix cold, salty marine water into the coastal zone did not occur within the observation period.

The persistent homogeneous condition of the bay for the first five weeks of surveillance indicates that there is no significant freshwater source to reduce salinity, other than the observed freshening by runoff from the occasional rainstorm. While Mikkelsen Bay did not reach a fully marine condition by the end of August, this is believed attributable to the lack of wind events necessary to promote mixing of marine water into the bay before that time.

4.4 HYDROLOGY

Major rivers crossing the study area are the Sagavanirktok, Kadleroshilik, Shaviovik, and No Name. The No Name River originates in the lower foothills of the Brooks Range, and the Kadleroshilik River originates in the higher foothills. The Sagavanirktok and the Shaviovik rivers head in the Brooks Range. Characteristics of these rivers are:

- Steep slopes at the headwaters and stream channel braiding at high flows;
- Decreasing stream gradients toward the coast and deposition of sediment load;
- Relatively broad and shallow stream cross-sections, except where local scour occurs;
- Extremely peaked runoff hydrographs, due to accumulation of snow and ice and subsequent ponding of meltwater, which results in snowmelt flooding, generally during the first week in June; and
- High erosion during summer floods, resulting from unusually large rainstorms in the Brooks Range and occurring when the bed and banks are thawed.

4.4.1 Drainage and Erosion

The entire Arctic Coastal Plain is poorly drained, due to the shallow depth to permafrost and the low slope of the terrain. Most streams in the study area originating on the coastal plain are poorly developed because the frozen ground resists erosion. Small drainages form when near-surface ground ice melts, normally along ice-wedge polygon boundaries. Drainage channels are not formed by erosion of soil material, but by subsidence of soils due to the melting of ground ice. As the drainage channels join and grow larger toward the coast, they develop the capacity to erode their bed and banks, and to transport sand and gravel. Arctic coastal streams of all sizes do not exhibit the regular and predictable forms of temperate zone streams. Lateral erosion of the banks of small streams is restricted by frozen ground. Rivers originating in the Brooks Range and foothills occupy beds of outwashed sands and gravels, and are thus relatively free to erode and deposit so as to adjust their own boundaries. However, lateral erosion of even the largest rivers is restricted by the adjacent permafrost terraces. Erosion of frozen banks is a process of thermal nitching (which is the undercutting of blocks of frozen soil), followed by slumping of the blocks into the stream (Scott 1978).

4.4.2 Snowmelt Floods

During the long winter, an average of about 5 inches of water falls in the form of snow, which is moved by the wind and forms drifts; a substantial portion of the precipitation is lost to evaporation. For small drainages in the study area, an average of 3 inches of water generally remains on the ground to form snowmelt runoff. Because of the transport of snow by drifting, the actual amount available in a particular small drainage can vary widely, depending on the ability of the local relief to create snowdrifts. During snowmelt, the first runoff occurs as sheet flow over the ground surface; and because the ground is frozen, infiltration is practically nonexistent. When breakup commences, the first snowmelt runs over the frozen surface of small streams and ponds behind snowdrifts. As breakup progresses, these small drifts thaw or are overtopped, and the accumulated meltwater is released to flow downstream until it again ponds behind a larger snowdrift in a larger stream or river. The storage and release process results in an extremely peaked runoff hydrograph. As a result, flow during breakup is both unsteady and nonuniform, and snowmelt floods occur every year.

Once the breakup crest has passed a particular point on a stream, the recession is rapid. Typically, the flow on a small stream two weeks after the breakup crest will be less than 1 percent of the peak flow, and the smallest drainages will be completely dry within two weeks. During breakup the bed and banks of small drainages tend to remain frozen, and erosion is limited.

4.4.3 Rainfall Floods

Summer floods are not anticipated to occur on the smaller Arctic Coastal Plain streams within the study area. Similar small streams have not produced floods because the rainfall intensity is low, the tundra and thaw lakes have a large capacity to absorb and retard runoff, and snow does not accumulate in snowdrifts. However, summer floods resulting from unusually large rainstorms in the Brooks Range occur on rivers originating in the Brooks Range, such as the Sagavanirktok. These floods are not frequent but may be larger than the breakup floods. Summer floods occur when the bed and banks are thawed, and erosion is not limited by frozen ground.

4.4.4 Snow and Ice Blockages

During the winter, sheets of ice form on streams that sustain winter flow, and smaller streams that are normally dry in winter become blocked by snowdrifts. These winter snow and ice blockages play three important roles during breakup. The first role is the collection and release of runoff, with the increased peak rate of discharge previously described. The second role is decreasing the channel area available to convey water, thus increasing the stage (or height) for a given discharge. This increased stage causes more area to be flooded and is also responsible for the third role, diversion of flow between adjacent stream channels.

4.4.5 Flood Timing

Floods on small streams have historically occurred solely as the result of snowmelt, which responds to the rapid seasonal increase in temperatures. As a result, snowmelt floods on a given stream tend to occur at about the same time each year. Rivers originating in the Brooks Range flood during the first week of June, while small Arctic Coastal Plain streams crest about one week later than the large rivers. Largest floods tend to be associated with later breakups. Small streams very close to the coast are the last to break up.

4.4.6 Description of Major Streams

The ***Sagavanirktok River*** is 180 miles long and has a drainage area of 5,600 square miles. The portion traversing the study area consists of an alluvial delta. Although long-term discharge data are not available for this area, discharge data have been obtained for several years during breakup (Table 4-4). Short-term records indicate that during breakup, the east channel carries about 50 percent and the west channel conveys about 40 percent of the flood flows. The remaining 10 percent of flood flows is believed to be distributed between a central and several small channels. Bed material ranges from coarse gravels and small cobbles near Deadhorse to sands and silts at the mouth. Armoring by gravel provides channel stability. Ice jams are unusual because most of the ice is bottomfast at breakup, and the initial flow is over the top. Storm tides associated with westerly winds frequently flood the lower portions of the delta; however, storm-tide effects have not been observed above the existing bridges on the west channel.

Discharge from the Sagavanirktok River was measured as part of the Endicott Monitoring Program from 1985 through 1993 (Envirosphere 1987, 1990, 1992; LGL 1994; SAIC 1993a, b, 1994). SAIC (1994) summarized the 1985-92 data, as well as additional 1982 data from the U.S. Geological Survey gauging station located near Pump Station 3 of the Trans-Alaska Pipeline System. For the seven-year period (1982, 1985–1990), the mean seasonal daily average discharge during summer (25 June through 14 September) ranged from a low of 176 cubic meters per second (6,211 cubic feet per second, cfs) in 1985 to a high of 333 cubic meters per second (11,751 cfs) in 1987. Percent of daily average flow ranged from 37 to 53 percent (mean 47 percent) for the main east channel and between 44 and 61 percent (mean 50 percent) for the west channel. The remainder of the flow (approximately 3 percent) was through a minor east channel that discharges into Foggy Island Bay. Channel shifts generally occur during high summer flows.

The ***Kadleroshilik River***, which is 65 miles long, has a drainage area of 500 square miles and a bed of fine to medium gravel. Sediment transport rates are relatively low, as demonstrated by the lack of a delta or islands at the mouth. Oxbow lakes are common features of the floodplain. Because the river does not originate in the Brooks Range, large summer floods are probably rare.

The ***Shaviovik River***, from its headwaters in Juniper Creek to the coast, is about 100 miles long and, with its major tributary the Kavik River, has a drainage area of about 1,740 square miles. Deposition of material has formed a delta with several distributaries

TABLE 4-4
SUMMARY OF ESTIMATED FLOOD DISCHARGE PROBABILITIES FOR THE SAGAVANIRKTOK RIVER
(cubic feet per second)

AVG RECURRENCE INTERVAL * (YRS)	ANNUAL DISCHARGE	PEAK BREAKUP DISCHARGE	PEAK SUMMER DISCHARGE
2	41,500	31,900	36,400
5	60,900	48,100	56,500
10	76,800	59,100	71,200
20	92,500	71,200	86,100
25	98,100	75,000	91,000
50	117,000	86,900	107,000
100	137,000	99,300	123,000

* Short-term stage and discharge measurements obtained near the mouth of the Sagavanirktok River were correlated with available long-term U.S. Geological Survey data collected upstream of the confluence with its major tributary, the Ivishak River, to calculate estimated annual and peak flood magnitudes for selected return intervals (McDonald 1984).

in the lower 5 miles of the river. Most of the flow from the Shaviovik River appears to discharge into Foggy Island Bay, west of Tigvariak Island. Upstream of the delta, the river has a braided, meandering channel, with low banks and broad floodplains consisting of gravel terraces.

The ***No Name River*** is 42 miles long and has a drainage area of 147 square miles. The river has a bed of medium-sized gravel. Sediment transport rates are relatively low, as demonstrated by the lack of a delta or islands at the mouth.

4.4.7 Description of Small Tundra Streams

Streams within the Badami area are primarily tundra streams (Craig and McCart 1975), which are generally small, meandering streams 30 to 65 kilometers (~20 to 40 miles) long that drain into larger streams or the Beaufort Sea. For the most part, they are confined to a single channel, although the largest tundra streams may have braided channels. Many tundra streams are beaded, i.e., they consist of a series of small ponds interconnected by short, narrow stream segments. During spring flooding, banks often overflow with runoff which is moderated by the surrounding tundra, lakes, ponds, and marshy areas. Tundra streams are usually acidic (pH 6.5 to 8.5), have low conductivity and calcium levels, and often are stained yellow-brown from the surrounding peat (Craig and McCart 1975).

Some of the tundra streams in the Badami study area were the subject of a survey by the Alaska Department of Fish and Game in the summer of 1994 (Hemming and Ott 1994). Near the East Channel of the Sagavanirkok River, the route crosses two beaded streams, one of which has two branches. West of the Kadleroshilik River, the route crosses another beaded tundra stream. Finally, the route crosses a west tributary of the Shaviovik River and two branches of "West Badami Creek," a coastal tundra stream that drains into the estuary adjacent to the Badami site.

4.5 WATER QUALITY

4.5.1 Fresh Water

North Slope rivers have been sampled by the U.S. Geological Survey (Feulner et al. 1971, Kemnitz et al. 1993) and are characterized by low dissolved solids, with concentrations less than 120 milligrams per liter (mg/l). The Sagavanirktok River was sampled during 1985 as part of the Endicott Monitoring Program (Envirosphere 1987). Total suspended solids ranged from 0.2 to 30.0 mg/l, and turbidity ranged from 0.4 to 24.0 NTU (nephelometric turbidity units). Maximum values were associated with mid-season peaks in discharge following large rainfall events, while low values corresponded to low flow periods later in the summer season.

Water temperatures in the Sagavanirktok River exhibit a seasonal pattern of general warming in June and July followed by cooling during August through mid-September (SAIC 1994). Ranges of monthly averages for a six-year period (1985-1990) were as follows:

June:	7.6°C to 13.1°C (45.7°F to 55.6°F)
July:	9.9°C to 13.3°C (49.8°F to 55.9°F)
August:	6.8°C to 11.6°C (44.2°F to 52.9°F)
September:	2.5°C to 6.7°C (36.5°F to 44°F)

Based on 14 years of data, the mean date when the Sagavanirktok Delta is frozen in (used as a milestone to indicate the Sagavanirktok River was also frozen in) is 12 October (range 1–25 October) (SAIC 1994).

4.5.2 Marine Water

Marine waters are generally cold (30°F to 37°F) and saline (27 to 32 ppt) (Craig 1984). During the summer months, the nearshore region is characterized by an area of relatively warm (41°F to 50°F), turbid, and often brackish (<20 ppt) water. This estuarine zone extends over much of the length of the Beaufort Sea coast. Temperature and salinity within the nearshore zone are strongly influenced by the direction and speed of prevailing summer winds, as well as by discharge of fresh water from coastal river systems and proximity of ice. The water in this shallow nearshore area is subject to frequent and dramatic shifts in temperature and salinity due to shifts in wind speed and direction. These changes are evident during the open water season from breakup, when the nearshore area is fresh (0 ppt) and generally warm, to just prior to freeze-up, when waters are generally saline (>30 ppt) and cold. These conditions result in a highly variable and constantly changing environment for the fish that use the nearshore area for feeding and movements during summer. Because the discharge from North Slope rivers between the Sagavanirktok and Canning rivers is relatively small, the width of the estuarine band is generally narrower in this region than in the area west of the Sagavanirktok River and east of the Canning River (Craig 1984).

4.6 VEGETATION AND WETLANDS

The Badami study area is within what has been termed a gently rolling thaw-lake plain landscape (Walker and Acevedo 1987). Since tundra in the area gradually rises 20 to 25 feet above the level of streams and river channels, the landscape has a gently rolling appearance. Many areas are well-drained because of this topographic relief, and hence moist and dry tundra vegetation types are common throughout the area, typically on terrain with high-centered ice-wedge polygons. Drainage is poor, however, away from fluvial gradients; and in these wetter areas, low-centered ice-wedge polygons, strangmoor, thaw-lakes and ponds, and drained lake basins are common. Wet tundra vegetation types predominate in many of these areas.

There are currently two types of wetlands maps available between the east channel of the Sagavanirktok River and the Badami project area. As part of the environmental assessment process for the Badami project, LGL Alaska Research Associates, Inc. (LGL) and AeroMap, U.S., Inc. prepared a vegetation/land cover map at a scale of 1 inch = 500 feet that covered the area between the Shaviovik River and "East Badami Creek." This detailed mapping is intended to assist in project design and impact assessment in that part of the project area subject to the greatest level of facilities construction. In addition to the vegetation mapping prepared for this project, LGL also used existing National Wetlands Inventory (NWI) maps prepared by the U.S. Fish and Wildlife Service (Cowardin et al. 1979) at a scale of 1:63,360 (1 inch = 1 mile). These maps provide coverage for the entire North Slope and were used to assess potential impacts to wetlands along the proposed pipeline corridor between the Badami development site and the Endicott sales oil line located west of the east channel of the Sagavanirktok River. Aeromap, U.S., Inc. prepared an overlay of the finalized buried pipeline route scaled to fit NWI maps at 1:63,360. This overlay was used by LGL to assess wetland types along the pipeline route. The wetland classes along the route were measured at an accuracy of 1/60 inch, or 0.017 mile (89 feet). Wetland categories and vegetation map equivalents are described in Table 4-5.

The vegetation/land cover map (Figure 4-1) includes the area surrounding the proposed wellsite and extends about 5 miles westward to the No Name River (Figure 4-2 shows the Badami facilities superimposed on the wetlands map for the wellsite vicinity). The area included in Figure 4-1 is characterized by large expanses of moist sedge and dwarf shrub dominated tundra (primarily *Carex*, *Eriophorum*, and *Salix* spp.) which are interrupted by areas of drier, well-drained tundra, clusters of frost boils, thaw-lakes and ponds, drained lake basins, and several streams. Along the coast, eroding bluffs and sand beaches alternate with lower tundra areas which receive occasional saltwater intrusions, as well as small areas of sand dunes, sandy spits, and estuarine areas at the mouths of streams. The drier, well-drained (and acid-tolerant) vegetation typically occurs both on tundra plateaus above streams, and at the margins of drained lake basins, but it also occurs in smaller patches throughout the map area where drainage is good (often among clusters of ponds and lakes). Large aggregations of frost boils are particularly common in the southeast portion of the map area. Thaw-lakes and ponds are scattered throughout the area, and these often support emergent vegetation (dominated by *Arctophila fulva* and *Carex aquatilis*) in the shallow water margins, especially in lakes and ponds with complex, irregular shorelines. Drained lake basins occur throughout the map area and are characterized by non-patterned ground, low-centered ice-wedge polygons, and strangmoor in complexes with smaller thaw-lakes and ponds within the basins. These areas are dominated by wet sedge tundra. Clusters of small ponds and extensively

TABLE 4-5
DEFINITION OF WETLAND NWI MAP CODES AND EQUIVALENT WALKER (1983) CATEGORIES FOR WETLAND TYPES CROSSED BY THE PROPOSED BADAMI PIPELINE ROUTE

TYPE	NWI DESCRIPTION [1]	WALKER (1983) EQUIVALENTS
	Estuarine (E) System	
E1OWL	Subtidal, open water, subtidal	Ia. Water
	Riverine (R) System	
R2OW/EM2H	Lower perennial, open water/emergent, nonpersistant, permanently flooded	IIb. Aquatic Graminoid Tundra
R2OWH	Lower perennial, open water, permanently flooded	Ia. Water
R2US/OW	Lower perennial, unconsolidated shore/open water	Ia. Water
	Palustrine (P) System	
PEM1B	Emergent, persistent, saturated	IVa, Va, Ve. Moist Sedge or Graminoid Tundra
PEM1E	Emergent, persistent, seasonally flooded/saturated	IIIa, IIIc, IIId. Wet Sedge or Graminoid Tundra
PEM1F	Emergent, persistent, semipermanently flooded	IIb, IId. Aquatic Graminoid Tundra, Pond Complexes
PEM1/OWH	Emergent, persistent/open water, semipermanently flooded	IIb, IId. Aquatic Graminoid Tundra, Pond Complexes
PEM/SS1A	Emergent, persistent/scrub shrub, broad leaved deciduous, temporarily flooded	IXb. Dry Barren/Dwarf Shrub, Forb Grass Complex
PEM/SS1B	Emergent, persistent/scrub shrub, broad-leaved deciduous, saturated	IVa, Va, Ve. Moist/Wet, Moist or Dry Sedge/Dwarf Shrub Tundra
PEM/SS1E	Emergent, persistent/scrub shrub, broad-leaved deciduous, seasonally flooded/saturated	IIIa, IVa. Wet or Moist/Wet Sedge/Dwarf Shrub Tundra
PEM1/USB	Emergent, persistent/unconsolidated shore, saturated	IIIa, IIIc, IIId. Wet Sedge or Graminoid Tundra
POWH	Open water (less than 20 acres), permanently flooded	Ia. Water
U	Upland	Vc, Vd, Dry Dwarf Shrub Tundra

1. National Wetlands Inventory, U.S. Fish and Wildlife Service, Cowardin et al. (1979)

NOTE: The pipeline route is generally located in the shaded types.

thermokarsted polygon troughs often occur over broad areas within a matrix of mixed moist and wet tundra. These areas are characterized by mixed high- and low-centered ice-wedge polygons and strangmoor. Along the streams are both typical wet and moist tundra types (on terraces), as well as dry, partially vegetated gravel bars and mostly barren gravels in active channels. The mouth of "West Badami Creek" supports wet, arctic saltmarsh vegetation, and the mouths of the two larger streams in the map area support a complex mix of wet arctic saltmarsh vegetation, drier coastal barrens, salt-killed tundra, typical moist and wet tundra, and dry, partially vegetated gravel bars. Vascular-plant species diversity is highest in the drier tundra habitats, especially in gravel bar areas.

The vegetation in the Badami area was classified and mapped from natural-color aerial photographs. This vegetation mapping effort was conducted primarily to delineate wetland vegetation types which serve as preferred habitat for wildlife, specifically waterbirds.

Vegetation was classified using a hierarchical scheme designed specifically for the North Slope of Alaska (Walker 1983). This scheme was selected because it is commonly used by the U.S. Fish and Wildlife Service to delimit habitats important to waterbirds on the North Slope. In addition, because of its hierarchical nature, this scheme allows vegetation to be classified at various map scales and facilitates direct comparisons with vegetation maps of other parts of the North Slope. For example, Walker's (1983) classification scheme was used to map a large portion of the vegetation of the coastal plain in the Arctic National Wildlife Refuge (Walker et al. 1982, Walker and Webber 1983) at a 1:250,000 scale (1 inch = 4 miles), and a modified version of the classification scheme was also used to map the U.S. Geological Survey (USGS) Beechey Point Quadrangle, encompassing the Prudhoe Bay area, at a 1:63,360 scale (1 inch = 1 mile) (Walker and Acevedo 1987).

Walker's (1983) vegetation and land cover classification scheme involves categorizing sites with respect to site moisture regime and dominant plant growth forms (and landform type when plant cover is very sparse or non-existent). The site moisture terms (*dry, moist, wet,* or *aquatic*) are subjective terms based on the soil moisture at the end of the growing season. Dominant plant growth forms are relatively straightforward and are dependent to a great degree on the site moisture regime and landform type. Many areas on the North Slope consist of complexes of landforms which result in complexes of site moisture and vegetation types. In areas such as these, the classification scheme calls for combining site moisture and plant growth form terms to more accurately describe the character of the area.

The vegetation of the Badami area was mapped using a series of 1:6000 (1 inch = 500 feet) photo enlargements of 1:18,000 (1 inch = 1500 feet) natural-color aerial photographs taken on 1 July 1993. A preliminary map was made without ground reference data, and the map was revised when ground reference data were acquired in August 1994. Map units delimiting the vegetation types were drawn by hand on acetate overlays placed on top of the photos, fitted to a topographic map (base map) of the area by matching water bodies and coastlines, and then digitized. A combination of the 1955 USGS topographic map of the area and a new (1994) digital topographic map produced by AeroMap U.S., Inc. covering most of the coastal portion of the Badami area was used as the base map for the vegetation/land cover map. Map units were assigned colors depicting vegetation types at Level B in Walker's (1983) hierarchical vegetation classification scheme (see Figure 4-1 legend and Table 4-6). Actual vegetation types were mapped and labeled at a finer resolution, Level C; but for clarity, map colors were assigned only at Level B. The exceptions to this were in the cases of saline-influenced areas along the coast. The two types of wet saltmarsh vegetation which occur separately in the wet tundra and partially vegetated Level B categories were assigned the same map color to make these important habitats easily identifiable on the map. Similarly, two categories of partially vegetated coastal sites were given colors in order to distinguish them from partially vegetated riparian areas which share the same (partially vegetated) Level B category.

Ground reference data for the vegetation/land cover map were collected during 6-9 August 1994. A total of 133 points in the Badami area were visited; and vegetation, site moisture regime, and landform data were recorded. Species lists of the dominant vascular plants were also recorded at representative sites. Aerial photos of the area were taken to the field, and a concerted effort was made to record data for each of the vegetation/land cover categories represented on the preliminary map of the area and to evaluate those vegetation and land cover types which were not clearly identifiable on the aerial photos. Many of these data points were clustered around the immediate area proposed for development, but areas of questionable designation on the preliminary vegetation/land cover map were also visited. Because field work was conducted on foot and because the mapped area is rather large, not all vegetation types could be visited (2 of 22 vegetation/land cover units were not visited). These ground reference data indicated errors in the preliminary vegetation/land cover map and necessitated significant changes. Based on available ground-reference data and the aerial photos used to produce the preliminary map, all vegetation classifications on the map were reevaluated and all map units redrawn on the topographic map base.

Table 4-6 lists the hierarchical vegetation and land cover categories for the Badami area vegetation/land cover map. Vegetation types were mapped at Level C. Twenty-one Level C categories were identified on the photos of the Badami area. Coastal beach sand/gravel was delimited as a 22nd category, since this land cover type had no equivalent in Walker's (1983) classification system.

Away from the immediate coast, those map units classified as I, II or III are probably the most important for waterfowl and shorebirds (Troy 1992). These include lake margins, shallow ponds with or without emergent vegetation, pond/tundra complexes, areas of aquatic graminoid tundra, and areas of wet sedge tundra. These are

TABLE 4-6
HIERARCHICAL VEGETATION CATEGORIES FOR THE BADAMI AREA VEGETATION/LAND COVER MAP (FIGURE 4-1)

(Walker's [1983] vegetation classification scheme was used. Types were mapped at Level C).

LEVEL A SMALL-SCALE UNITS	LEVEL B LANDSAT-SCALE UNITS	LEVEL C PHOTO-INTERPRETED MAP UNITS	LEVEL D TYPICAL PLANT COMMUNITIES
A. Water	I. Water	Ia. Water (ponds, lakes, rivers, streams, saltwater)	No vegetation
B. Wet Tundra	II. Very Wet Tundra	IIb. Aquatic Graminoid Tundra (emergent vegetation)	Aquatic *Arctophila fulva* Grass Tundra Aquatic *Carex aquatilis* Sedge Tundra
		IId. Water/Tundra Complex (pond complex with emergent vegetation)	Typical communities listed in IIb, IIIa, and Va
	III. Wet Tundra	IIIa. Wet Sedge Tundra	Wet *Carex aquatilis, Scorpidium scorpioides* Sedge Tundra (wettest facies of wet alkaline tundra) Wet *Carex aquatilis, Eriophorum angustifolium, Pedicularis sudetica, Drepanocladus brevifolius* Sedge Tundra (wet alkaline tundra) Wet *Eriophorum angustifolium, Dupontia fisheri, Campylium stellatum* Graminoid Tundra (wet acidic tundra, coastal areas)
		IIIb. Wet Graminoid Tundra (wet saline tundra, saltmarsh)	Wet *Carex subspathacea, Puccinellia phryganodes, Stellaria humifusa, Cochlearia officinalis* Sedge Tundra
		IIIc. Wet Sedge Tundra/Water Complex (pond complex, no emergent vegetation)	Typical communities listed in IIIa and Va
		IIId. Wet Sedge/Moist Sedge, Dwarf Shrub Tundra Complex (wet patterned-ground complex)	Typical communities listed in IIIa and Va, and sometimes IIb
C. Moist Tundra	IV. Moist/Wet Tundra Complex	IVa. Moist Sedge, Dwarf Shrub/Wet Graminoid Tundra Complex (moist patterned ground complex)	Typical communities listed in IIIa and Va
	V. Moist or Dry Tundra	Va. Moist Sedge, Dwarf Shrub Tundra	Moist *Carex bigelowii, Eriophorum angustifolium, Dryas integrifolia, Salix reticulata, Tomenthypnum nitens, Thamnolia subuliformis* Sedge, Dwarf Shrub Tundra (moist alkaline tundra) Moist *Luzula arctica, Poa arctica, Saxifraga cernua, Salix planifolia, Dicranum elongatum, Ochrolechia frigida* Graminoid, Dwarf Shrub, Crustose Lichen Tundra (moist coastal acidic tundra)

TABLE 4-6 (Cont'd)
HIERARCHICAL VEGETATION CATEGORIES FOR THE BADAMI AREA VEGETATION/LAND COVER MAP (FIGURE 4-1)

LEVEL A SMALL-SCALE UNITS	LEVEL B LANDSAT-SCALE UNITS	LEVEL C PHOTO-INTERPRETED MAP UNITS	LEVEL D TYPICAL PLANT COMMUNITIES
C. Moist Tundra (CONT'D)	V. Moist or Dry Tundra (CONT'D)	Va. Moist Sedge, Dwarf Shrub Tundra (CONT'D)	Moist *Carex aquatilis, Eriophorum angustifolium, Salix planifolia, Campylium stellatum* Sedge, Dwarf Shrub Tundra (moist acidic tundra, wetter facies)
		Vc. Dry, Dwarf Shrub, Crustose Lichen Tundra (*Dryas* tundra, pingos, river bars)	Dry *Dryas integrifolia, Carex rupestris, Oxytropis nigrescens, Salix reticulata, Ditrichum flexicaule, Lecanora epibyron* Dwarf Shrub, Forb, Crustose Lichen Tundra (*Dryas* tundra, pingos) Dry *Dryas integrifolia, Astragalus alpinus, Oxytropis borealis, Salix reticulata, Distichium capillaceum, Lecanora epibyron* Dwarf Shrub, Forb, Crustose Lichen Tundra (*Dryas* tundra, river bars)
		Vd. Dry, Dwarf Shrub, Fruticose Lichen Tundra (dry acidic tundra)	Dry *Salix rotundifolia, Pedicularis kanei, Luzula arctica, Polystichum* sp., *Alectoria nigricans, Cetraria islandica* Dwarf Shrub, Fruticose Lichen Tundra (dry acidic tundra near coast)
		Ve. Moist Graminoid, Dwarf Shrub Tundra/Barren Complex (frost-scar tundra complex)	Typical communities listed in Va plus either completely barren frost scars or communities such as: Dry *Saxifraga oppositifolia, Dryas integrifolia, Chrysanthemum integrifolium, Juncus biglumis, Arctagrostis latifolia, Ochrolechia frigida* Barren (alkaline frost scars)
E. Partially Vegetated and Barren	IX. Partially Vegetated	IXb. Dry Barren/Dwarf Shrub, Forb Grass Complex (forb rich river bars)	Typical communities listed in Vc, and mixed forb, grass and dwarf shrub communities such as: Dry *Bromus pumpellianus, Festuca rubra, Astragalus alpinus, Androsace chamaejasme, Salix ovalifolia* Grass, Forb, Dwarf Shrub Tundra (forb rich river bars) Dry *Dryas integrifolia, Artemisia borealis, A. glomerata, Salix ovalifolia, Androsace chamaejasme* Dwarf Shrub, Forb Tundra (*Dryas* river bars near arctic coast)
		IXc. Dry Barren/Forb Complex (active river channels)	Dry *Epilobium latifolium, Artemisia arctica, Wilhelmsia physodes* Forb Barren (active river channels)
		IXe. Dry Barren/Grass Complex (coastal sand dune grassland)	Dry *Elymus arenarius* Grass Tundra (coastal sand dune grassland)
		IXh. Wet Barren/Wet Sedge Tundra Complex (barren/saline tundra complex, saltmarsh)	Typical communities listed in IIIb

TABLE 4-6 (Cont'd)
HIERARCHICAL VEGETATION CATEGORIES FOR THE BADAMI AREA VEGETATION/LAND COVER MAP (FIGURE 4-1)

LEVEL A SMALL-SCALE UNITS	LEVEL B LANDSAT-SCALE UNITS	LEVEL C PHOTO-INTERPRETED MAP UNITS	LEVEL D TYPICAL PLANT COMMUNITIES
E. Partially Vegetated and Barren (CONT'D)	IX. Partially Vegetated (CONT'D)	IXi. Dry Barren/Forb, Graminoid Complex (coastal barrens)	Dry *Cochlearia officinalis, Stellaria humifusa, Puccinellia phryganodes, P. andersonii, Salix ovalifolia, Potentilla pulchella* Forb, Graminoid Tundra (coastal saline barrens)
	X. Light-colored Barrens (ground cover <30%)	Xa. River Gravels	Completely barren or with communities listed under IXb and IXc.
		Xe. Gravel Roads and Pads	Completely barren or partially vegetated with communities similar to IXb and IXc.
		BS. Barren Sand/Gravel (coastal beaches)	Completely barren or with patches of community IXe.
	XI. Dark-colored Barrens (ground cover <30%)	XIa. Wet Mud (drained lakes and ponds)	Completely barren or occasionally wtih colonizing species such as *Deschampsia caespitosa* and *Senecio congestus.*
		XIc. Bare Peat (mostly barren coastal areas caused by storm surges)	Completely barren or with sparse communities similar to IIIa, Va, and IXi.

important areas for feeding birds and in some cases also serve as nesting habitat, especially for waterfowl (Troy 1992). However, most tundra-nesting bird species — especially shorebirds — tend to select nest sites in areas drier than those where they prefer to feed (Troy 1992). Thus, the drier habitats in the Badami area (map unit V [all types] and to a lesser extent, IXi), although less important for feeding, probably provide nesting habitat for some species. The vegetation complexes IIId and IVa are likely to be important bird habitats because these areas provide both moist sites suitable for nesting and nearby wet sites favored for feeding. This is especially so when these vegetation types encompass clusters of lakes and ponds. On the immediate coast, map units IIIb and IXh (arctic saltmarsh and partially barren arctic saltmarsh vegetation, respectively) are particularly important feeding areas for post-breeding migrant birds, especially Brant (*Branta bernicla*) (Bergman et al. 1977, Martin and Moitoret 1981) and shorebirds (Martin and Moitoret 1981, TERA 1994a, and references within). The other vegetation/land cover categories on the map refer to sparsely vegetated areas such as gravel bars along rivers, open river gravels, artificial gravel on the tundra, coastal sand/gravel beaches, open wet mud, and barren peat. Most of these areas are probably less important habitats for birds, and river gravels in particular have been documented as such (Pollard et al. 1990).

4.7 FISH AND WILDLIFE

4.7.1 Fish Use of Freshwater Habitats

Table 4-7 lists selected fish species in the Badami study area. The Alaska Department of Fish and Game *Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fish* identifies four streams (Sagavanirktok River, Shaviovik River, Kavik River, Juniper Creek) in the study area as containing either anadromous or resident nonanadromous fish (ADF&G 1992), while Ward and Craig (1974) provide fish data for the Kadleroshilik River:

- Sagavanirktok River (Dolly Varden charr [charr], broad whitefish, pink salmon, and chum salmon);
- Shaviovik River (charr, Arctic grayling, ninespine stickleback);
- Kavik River (charr, Arctic grayling, ninespine stickleback);
- Juniper Creek - tributary to the Shaviovik River (Arctic grayling), and
- Kadleroshilik River (Arctic grayling, ninespine stickleback, slimy sculpin).

In the summer of 1994, ADF&G personnel surveyed the river and stream crossings along the proposed pipeline route, as well as potential water and material

TABLE 4-7
SELECTED FISH SPECIES IN THE STUDY AREA

Arctic cisco (*Coregonus autumnalis*)
Arctic grayling (*Thymallus arcticus*)
Broad whitefish (*Coregonus nasus*)
Chum salmon (*Oncorhynchus keta*)
Dolly Varden charr (*Salvelinus malma*)
Fourhorn sculpin (*Myoxocephalus quadricornis*)
Least cisco (*Coregonus sardinella*)
Ninespine stickleback (*Pungitius pungitius*)
Pink salmon (*Oncorhynchus gorbuscha*)
Slimy sculpin (*Cottus cognatus*)

sources for the project (Hemming 1994, Hemming and Ott 1994). In their report, they indicated that fish presence is also highly likely in two beaded tundra streams (tributary to the Sagavanirktok) that the pipeline route crosses. In addition, they conducted fyke net sampling of two unnamed creeks termed "East Badami" and "West Badami" creeks. East Badami Creek has been proposed as the primary gravel source for the Badami project. Fourhorn sculpin, ninespine stickleback, and a juvenile Arctic grayling were collected in West Badami Creek. Ninespine stickleback and two young-of-the-year age-class Arctic grayling were collected in East Badami Creek.

The Dolly Varden charr is the most abundant and widely distributed of the five anadromous fishes (charr, broad whitefish, Arctic cisco, and occasionally pink and chum salmon) within the study area. The Sagavanirktok River supports a small population of broad whitefish and occasional pink and chum salmon, but the charr is the principal anadromous species that occurs in streams between the Sagavanirktok and Canning rivers (Craig 1984). Although it is considered the most euryhaline and eurythermal of anadromous species on the North Slope, the charr is primarily a freshwater species, with individuals spending only about 10 percent of their lives in marine waters (Craig 1989a, b). Juveniles remain in North Slope streams for several years before entering coastal waters for periods of 1.5 to 2.5 months to feed each summer. The charr is an opportunistic feeder, with amphipods and mysids making up the largest part of its diet in nearshore waters (Craig and Haldorson 1981) and aquatic insect larvae in streams (Craig 1977a, b). Large charr will also eat fish. Charr move into spring-fed mountain rivers in the central and eastern portion of the Brooks Range to spawn in mid-summer to fall (Craig 1989a, b; McCart 1980). Overwintering occurs primarily in spring-fed areas of larger North Slope rivers, including the Shaviovik and Sagavanirktok river tributaries (Craig 1989a, b).

The Arctic grayling is generally the most common resident species in fish-bearing streams in the study area and is considered both an important sport and subsistence fish in Alaska. Craig and Poulin's work (1974) in tributaries of the Shaviovik River indicated that spawning by Arctic grayling occurred shortly after breakup in early June. Fry emerged from streambed gravels in late June or early July and remained until freeze-up in mid-September. Overwintering by both juvenile and adult grayling occurred in a spring-fed area of the Shaviovik River.

The ninespine stickleback is also found in some streams in the study area. Too small to be of direct value to humans, ninespine stickleback is prey for Arctic grayling and charr, as well as for fish-eating birds (Morrow 1980).

A common feature of rivers in the study area that originate in the Brooks Range is the presence of perennial springs, which are used by charr for spawning and overwintering and by Arctic grayling for overwintering (Craig and McCart 1974). The scarcity of overwintering habitat in North Slope rivers has been proposed as limiting populations of both charr and Arctic grayling (Craig 1989a, b). During 1993 field studies, no springs were observed adjacent to the rivers within the study area.

4.7.2 Fish Use of Nearshore Marine Habitat

Background

Two general types of fish habitat have been identified in the Beaufort Sea: offshore marine waters and nearshore brackish waters (Craig 1984). The nearshore zone serves as a movement corridor for fishes that are intolerant of more marine conditions and as feeding habitat for both anadromous and marine fishes. Temperatures and salinities in this nearshore zone are, however, highly variable — both over short time periods (i.e., hours) and over the summer open-water period — and exert a significant influence on the direction and extent of fish movements. In addition to charr, anadromous fishes in the nearshore zone include Arctic cisco, least cisco, and broad whitefish. Arctic cisco and charr range across most of the Beaufort Sea coast; least cisco and broad whitefish, because they do not disperse far from their rivers of origin, are rarely found in nearshore waters east of the Sagavanirktok River and west of the Mackenzie River (Craig 1984). The low abundance of least cisco and broad whitefish in this region has also been attributed to scarcity of overwintering habitat, low river discharge, an exposed coastline, and marked increases in depth within a short distance from shore (Gallaway et al. 1991).

Species Accounts

The Arctic cisco is found in North American coastal waters from Point Barrow, Alaska, to Victoria Island, Northwest Territories (Morrow 1980). Arctic cisco in the Alaskan Beaufort Sea spawn in the Mackenzie River drainage from late August to November. Fry have emerged by spring breakup, and in late May to early June, they are swept downstream to coastal waters, where they begin feeding in brackish waters in front of the Mackenzie Delta. Young-of-the-year Arctic cisco are transported by nearshore currents; and in years with strong and predominantly east winds, Arctic cisco are swept westward from the Mackenzie Delta into Alaskan waters. They arrive in the Prudhoe Bay area by mid-August (Fechhelm and Griffiths 1990). Because their dispersal is dependent on wind strength and direction, the number of young-of-the-year Arctic cisco in Alaskan waters can vary substantially from year to year. Arctic cisco that reach the central Alaskan Beaufort Sea remain there for six to nine years until they are sexually mature. During summer months, Arctic cisco use the nearshore zone, where they feed primarily on amphipods, mysids, and copepods (Cannon et al. 1987). Arctic cisco are more tolerant of low temperature and high salinity than other whitefishes in the nearshore Beaufort Sea (Fechhelm et al. 1993, Fechhelm et al. 1991, 1992; Gallaway et al. 1983; Griffiths et al. 1992). Overwintering occurs in brackish water; and while the Colville and Mackenzie rivers are assumed to be the most important areas, small numbers of Arctic cisco have been found overwintering in the Sagavanirktok River in some years (Schmidt et al. 1989, Reub et al. 1991).

Least cisco occur in two disjunct distributory centers in the Beaufort Sea: one is associated with the Mackenzie River drainage and one with the Colville River and streams to the west (Craig 1984). Spawning and overwintering are not known to occur in the region between these rivers; and as a consequence, least cisco is uncommon in the nearshore zone east of the Sagavanirktok River and west of the Mackenzie River (Griffiths et al. 1975, Craig 1984, Gallaway et al. 1991). Least cisco found in the Prudhoe Bay area during the summer arrive from the Colville River and return there to overwinter (Fechhelm et al. 1989, Fechhelm et al. 1994, Schmidt et al. 1989).

Least cisco leave their overwintering habitats in the Colville and disperse along the Beaufort Sea coast to forage during summer months. These foraging movements carry adult least cisco into Simpson Lagoon and into the Prudhoe Bay region every year, but young least cisco move into the Prudhoe Bay region only when west winds are strong enough to transport them (Fechhelm et al. 1994). Recent studies show that young least cisco disperse to eastern Simpson Lagoon approximately 50 percent of the years (Fechhelm et al. 1994), and in turn, these young fish disperse into Prudhoe Bay itself in only 50 percent of those latter instances. Wind is thus an important factor governing the movement and dispersal of young least cisco along the coast, and Prudhoe Bay is at the easternmost fringe of least cisco summer foraging.

Least cisco prey on marine invertebrates, primarily amphipods and mysids (Cannon et al. 1987). Temperature and salinity preferences of least cisco are considered intermediate between those of Arctic cisco and broad whitefish (Griffiths and Gallaway 1982).

Broad whitefish are abundant in the Sagavanirktok River delta, but occur infrequently in coastal waters between the Sagavanirktok and Mackenzie rivers (Craig 1989a, b). It is essentially a freshwater species that ventures into brackish nearshore water to feed on amphipods and mysids during the open-water season (Craig 1989a, b). Individuals in the Prudhoe Bay area during the summer are likely from two stocks: one that originates from the Sagavanirktok River and another that migrates from the Colville River (Lockwood et al. 1991). Spawning takes place from September to October (Morrow 1980). Of the arctic coregonids, broad and other whitefishes, especially in the juvenile stage, are considered the least tolerant of cold, saline water (de March 1989). As salinity increases in the nearshore zone in August and September, broad whitefish retreat upstream to the lower reaches of the Colville and Sagavanirktok rivers, where they overwinter.

A decade of monitoring population size and age structure of broad whitefish in the Prudhoe Bay region has shown that their abundance fluctuates widely from year to year (Gallaway et al. 1995). Between 1982 and 1985, abundance levels were high. Between 1985 and 1987, the population declined precipitously, but quickly rebounded, and by

1991 resembled the 1982 population in size and age structure. Evidence from long-term monitoring studies suggests that this species fluctuates on about a ten-year cycle, likely governed by density-dependent factors that limit the size of the population that can overwinter in limited space in the Sagavanirktok River (Gallaway et al. 1995).

Arctic grayling occasionally disperse into the nearshore Beaufort Sea, but only when nearshore waters become nearly fresh (<5 ppt). This species cannot tolerate saline conditions. In these instances, grayling may move out of larger river winter habitat during the early summer and into nearby tundra streams where invertebrate prey is more abundant. They remain in tundra streams for the summer. The fate of these summer resident grayling is unknown; however, late-summer mortality may be high. These fish must move through the coastal zone, where salinities rapidly increase during late summer, and back into larger rivers to find suitable overwintering habitat (tundra streams freeze solidly each winter).

Mikkelsen Bay

Fish monitoring studies conducted in the Mikkelsen Bay area have consisted largely of limited gillnet, seine, fyke net, tow net, and trawl surveys associated with broader coastal inventories of regional fishery resources (Craig and Mann 1974; Craig 1977a; Griffiths et al. 1975; Bendock 1979; Craig and Griffiths 1981; Thorsteinson et al. 1990, 1991). They have also included an extensive inventory of North Slope river systems (Craig and McCart 1974). Gill net and weir surveys of the Shaviovik River, which empties into the Beaufort Sea 6 miles west of the proposed Badami Development, were conducted by Craig (1977b), the primary emphasis being to profile the river's resident Dolly Varden charr (referred to as "Arctic char" in early studies) population. The nearest intensive fyke net surveys were conducted during the summers of 1985 (Cannon et al. 1987) and 1986 (Glass et al. 1990) in conjunction with the Endicott Environmental Monitoring Program. Fyke nets located several miles west of the Kadleroshilik River were fished from late June through mid-September of each year.

Many of the data collected in these surveys provide little direct information about Mikkelsen Bay, since most of the catch and life-history statistics have been reported in a pooled format with data collected at other coastal sampling sites. From these earlier studies, there is often no way to determine whether the fishes and coastal habitat of Mikkelsen Bay represent a unique situation relative to other Beaufort Sea locales.

Based on the available data, it is expected that four key anadromous species will occur in the coastal waters of Mikkelsen Bay: Arctic cisco, broad whitefish, Dolly Varden charr, and least cisco. However, few data exist to describe abundance levels, age structures, and movement/migration patterns for these species within this area.

Arctic cisco young-of-the-year move through the study area only when east winds are of sufficient strength and duration to transport them from Canada (Gallaway et al. 1983); this happens in approximately 50 percent of the years (Fechhelm and Griffiths

1990). Large Arctic cisco may be present in the area, but not in large numbers since they forage principally in Simpson Lagoon and Prudhoe Bay to the west. Least cisco also will be rare in Mikkelsen Bay, although occasional large fish may move this far east; Prudhoe Bay is generally the easternmost fringe of the large least cisco summer foraging range. Few small broad whitefish will occur in the area, since they rarely leave the brackish confines of the Sagavanirktok River delta. Larger broad whitefish also will be rarely found in the area, since they cannot tolerate the high salinities that may be found between the Sagavanirktok Delta and Mikkelsen Bay. Charr will be abundant but transient visitors to the area; this species forages considerable distances from their overwintering streams, moving along the coast early in the open water season, and again later in summer as they return to streams to overwinter. An occasional Arctic grayling may move out of the Shaviovik River and into adjacent tundra streams to feed; this will occur to a limited extent, however. Few grayling were observed to move along the coast of the Arctic National Wildlife Refuge during several years of monitoring in 1988–1991 (Tevis Underwood, USFWS, pers. comm.) or along the coast in the Prudhoe Bay region (William Griffiths, LGL, pers. comm.).

4.7.3 Birds

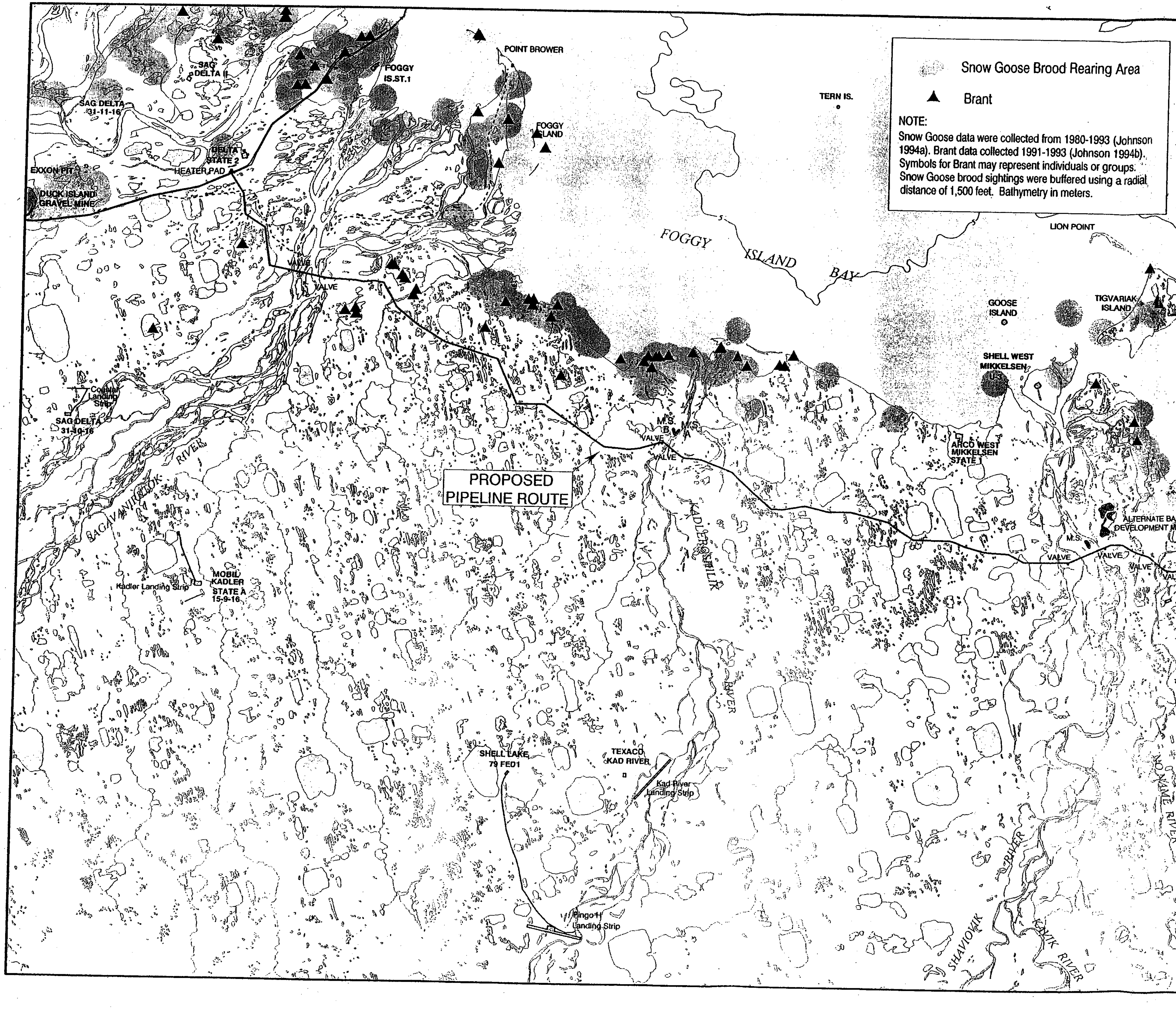
General

An estimated 10 million birds including over 240 aquatic and terrestrial species utilize the Beaufort Sea area (Johnson and Herter 1989). Birds use this area for spring migration/pre-nesting, nesting, molting and brood-rearing, and fall staging/migration. Most species are migratory, arriving in late May or early June to breed and departing by late September. Major groups present in the study area include:

- **Waterfowl:** Ducks, loons, Tundra Swan, White-fronted Goose, Snow Goose, Brant, Canada Goose, and eiders;
- **Shorebirds:** Lesser Golden-Plover, Semipalmated Sandpiper, Pectoral Sandpiper, Dunlin, and Red Phalarope;
- **Passerines:** Lapland Longspur and Snow Bunting.

Few birds overwinter in the study area including small numbers of Gyrfalcon, ptarmigan, Snowy Owl, and Common Raven. Table 4-8 lists species likely to occur in the study area. Figure 4-3 shows areas used by Snow Geese and Brant in the study area, while Figure 4-4 shows Tundra Swan pair observations and nest locations.

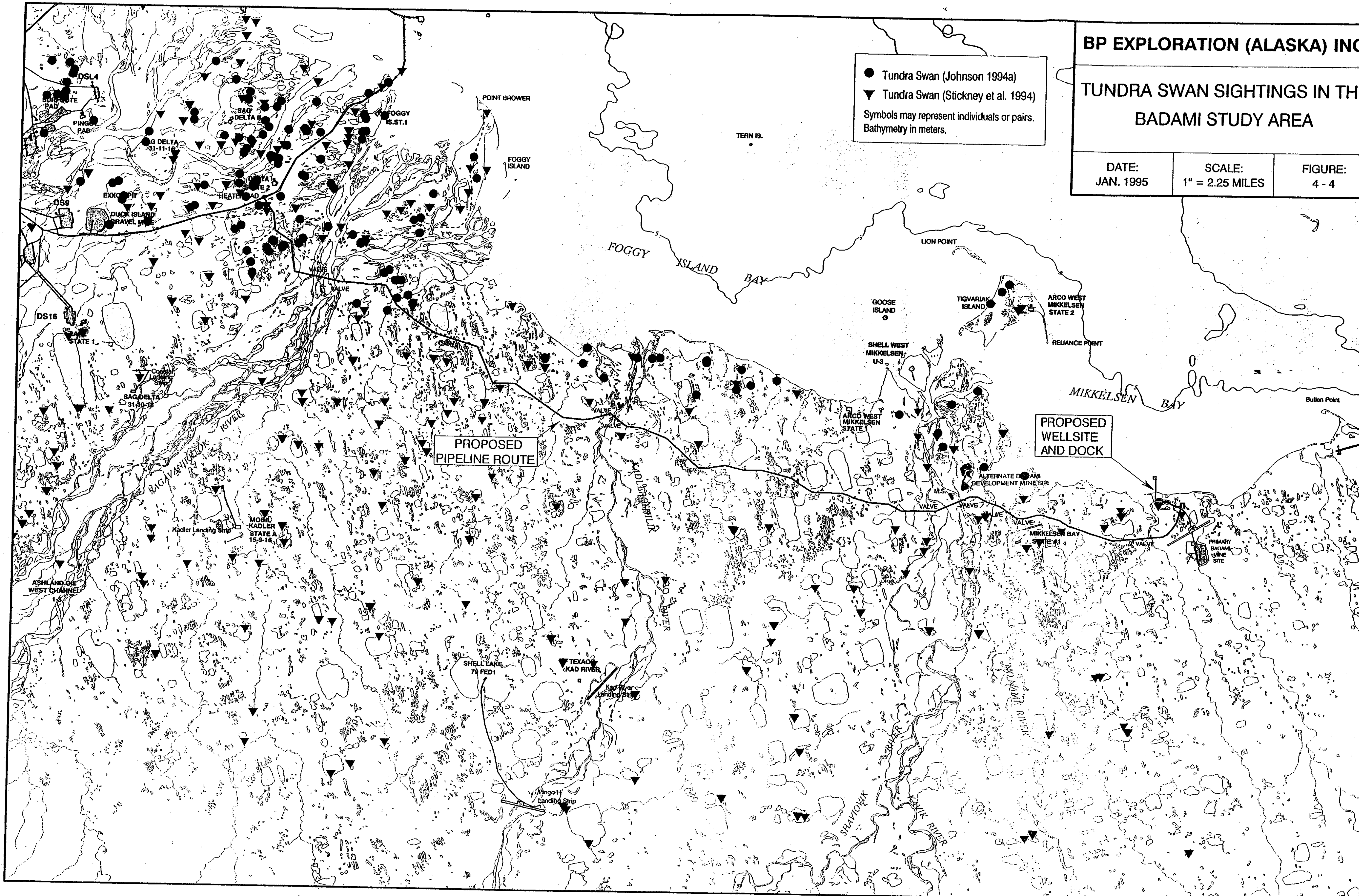
Waterfowl migrate in large flocks. For example, flocks of hundreds to thousands of Snow Geese or tens of thousands of eiders may occur. In spring, they congregate on snow-free and ice-free areas such as river deltas or the foothills until nesting areas are free of snow. Waterfowl nest everywhere in the study area. From July through early



BP EXPLORATION (ALASKA) INC.

SNOW GEESE BROOD REARING AREAS AND BRANT SIGHTINGS IN THE BADAMI STUDY AREA

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 2.25 MILES	4 - 3



BP EXPLORATION (ALASKA) INC.

TUNDRA SWAN SIGHTINGS IN THE BADAMI STUDY AREA

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 2.25 MILES	4 - 4

ex12485.dgn

TABLE 4-8
SELECTED BIRD SPECIES LIKELY TO OCCUR IN THE STUDY AREA

Pacific Loon (*Gavia pacifica*)
Red-throated Loon (*Gavia stellata*)
Yellow-billed Loon (*Gavia adamsii*)
Tundra Swan (*Cygnus columbianus*)
Greater White-fronted Goose (*Anser albifrons*)
Snow Goose (*Chen caerulescens*)
Ross' Goose (*Chen rossii*)
Brant (*Branta bernicla*)
Canada Goose (*Branta canadensis*)
Mallard (*Anas platyrhynchos*)
Northern Pintail (*Anas acuta*)
Northern Shoveler (*Anas clypeata*)
Gadwall (*Anas strepera*)
American Wigeon (*Anas americana*)
Greater Scaup (*Aythya marila*)
Common Eider (*Somateria mollissima*)
King Eider (*Somateria spectabilis*)
Spectacled Eider (*Somateria fischeri*)
Steller's Eider (*Polysticta stelleri*)
Oldsquaw (*Clangula hyemalis*)
Red-breasted Merganser (*Mergus serrator*)
Northern Harrier (*Circus cyaneus*)
Rough-legged Hawk (*Buteo lagopus*)
Golden Eagle (*Aquila chrysaetos*)
Merlin (*Falco columbarius*)
Peregrine Falcon (*Falco peregrinus*)
Gyrfalcon (*Falco rusticolus*)
Willow Ptarmigan (*Lagopus lagopus*)
Rock Ptarmigan (*Lagopus mutus*)
Sandhill Crane (*Grus canadensis*)
Black-bellied Plover (*Pluvialis squatarola*)
Lesser Golden-Plover (*Pluvialis dominica*)
Semipalmated Plover (*Charadrius semipalmatus*)
Whimbrel (*Numenius phaeopus*)
Hudsonian Godwit (*Limosa haemastica*)
Bar-tailed Godwit (*Limosa lapponica*)
Ruddy Turnstone (*Arenaria interpres*)
Semipalmated Sandpiper (*Calidris pusilla*)
Western Sandpiper (*Calidris mauri*)
White-rumped Sandpiper (*Calidris fuscicollis*)
Baird's Sandpiper (*Calidris bairdii*)
Pectoral Sandpiper (*Calidris melanotos*)
Dunlin (*Calidris alpina*)
Stilt Sandpiper (*Calidris himantopus*)
Buff-breasted Sandpiper (*Tryngites subruficollis*)
Ruff (*Philomachus pugnax*)
Long-billed Dowitcher (*Limnodromus scolopaceus*)
Common Snipe (*Gallinago gallinago*)
Red-necked Phalarope (*Phalaropus lobatus*)
Red Phalarope (*Phalaropus fulicaria*)
Pomarine Jaeger (*Stercorarius pomarinus*)
Parasitic Jaeger (*Stercorarius parasiticus*)
Long-tailed Jaeger (*Stercorarius longicaudus*)
Slaty-backed Gull (*Larus schistisagus*)
Glaucous Gull (*Larus hyperboreus*)
Ross' Gull (*Rhodostethia rosea*)
Sabine's Gull (*Xema sabini*)
Arctic Tern (*Sterna paradisaea*)
Snowy Owl (*Nyctea scandiaca*)
Short-eared Owl (*Asio flammeus*)
Horned Lark (*Eremophila alpestris*)
Bank Swallow (*Riparia riparia*)
Barn Swallow (*Hirundo rustica*)
Common Raven (*Corvus corax*)
Northern Wheatear (*Oenanthe oenanthe*)
Northern Shrike (*Lanius excubitor*)
Yellow Wagtail (*Motacilla flava*)
Savannah Sparrow (*Passerculus sandwichensis*)
Lapland Longspur (*Calcarius lapponicus*)
Smith's Longspur (*Calcarius pictus*)
Snow Bunting (*Plectrophenax nivalis*)
Common Redpoll (*Carduelis flammea*)

September, molting seaducks (primarily Oldsquaw) congregate in the lagoons created by the barrier islands. While molting, waterfowl utilize wetland habitat in the study area. Molting geese congregate near large waterbodies where the water provides escape habitat and the surrounding tundra provides foraging areas. Dabbling ducks, especially Northern Pintails, molt in areas of dense cover, such as aquatic tundra in drained lake basins. Geese congregate on the Arctic Coastal Plain to feed prior to fall migration. Some species, such as loons and Tundra Swans, remain in the study area until waterbodies are nearly frozen, usually in late September.

The corridor surrounding the proposed Badami project encompasses a diverse landscape including river floodplain, thaw-lake coastal plain, and tundra in the transition zone to the ancient Canning alluvial fan to the east. The results of 1994 investigations by Troy Ecological Research Associates (TERA) reveal that bird use is as heterogeneous as the terrain types it includes (TERA 1994c). Two areas received detailed study: the immediate vicinity of the proposed Badami production site (Badami study area) and the thaw lake plain more or less typical of the area along the proposed pipeline corridor between the Kadleroshilik and Shaviovik rivers (Kadleroshilik study area). These areas were found to be quite dissimilar in bird use, and in many respects were different from the Prudhoe Bay area.

Nesting

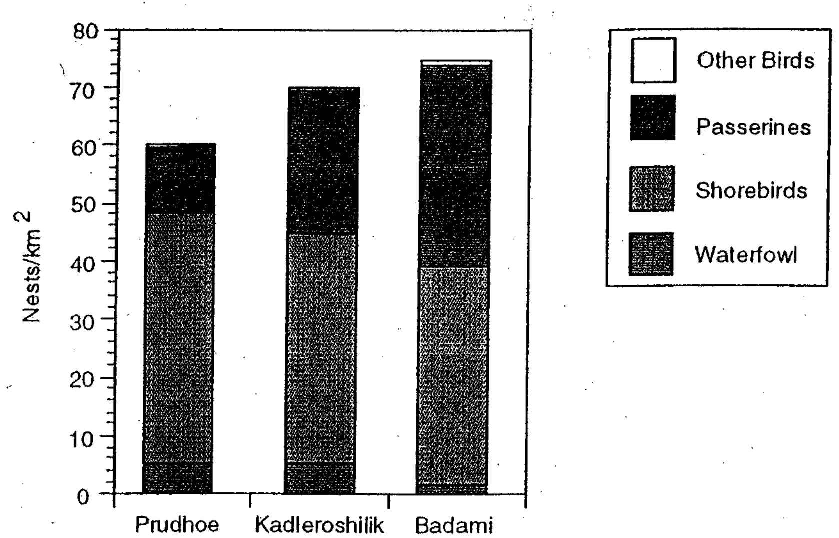
Studies of tundra birds have focused on areas within the North Slope oil fields, generally west of the Sagavanirktok River delta, and in the Arctic National Wildlife Refuge (ANWR) east of the Staines and Canning rivers. In aggregate, the results of these studies suggest two broad communities of nesting birds, here referred to as "flat thaw lake plain" (FTLP) and "rolling coastal plain" (RCP) communities. A typical FTLP location, such as is generally found in the oil fields but also in the Canning River delta (Martin and Moitoret 1981), is dominated by four species: Lapland Longspur, Semipalmated Sandpiper, Pectoral Sandpiper, and one of the phalaropes. A RCP site, such as most ANWR study areas (e.g., Oates et al. 1987) or Yukon Gold (TERA 1993c), generally has only two dominant species: Lapland Longspur and Pectoral Sandpiper. Waterfowl tend to be about twice as numerous in FTLP sites as in RCP sites; however, waterfowl nesting densities are generally much lower than for the dominant species.

The sampling at Badami and Kadleroshilik provides information from areas geographically intermediate between the ANWR and Prudhoe Bay regions. Sampling in 1994 took place in Prudhoe Bay concurrent with the Badami and Kadleroshilik studies and provides comparative results. Nest densities at the three study sites were similar in 1994: Badami and Kadleroshilik had close to 70 nests/km^2, while Prudhoe had a slightly lower nest density of about 60 nests/km^2 (Table 4-9 and Figure 4-5) (TERA 1994c). The similar total densities mask large differences in the composition of the nesting bird communities among study areas. Waterfowl nest densities increased from east to west,

TABLE 4-9
NEST DENSITIES IN THE BADAMI, KADLEROSHILIK, AND PRUDHOE STUDY AREAS, SUMMER 1994

SPECIES	PRUDHOE	KADLEROSHILIK	BADAMI
Red-throated Loon	0.0	0.0	0.3
Pacific Loon	0.5	1.0	0.0
Greater White-fronted Goose	1.4	0.3	0.0
Canada Goose	0.0	1.3	0.0
Northern Pintail	0.5	0.0	0.0
King Eider	1.0	0.7	0.7
Spectacled Eider	0.5	0.3	0.0
Oldsquaw	1.4	1.3	0.3
Rock Ptarmigan	0.0	0.0	0.3
Black-bellied Plover	0.5	0.7	0.3
Lesser Golden-Plover	1.0	1.7	2.7
Semipalmated Sandpiper	17.1	9.0	16.0
Baird's Sandpiper	0.0	0.0	1.0
Pectoral Sandpiper	8.6	12.0	9.0
Dunlin	3.3	4.0	3.3
Stilt Sandpiper	1.0	1.3	1.3
Buff-breasted Sandpiper	1.0	0.0	0.0
Long-billed Dowitcher	0.0	0.0	0.7
Red-necked Phalarope	3.8	3.3	1.0
Red Phalarope	6.7	7.7	2.3
Lapland Longspur	11.9	25.0	35.0
Waterfowl	5.2	5.0	1.3
Shorebirds	42.9	39.7	37.7
Passerines	11.9	25.0	35.0
Other Birds	0.0	0.0	0.3
All Birds	60.0	69.7	74.3

FIGURE 4-5
COMPARISON OF NEST DENSITIES OF MAJOR GROUPS OF BIRDS IN THE BADAMI, KADLEROSHILIK, AND PRUDHOE STUDY AREAS, SUMMER 1994



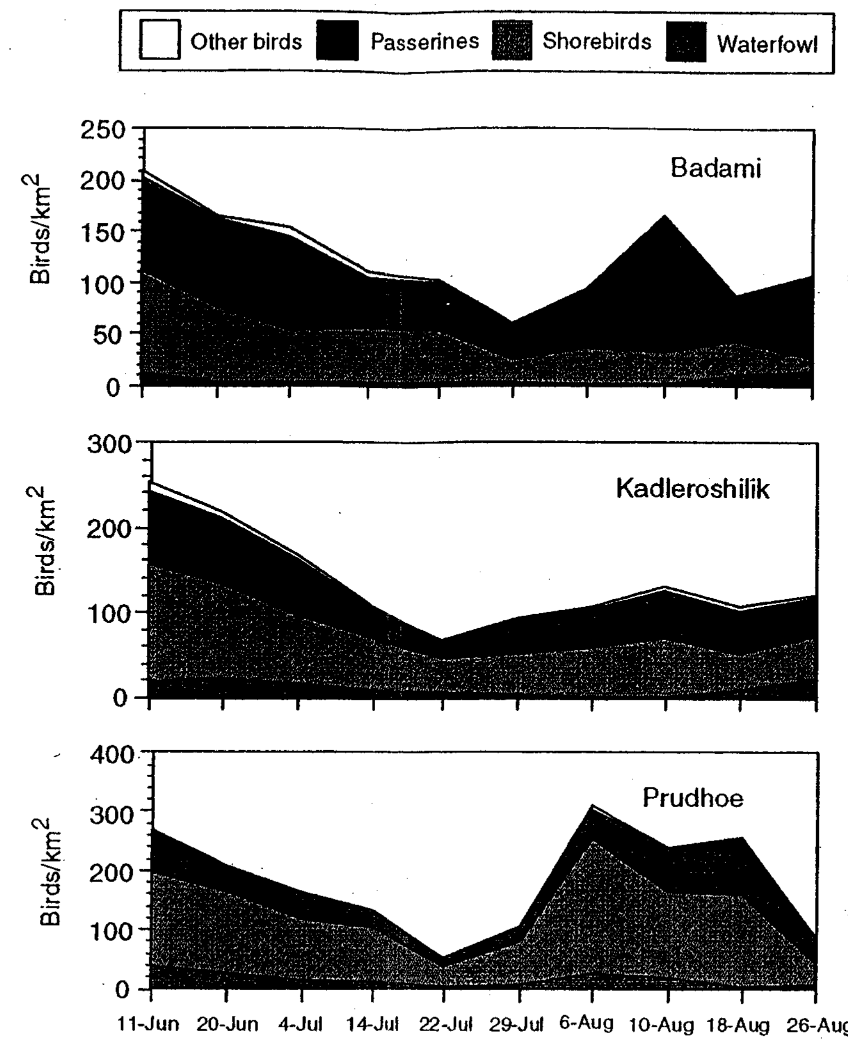


FIGURE 4-6
SEASONAL TRENDS IN BIRD ABUNDANCE IN THE BADAMI, KADLEROSHILIK, AND PRUDHOE STUDY AREAS, SUMMER 1994

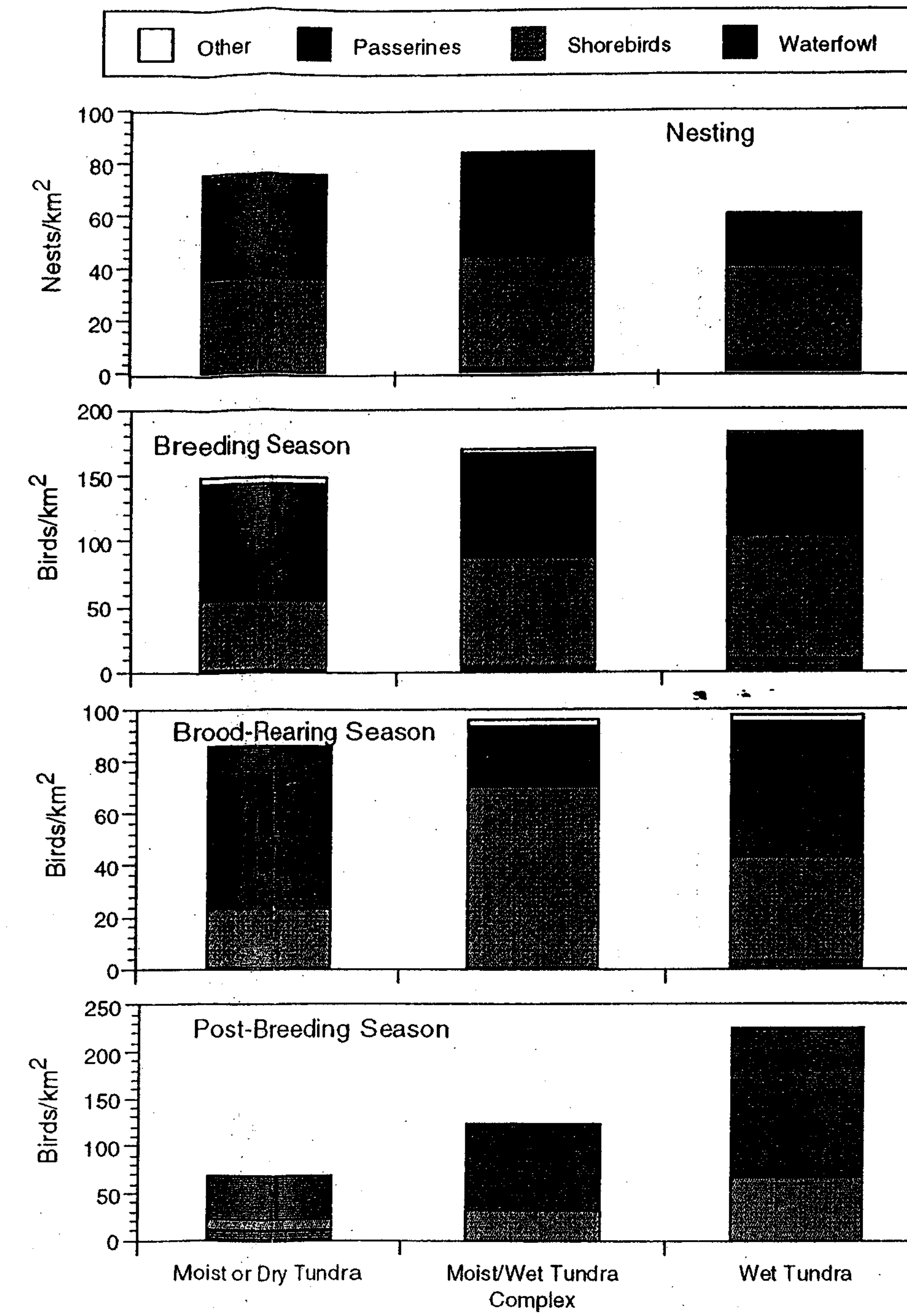


FIGURE 4-7
BIRD USE OF MAJOR VEGETATION TYPES IN THE BADAMI AREA, SUMMER 1994

FIGURES 4-5, 4-6, AND 4-7
AND
TABLE 4-7

with densities being markedly lower in the Badami area than in the other study areas. Shorebird densities also increased from east to west; however, differences among areas were not as extreme as for waterfowl. The nest density of passerines, primarily Lapland Longspur, was markedly higher in the Badami area than elsewhere and lowest in the Prudhoe study area. Overall, Kadleroshilik had a typical FTLP nesting community, whereas the Badami community was most like a RCP community but somewhat intermediate between the two types.

Seasonal Abundance of Birds

Over the summer, bird use of a given area of the Arctic Coastal Plain can change rapidly and markedly due to influxes (or exodus) of particular age and sex groups or changes in use of specific habitats (TERA 1994a). In the Prudhoe Bay area, waterfowl often exhibit bimodal patterns of abundance, with peaks in June and August. The relative importance of the peaks varies depending on the species. For example, male eiders and Oldsquaws depart to molt in mid-summer and do not return; hence, June densities are generally highest. In contrast, goose numbers may peak in August when adults and young-of-the-year are present. Shorebirds can exhibit complicated patterns of abundance, since there are up to three surges of out-migration, with adults leaving in two waves (corresponding to the two sexes) during mid-summer, followed by later migration of the juveniles. In addition, spatial patterns can be superimposed on these temporal patterns. Connors et al. (1979) described a post-breeding movement of shorebirds to littoral habitats. In tundra areas at Prudhoe Bay, increased use of saline habits has been documented after nesting; however, the Arctic Coastal Plain as a whole appears to be important to migrating shorebirds and waterfowl (TERA 1994a).

Many of the patterns described above can be detected in the Badami and Kadleroshilik study areas, but the results of the 1994 sampling were more striking for the absence of rapid changes in bird abundance (Figure 4-6). In both areas, abundance of waterfowl and shorebirds was at peak at the start of sampling (early June) and gradually diminished over the course of the summer. A secondary peak in bird abundance was recorded in August in both areas, but this was largely due to higher densities of Lapland Longspur. In contrast, bird abundance at Prudhoe in 1994 was highest in August.

The predominant waterfowl differed among the study areas, with only Greater White-fronted Goose and King Eider being numerically dominant in all areas. Greater White-fronted Goose was present primarily as a migrant in the Badami and Kadleroshilik study areas. The overall low breeding-season densities of waterfowl in the Badami area relative to the other study areas correspond to the pattern based on nest densities. The most significant occurrences of waterfowl in the Badami area were of Greater White-fronted Geese in early June and of Canada Geese and Oldsquaw during late August. The Kadleroshilik study area supported more waterfowl than Badami; in particular, Oldsquaw were numerous during the breeding season and Greater White-fronted Geese during late August.

Habitat Use at Badami

Tundra birds disperse throughout tundra that is free from snow cover in late May or early June. Studies conducted in the Prudhoe Bay area since 1981 have been used to characterize the relative use of various types of tundra to birds (TERA 1993a, Troy 1991). Both vegetation and surface-forms as defined by Everett et al. (1981) were found to be important determinants of bird use. Vegetation includes dry prostrate shrub tundra and aquatic sedge tundra, while examples of surface-forms are low-centered polygon, strangmoor, and frostscar. Many combinations of vegetation types and surface forms are present, and each species may use multiple tundra types. For example, birds may select one type for nesting and a completely different type for feeding. In general, heterogeneous terrain types characterized by drier vegetation types and high microrelief support the highest densities of birds (especially those nesting) early in the summer. As the summer progresses, many birds move into wetter areas, and microrelief becomes less important.

Comparable detail regarding habitats and bird distribution is not available for the Badami area as is for Prudhoe. Preliminary assessment of the importance of land cover types at Badami was made by summarizing bird densities in relation to predominate cover type in study plots as determined by overlaying plot locations on the Badami geobotanical maps. Fourteen plots (1.4 km^2) sampled moist or dry tundra, 5 plots (0.5 km^2) moist/wet tundra, and 6 plots (0.6 km^2) wet tundra. Five additional plots were excluded from these analyses because they were judged to overlap too many land cover types to be representative of any particular land-cover class. The three land-cover types evaluated are the most numerous in the Badami area and those most affected by the proposed project (Table 5-2 in Section 5); however, many land-cover types were not sampled, including the relatively extensive partially vegetated tundra. Total bird use of the three sampled land-cover types was relatively uniform for much of the summer; however, some differences among species groups are evident (Figure 4-7).

Nest density peaked in the moist/wet tundra complex due to high densities of shorebirds, especially Semipalmated Sandpiper. Wet tundra supported the lowest total nest density, primarily due to low use by Lapland Longspur and Pectoral Sandpiper. However, waterfowl nest density was highest in this land cover type. The widespread moist or dry tundra supported relatively high nest densities, being most important for Pectoral Sandpiper and Dunlin, but no waterfowl nests were found on these plots. Habitats used by birds during the breeding season generally exhibit similarity to the nest results; however, differences can emerge due to differences in habitats used for foraging and nesting. This was the case at Badami, where during the breeding season the highest bird densities were found in wet tundra, the land cover type with the lowest nest density.

Wet tundra was the most important cover type for waterfowl and shorebirds, especially Red Phalarope. Moist or dry tundra was the least-used habitat supporting relatively low densities of shorebirds (Semipalmated Sandpiper and Red-necked Phalarope were found in low abundance relative to other cover types), although Lapland Longspur was most numerous in this habitat type. Despite these differences, the total bird density in all three cover types were relatively uniform (Figure 4-7)

During the brood-rearing season, total bird densities remained remarkable uniform across land cover types, but marked differences in species composition existed. Each land-cover type was most important to one of the species groups: waterfowl in wet tundra, shorebirds in moist/wet tundra, and passerines (Lapland Longspur) in moist or dry tundra. Relative to the breeding season, the brood-rearing season was characterized by a shift in use by many shorebirds (especially Pectoral Sandpiper and Dunlin) from moist or dry tundra to moist/wet tundra complex. This change likely represents movements of shorebirds with broods to wetter habitats following hatch.

Shifts in habitat use by birds continued into the post-breeding season. During this period (late summer), total bird use overwhelmingly favored wet tundra. At this time shorebirds and passerines in particular were most numerous in wet tundra. In contrast, waterfowl were found only on plots in moist or dry tundra. This apparent shift (all previous analyses indicated waterfowl were most numerous in wet tundra) was due entirely to the influx of Canada Geese into the area.

4.7.4 Mammals

Although there has been extensive research on wildlife both the Prudhoe Bay oil fields and the Arctic National Wildlife Refuge (ANWR), little has been done in the proposed project area. During 1993 and 1994, LGL Alaska Research Associates, Inc., (LGL) conducted aerial reconnaissance surveys in the Badami study area. These efforts focused on caribou, muskoxen, brown bear, and Arctic fox. Moose are sometimes seen in the area in summer, and polar bears may be present in late summer and winter. In addition, the Alaska Department of Fish and Game has conducted surveys of grizzly bears in the Prudhoe Bay oil field since 1991, and in August 1994 extended the survey to the east into the Badami study area. Table 4-10 provides a list of selected mammal species in the study area.

From June through early September 1993, LGL conducted nine aerial surveys of large mammals; the survey area extended from the Beaufort Sea coast inland to the 69° 55' 00" N latitude line, and from Drill Site 16 on the west to the Staines River delta on the east. To more accurately reflect wildlife abundance and distribution in the Badami study area, data from the nine aerial surveys were excerpted; the adjusted survey area extends from the Beaufort Sea coast inland to approximately the 70° 01' N latitude line and from

TABLE 4-10
SELECTED MAMMAL SPECIES IN THE STUDY AREA

Caribou (*Rangifer tarandus granti*)
Muskox (*Ovibos moschatus*)
Brown bear (*Ursus arctos*)
Arctic fox (*Alopex lagopus*)
Moose (*Alces alces*)
Polar bears (*Ursus maritimus*)
Arctic ground squirrel (*Spermophilus parryi*)

Drill Site 16 on the west to approximately 1 mile east of Bullen Point. In addition to the 1993 surveys, LGL conducted ten aerial surveys from June through early August 1994. The survey area for the 1994 surveys extended from Drill Site 3 on the west to Bullen Point on the east, and from the Beaufort Sea inland to approximately 70° 05' N latitude.

Caribou

The Porcupine Caribou Herd (PCH) and the Central Arctic Herd (CAH) occur near or in the study area. The summer range of the PCH extends from Canada westward to the Staines River. PCH studies conducted over the past 20 years have shown that little, if any, calving occurs in the study area and that the area is not used by large numbers of PCH caribou during post-calving and dispersal periods (Clough et al. 1987). Spring and fall migration routes are generally to the east and south of the study area (Clough et al. 1987). The PCH has reportedly declined from 178,000 in 1991 to 160,000 in 1992 (Abbott 1993).

The Central Arctic Herd (CAH) has grown from 5,000 animals in 1979 (Cameron and Whitten 1980) to approximately 23,000 animals in 1992 (Cameron 1993), concurrent with expanding oil field development. The eastern segments of the CAH use a broad area along the Arctic Coastal Plain between the Sagavanirktok River and the Hulahula River (located 36 miles east of the Staines River) as summer range (Clough et al. 1987). During spring migration, CAH caribou move from the northern foothills of the Brooks Range to the Arctic Coastal Plain, often using the major drainages in and adjacent to the study area (Gavin 1983, Elison et al. 1986). In some years, their northward movements are more dispersed and they do not follow restricted travel routes (Carruthers et al. 1984). In general, cows arrive on the coastal plain between late April and early June, while bulls do not arrive at the coast until post-calving in early July (Whitten and Cameron 1980, Jakimchuk et al. 1987). Tables 4-11A and 4-11B summarize data from aerial surveys of CAH caribou conducted from June through early September 1993 and from June through August 1994. Figure 4-8 includes all sightings from the 1993 and 1994 surveys and is intended to illustrate general usage patterns for the study area during summer.

Although the distribution of calving caribou is annually variable, they have consistently used that portion east of the study area between Bullen Point and the Canning River in most years since 1969 (Cameron and Whitten 1978, Gavin 1983, Lawhead and Curatolo 1984, Whitten and Cameron 1985, Cameron et al. 1989). This area is immediately east of the Badami study area. In 1993, the majority of cow/calf pairs were observed south of the study area between the Shaviovik and Staines rivers.

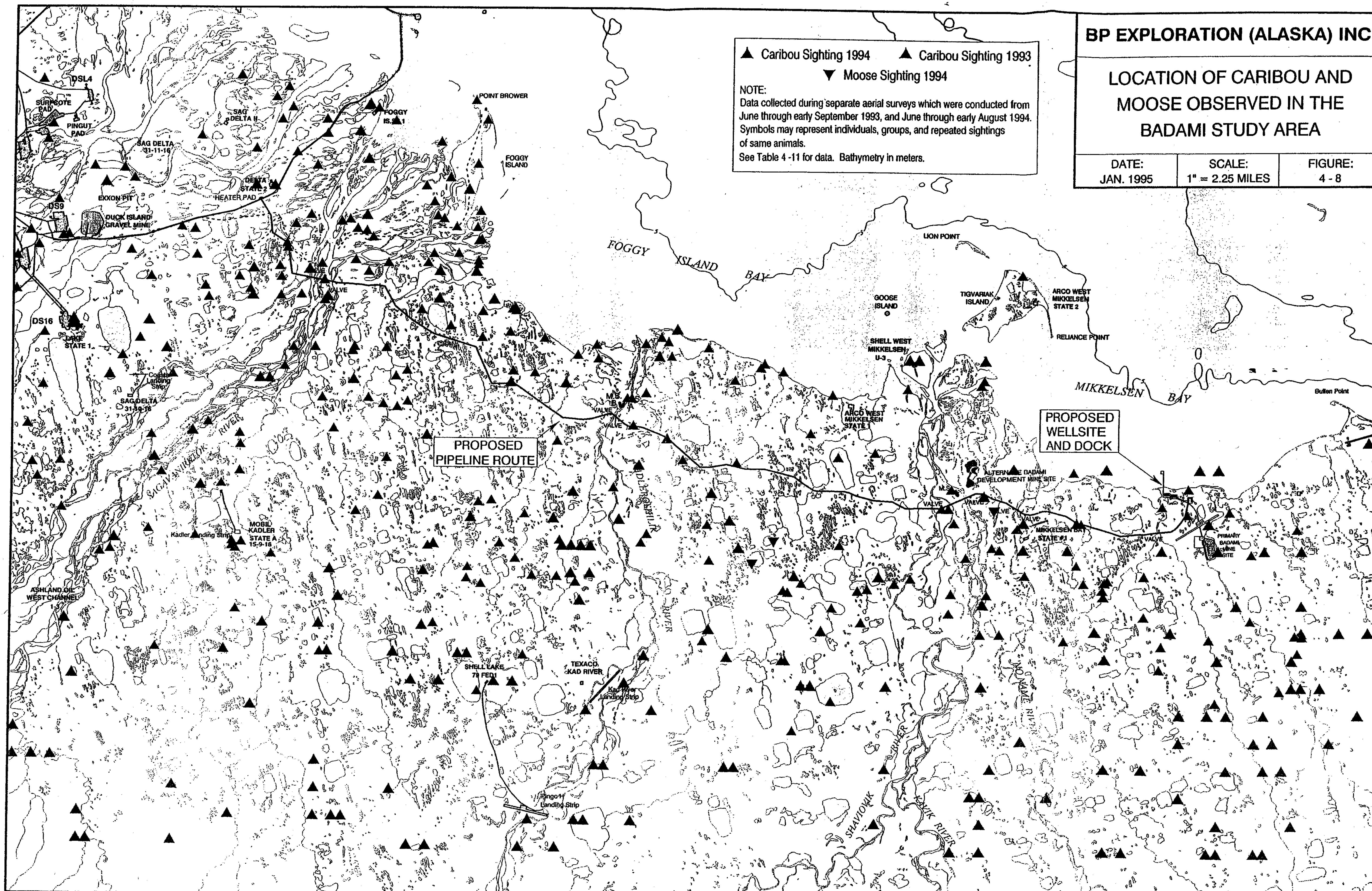
Much of the variability in caribou distributions during calving has been attributed to variations in snow cover and flooding during that season (Whitten and Cameron 1985). In seasons of deep snow and/or flooding on the coastal plain, concentrations of CAH caribou have tended to calve inland near drier upland sites. Deep snow in the foothills of the Brooks Range also may delay migration and cause cows to have their calves farther

TABLE 4-11A
NUMBERS AND SEX COMPOSITION OF CARIBOU OBSERVED DURING AERIAL SURVEYS CONDUCTED FROM JUNE THROUGH EARLY SEPTEMBER 1993 IN THE STUDY AREA (FIGURE 4-8)

SURVEY	DATE	NUMBER OF CARIBOU					
		BULLS	COWS	CALVES	YEARLINGS	UNCLASS.	TOTAL
1	8,10 Jun	3	21	13	3	0	40
2	17,18 Jun	13	337	152	3	4	509
3	22,23 Jun	22	324	195	44	5	590
4	6,7 Jul	0	0	0	0	0	0
5	19,20 Jul	3	0	0	0	0	3
6	27 Jul	177	89	70	12	79	427
7	5 Aug	0	2	2	0	0	4
8	18 Aug	0	0	0	0	0	0
9	9 Sep	43	0	0	0	0	43

TABLE 4-11B
NUMBERS AND SEX/AGE COMPOSITION OF CARIBOU OBSERVED DURING AERIAL SURVEYS CONDUCTED FROM JUNE THROUGH EARLY AUGUST 1994 IN THE STUDY AREA (FIGURE 4-8)

SURVEY	DATE	NUMBER OF CARIBOU					
		BULLS	COWS	CALVES	YEARLINGS	UNCLASS.	TOTAL
1	1-Jun	0	68	6	9	9	92
2	6-Jun	2	13	1	3	8	27
3	16-Jun	8	18	6	0	2	34
4	5,6-Jul	1418	807	746	28	317	3316
5	11,12-Jul	11	3	0	0	1	15
6	19,20-Jul	138	153	85	6	94	476
7	25,26-Jul	18	13	3	1	20	55
8	28-Jul	16	6	2	0	0	24
9	1-Aug	15	10	4	1	0	30
10	8-Aug	19	32	5	1	1	58



BP EXPLORATION (ALASKA) INC.

LOCATION OF CARIBOU AND MOOSE OBSERVED IN THE BADAMI STUDY AREA

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 2.25 MILES	4 - 8

ex12486.dgn

inland (Gavin 1983). Thus, the relative lack of calving caribou in the study area during 1994 may be due, in part, to snow and flood conditions that existed during calving period surveys. However, the low number of calving caribou in the study area is probably more related to the fact that historically, large numbers of CAH caribou have not consistently used this area for calving.

CAH caribou use the study area during the post-calving period, when they move to the Beaufort Sea coast and to the deltas and channels of the Kadleroshilik, Shaviovik, and Sagavanirktok rivers seeking relief from insect harassment (Clough et al. 1987, Gavin 1983). During insect-free periods, caribou move inland to preferred foraging areas.

Muskoxen

Muskoxen were exterminated from the North Slope of Alaska by the late 1800's but were reintroduced into the Arctic National Wildlife Refuge (ANWR), located east of the study area, in 1969 and into the Kavik River area in 1970 (Clough et al. 1987). The population has grown exponentially since 1974 and now numbers close to 800 animals (P. Reynolds, U.S. Fish and Wildlife Service, pers. comm.). In recent years, emigration of muskoxen to the west has resulted in establishment of resident muskoxen populations on the Arctic Coastal Plain between the Kuparuk and Canning rivers, including the study area.

Muskoxen are non-migratory but move in response to seasonal changes in snow cover and vegetation. They use riparian habitat associated with the major river drainages on the Arctic Coastal Plain year-round. Calving generally occurs from April to early June, and newborn calves have been observed in ANWR during mid-June (Garner and Reynolds 1987). While data are scarce regarding actual calving areas, the data suggest that the majority of the population calves in the southern portion of the Arctic Coastal Plain on wind-blown, snow-free banks within riparian areas, and in upland sites in the foothills (Reynolds 1992). Studies of muskoxen distribution on the Arctic Coastal Plain in ANWR showed that calving distribution was similar to winter (November to February) distribution (Reynolds 1992). Little movement occurred during winter, but some mixed-sex groups moved relatively long distances during this time (Reynolds 1992). Major shifts in distribution occurred during summer (mid-June to October) in the eastern portion of the Arctic Coastal Plain in ANWR, while in the western portion, less shifting between winter and summer range was apparent (Reynolds 1992).

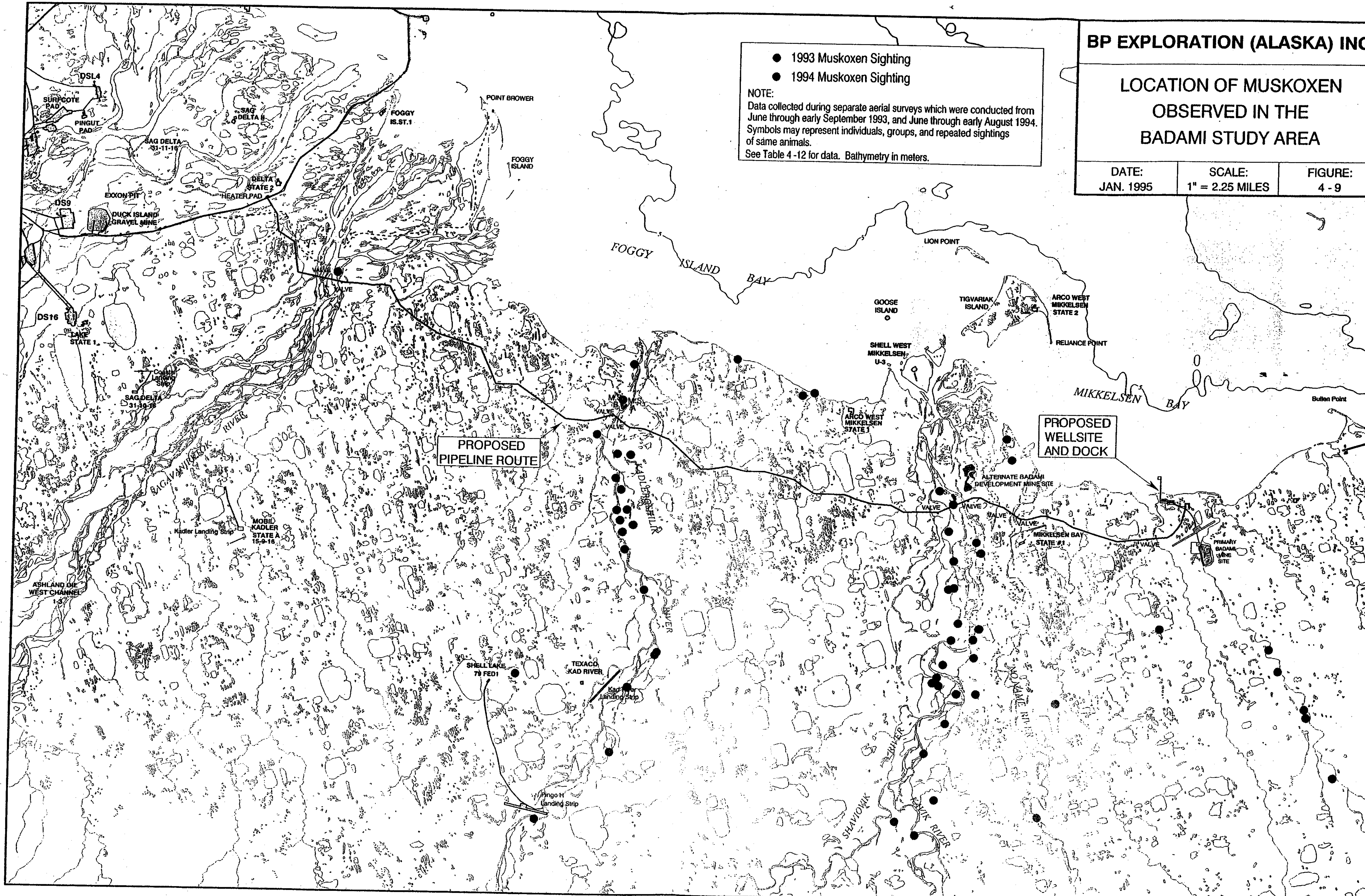
Tables 4-12A and 4-12B summarize data from aerial surveys of muskoxen conducted from June through early September 1993 and from June through early August 1994 in the study area, where the majority of muskoxen were observed along rivers (Figure 4-9). In 1993, numbers of muskoxen remained relatively low until mid- to late June. Mixed-sex groups moved up and down the major rivers in the study area throughout the summer, using riparian habitat. Similar patterns of use were documented in the 1994 surveys. No calving period surveys of muskoxen were conducted in either 1993 or 1994.

TABLE 4-12A
NUMBER OF MUSKOXEN ADULTS AND CALVES OBSERVED DURING AERIAL SURVEYS CONDUCTED FROM JUNE THROUGH EARLY SEPTEMBER 1993 IN THE STUDY AREA (FIGURE 4-9)

		NUMBER OF MUSKOXEN		
SURVEY	DATE	ADULTS	CALVES	TOTAL
1	8,10 Jun	2	2	4
2	17,18 Jun	14	0	14
3	22,23 Jun	2	2	4
4	6,7 Jul	4	2	6
5	19,20 Jul	59	12	71
6	7 Jul	99	28	127
7	5 Aug	5	1	6
8	18 Aug	64	15	79
9	9 Sep	53	13	66

TABLE 4-12B
NUMBER OF MUSKOXEN ADULTS AND CALVES OBSERVED DURING AERIAL SURVEYS CONDUCTED FROM JUNE THROUGH EARLY AUGUST 1994 IN THE STUDY AREA (FIGURE 4-9)

		NUMBER OF MUSKOXEN		
SURVEY	DATE	ADULTS	CALVES	TOTAL
1	1-Jun	45	0	45
2	6-Jun	44	1	45
3	16-Jun	10	1	11
4	5,6-Jul	7	3	10
5	11,12-Jul	17	4	21
6	19,20-Jul	27	6	33
7	25,26-Jul	31	8	39
8	28-Jul	29	10	39
9	1-Aug	31	10	41
10	8-Aug	0	0	0


BP EXPLORATION (ALASKA) INC.
LOCATION OF MUSKOXEN OBSERVED IN THE BADAMI STUDY AREA
DATE: JAN. 1995
SCALE: 1" = 2.25 MILES
FIGURE: 4 - 9
1993 Muskoxen Sighting
1994 Muskoxen Sighting
NOTE:
Data collected during separate aerial surveys which were conducted from June through early September 1993, and June through early August 1994. Symbols may represent individuals, groups, and repeated sightings of same animals.
See Table 4 -12 for data. Bathymetry in meters.
PROPOSED PIPELINE ROUTE
PROPOSED WELLSITE AND DOCK
FOGGY ISLAND BAY
MIKKELSEN BAY
POINT BROWER
FOGGY ISLAND
FOGGY IS.ST.1
LION POINT
GOOSE ISLAND
TIGVARIAK ISLAND
ARCO WEST MIKKELSEN STATE 2
RELIANCE POINT
SHELL WEST MIKKELSEN U-3
ARCO WEST MIKKELSEN STATE 1
Bullen Point
ALTERNATE BADAMI DEVELOPMENT MINE SITE
MIKKELSEN BAY STATE #1
PRIMARY BADAMI MINE SITE
VALVE
DSL4
SURFCOTE PAD
PINGUT PAD
SAG DELTA II
SAG DELTA 31-11-16
DELTA STATE 2
HEATER PAD
EXXON PIT
DS9
DUCK ISLAND GRAVEL MINE
DS16
LAKE STATE 1
SAG DELTA 31-10-16
SAGAVANIRKTOK RIVER
MOBIL KADLER STATE A 15-9-16
Kadler Landing Strip
ASHLAND OIL WEST CHANNEL 1-3
SHELL LAKE 79 FED1
TEXACO KAD RIVER
Pingo H Landing Strip
RIVER
SHAVIOVIK RIVER
NO NAME RIVER

ex12488.dgn

However, it is probable that little calving occurred within the study area boundaries based on several factors. First, few calves were observed in the study area during early post-calving surveys (i.e., early June) during both years. Secondly, most muskoxen calving between the Sagavanirktok and Canning rivers has historically occurred farther inland, from the Kavik airstrip (about 24 miles from the coast) to the confluence of the Shaviovik and Kavik rivers (P. Reynolds, U.S. Fish and Wildlife Service, ANWR, pers. comm.) south of the study area. Additionally, muskoxen calving sites are generally characterized by moderate to high relief (Garner and Reynolds 1987), and little high-relief habitat exists within the study area.

Brown Bear

Little information exists about grizzly bear use of the Badami study area before 1991. Since 1991, the Alaska Department of Fish and Game (ADF&G) oil field grizzly project has radio-collared several bears whose home ranges overlapped all or part of the Badami area (R. Shideler, ADF&G, pers. comm.). In August 1994, BPXA funded an expansion of that project to focus on the Badami area, and data gathering from that project will continue until early summer 1995.

Grizzlies were present in the Badami study area before 1991, as indicated by unconfirmed reports from Bullen Pt. DEW station personnel in the 1970s and the reported harvest of two bears in 1969 from sites along the Kadleroshilik River (ADF&G files). Since 1991, a minimum of 11 separate bears have been found in the area (Figure 4-10). An additional adult female with two dependent offspring has been observed just south of the Badami study area and in the Sagavanirktok River delta. She undoubtedly uses southern portions of the Badami area while following the Kadleroshilik and Shaviovik rivers. ADF&G also reported the sighting of a sow with three cubs (Shideler, ADF&G, pers. comm.). During the LGL aerial surveys conducted from June through early September 1993, seven brown bears were sighted, all of which were south and southeast of the study area. From June through early August 1994, LGL observed brown bears on two occasions within the study area. The bears sighted by LGL may be the same individuals reported by ADF&G.

Use of the Badami study area by grizzly bears varies as bears move to areas where nutritious forage or prey becomes more available. Long-distance movements of over 30 miles in one day are not uncommon for bears in this region, and large home ranges allow individual bears and family groups to exploit the best food sources. For example, a radio-collared female and her two offspring resided in the Badami study area for parts of each summer from 1991 to 1993, yet she also ranged southward up the Shaviovik River, to the upper Kadleroshilik River southeast of Franklin Bluffs, to Franklin Bluffs camp, and into the Prudhoe Bay oil field. These movements and home range size are typical of other bears in the region, suggesting that grizzly bears over a large area may use portions of the Badami study area.

With the exception of selection of denning sites, most grizzly bear habitat use is in response to foraging for vegetation, prey, carrion, or anthropogenic food. On the portion of the coastal plain that includes the study area, most grizzly bear use is in riparian areas or along the coast (e.g., foraging for marine mammal carcasses or preying on waterfowl). Grizzlies also feed on sedges (especially *Carex* and *Eriophorum*) and other graminoids, ungulates (moose, muskoxen and caribou as both prey and carrion), Arctic ground squirrels, microtine rodents, root plants (e.g., *Hedysarum alpinum*), berries (primarily bearberry, *Arctostaphylos alpina*, in this area), and anthropogenic foods.

Although bears use wet tundra and moist tundra seasonally for feeding when sedges are in early stages of growth, or for moving between riparian areas, the majority of the grizzly bear diet — Arctic ground squirrels, *Hedysarum*, and berries — is found in riparian habitats associated with the major rivers. Specific habitats receiving high use include forb-rich river bars (which contain root plants, bearberry, and ground squirrels), dry shrub tundra along river terraces (with ground squirrels, bearberry), and both coastal and river-delta dunes where ground squirrels are abundant. Caribou are seasonally abundant in early summer throughout the area, and muskoxen are locally abundant along the Kavik, Shaviovik, and Kadleroshilik rivers all year.

Two dens have been documented in the Badami area (Figure 4-10). Three dens have also been located in the sand dunes of the Sagavanirktok River delta within a few miles of the proposed tie-in point of the Badami pipeline with the Endicott pipeline. Dens elsewhere on the thaw-lake coastal plain have been found in pingos, river banks and terraces, low-based mounds, and raised areas around drained lake basins. None of these is in short supply in the Badami study area, suggesting that grizzly bear denning could occur throughout the area. The most important criteria for den selection appear to be a southern exposure and deep snow accumulation.

Grizzly bears in this area generally enter dens from early October to late November, with pregnant females entering first, followed by independent females and subadults, then adult males. Den exit generally occurs from early April to mid-May in approximately the reverse order of entry.

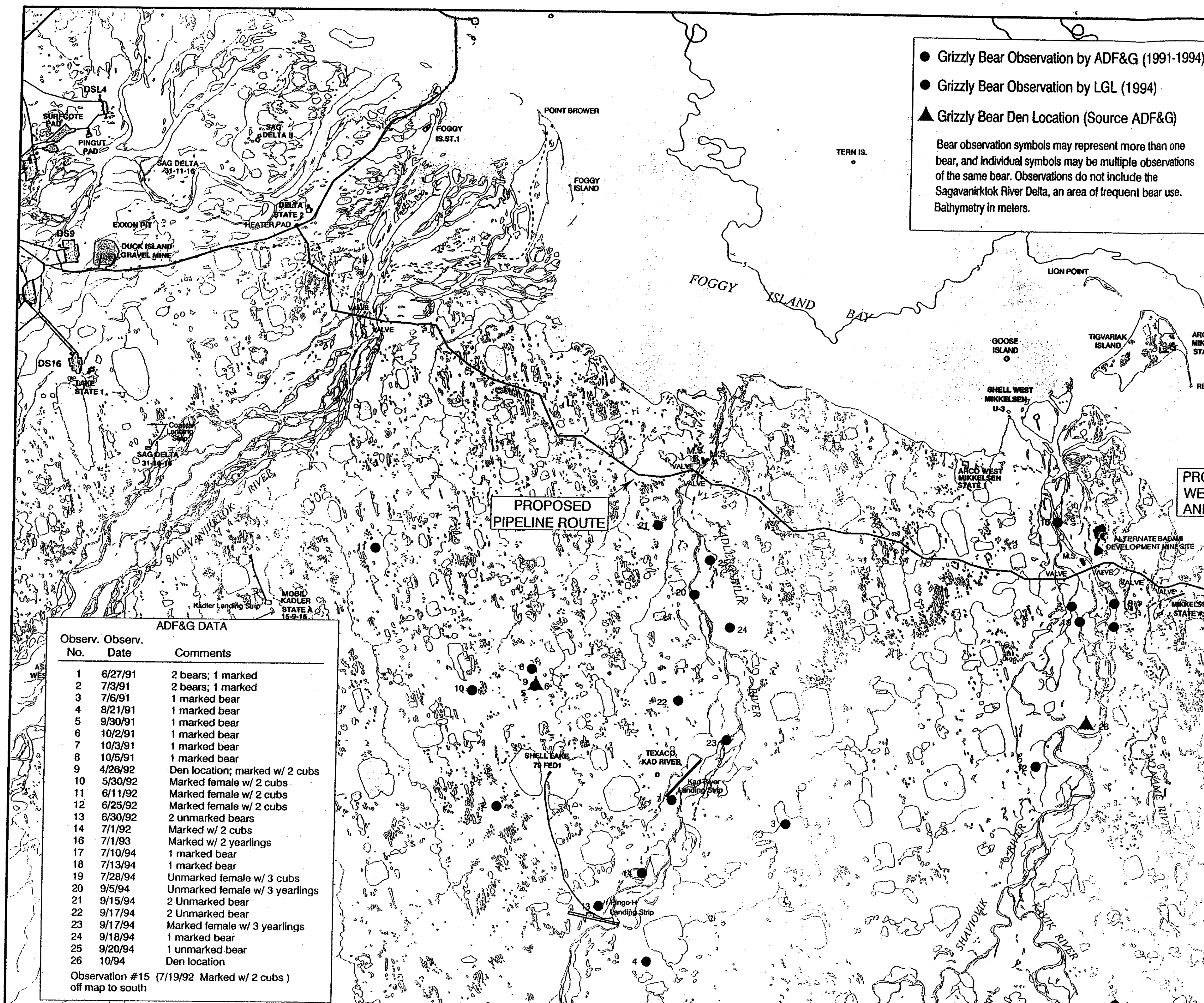
Arctic Fox

Arctic foxes, which occur across the Arctic Coastal Plain, move seasonally between summer breeding habitats in tundra and winter habitats along the northern Alaskan coast (Clough et al. 1987). The distribution and abundance of Arctic fox dens are controlled primarily by the availability of suitable landforms. Foxes choose as den sites well-drained areas that have warmer soil temperatures than surrounding areas (Smits et al. 1988). They commonly den in pingos, cutbanks along steams and rivers, and low mounds and ridges associated with high-centered polygon tundra (Eberhardt et al. 1983, Burgess and Banyas 1993). They are highly adaptable and tolerant of disturbances,

BP EXPLORATION (ALASKA) INC.

GRIZZLY BEAR OBSERVATIONS IN THE BADAMI STUDY AREA

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 2.25 MILES	4 - 10



ADF&G DATA

Observ. No.	Observ. Date	Comments
1	6/27/91	2 bears; 1 marked
2	7/3/91	2 bears; 1 marked
3	7/6/91	1 marked bear
4	8/21/91	1 marked bear
5	9/30/91	1 marked bear
6	10/2/91	1 marked bear
7	10/3/91	1 marked bear
8	10/5/91	1 marked bear
9	4/26/92	Den location; marked w/ 2 cubs
10	5/30/92	Marked female w/ 2 cubs
11	6/11/92	Marked female w/ 2 cubs
12	6/25/92	Marked female w/ 2 cubs
13	6/30/92	2 unmarked bears
14	7/1/92	Marked w/ 2 cubs
16	7/1/93	Marked w/ 2 yearlings
17	7/10/94	1 marked bear
18	7/13/94	1 marked bear
19	7/28/94	Unmarked female w/ 3 cubs
20	9/5/94	Unmarked female w/ 3 yearlings
21	9/15/94	2 Unmarked bear
22	9/17/94	2 Unmarked bear
23	9/17/94	Marked female w/ 3 yearlings
24	9/18/94	1 marked bear
25	9/20/94	1 unmarked bear
26	10/94	Den location

Observation #15 (7/19/92 Marked w/ 2 cubs) off map to south

ex12490.dgn

readily habituate to the presence of humans, will den in and near facilities, and have a high incidence of rabies endemic in the North Slope population.

Food habits of the Arctic fox vary seasonally depending on the distribution and abundance of prey species. Lemmings are the primary prey of Arctic fox throughout the year (Chesemore 1967, Eberhardt 1977), but other small mammals such as voles and ground squirrels are also taken. Carrion is especially important in winter. During the summer months, birds and eggs become an important food source, although lemmings continue to be the major prey during this period (Chesemore 1967). Arctic foxes also consume fish, insects, berries, and carrion (such as caribou and marine mammals), but these are usually not major components of their diet (Fine 1980). Where Arctic foxes come into contact with human activities and associated developments such as construction camps and oil facilities, artificial food in the form of garbage and handouts may be extensively used (Urquhart 1973, Eberhardt 1977, Eberhardt et al. 1982, Fine 1980, Rodrigues et al. 1994). The availability of artificial dens and food in developed areas may affect the survival, reproduction, and disease transmission in local populations of Arctic fox (Garrott et al. 1983).

Studies of Arctic foxes in the study area in 1992 found at least 23 dens (Burgess and Banyas 1993). In 1992, 10 of these dens were used as natal dens, while the other 13 dens were inactive (Figure 4-11).

Moose

In recent years, no formal surveys of moose have been conducted on the Arctic Coastal Plain in the area between the Sagavanirktok and Canning rivers by state or federal agencies (K. Harms, ADF&G, pers. comm.; F. Mauer, USFWS, pers. comm.). Therefore, data on moose distribution in this area are lacking. Most of the information that does exist on moose abundance and distribution on the Arctic Coastal Plain comes from studies that have been conducted in the 1002 area of ANWR. These studies have shown seasonal variation in moose distribution north of the Brooks Range. In winter, moose concentrations occur in the foothills of the Brooks Range along the Canning and Kongakut rivers, running from approximately 40 to 130 miles southeast of the Badami development area (Clough et al. 1987). In late spring-early summer, moose move northward along riparian systems. They use a variety of habitats during the summer, but the number of moose using coastal plain habitats in the 1002 area at any one time is relatively low (i.e., <25 animals) (Clough et al. 1987).

No moose were observed in the study area during the 1993 LGL surveys; however, in 1994, bull moose were seen on several occasions (Figure 4-8). A bull moose was observed midway between the Kadleroshilik and Shaviovik rivers on 26 July about 2.4 kilometers (~1.2 miles) south of the proposed pipeline route. On 28 July, a bull moose was observed in the same location as the one observed on 26 July, and another bull moose was observed adjacent to the Shaviovik River about 1.6 kilometers (~1 mile) north of the pipeline route. On 1 August, a bull moose was observed in the same area (about 3.7 kilometers [~2.2 miles] south of the pipeline route) where previous sightings of moose were made on 26 and 28 July.

Polar Bear

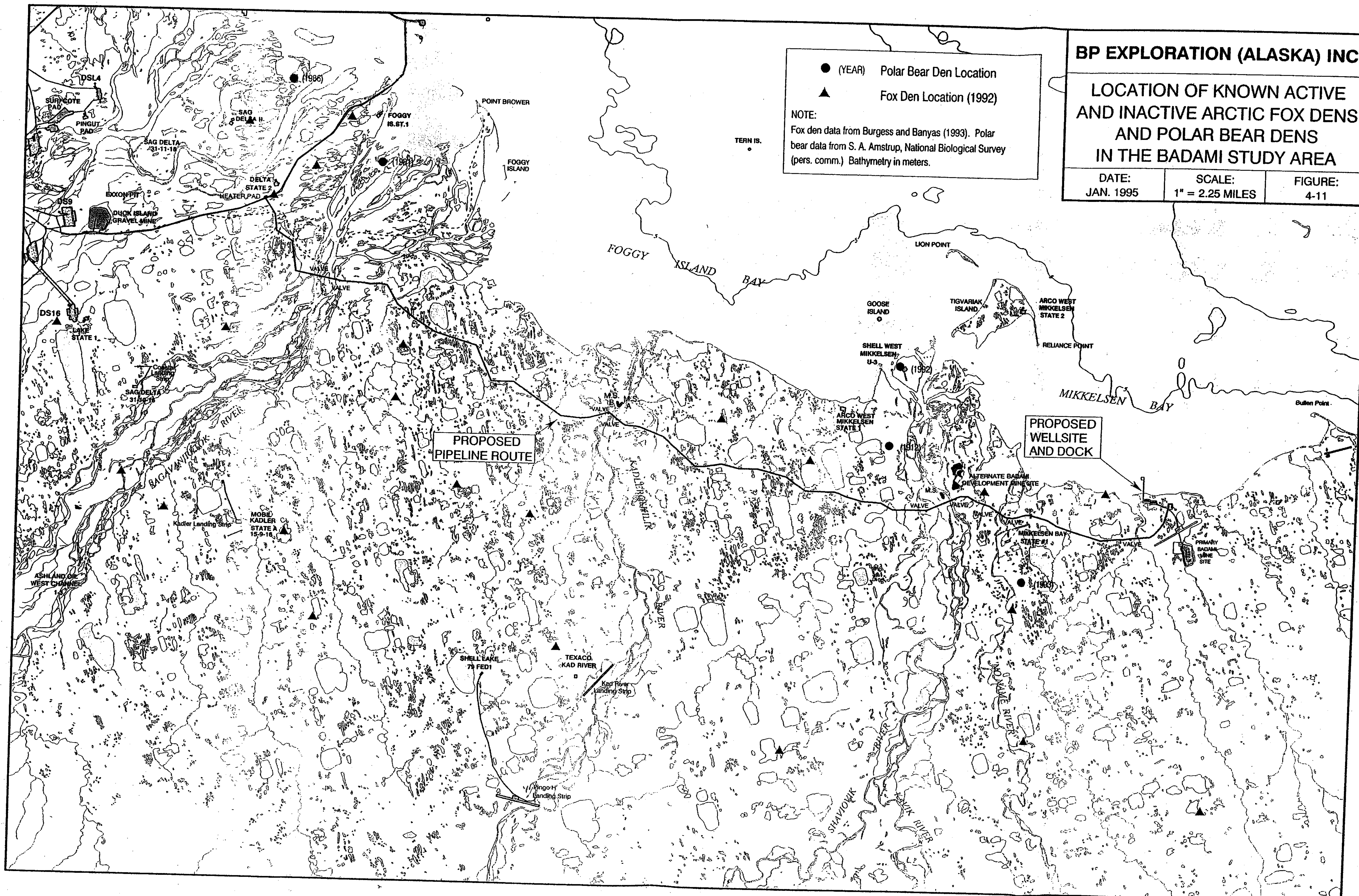
Polar bears have a circumpolar distribution throughout most ice-covered seas of the Northern Hemisphere and occur at low densities throughout these areas (Amstrup et al. 1986). Within this range, polar bears are divided into five geographically isolated populations. The Beaufort Sea population extends from the northwest Chukchi Sea northeast of the Point Lay area (located 360 miles west of Deadhorse), to the Cape Bathurst area, Canada (Lentfer 1974, Amstrup et al. 1986). Mean estimates for the Beaufort Sea population during 1972 through 1983 ranged from 1,300 to 2,500, yielding densities of one bear per 54–104 square miles.

In the study area, polar bears are present in coastal regions during the ice-covered period and infrequently during the summer. Polar bears generally prefer areas of heavy offshore pack ice (Stirling 1988), and adult males typically remain on the pack ice, rarely coming ashore (Amstrup and DeMaster 1988). However, denning females, females with cubs, and subadult males occasionally come ashore; and females with young cubs hunt in fast-ice areas. The majority of female polar bears (75 percent) den on the pack ice, but the rest den at terrestrial den sites. Most terrestrial dens are located within 5 to 6 miles of the coast. Four historical den sites have been identified within the study area (S. Amstrup, pers. comm.); none of these has been used more than once, and one den dates back to 1912 (Figure 4-11).

4.7.5 Threatened and Endangered Species

There are three threatened or endangered species in or adjacent to the study area. The only endangered or threatened species widespread in the study area is Spectacled Eider (*Somateria fischeri*). The Eskimo Curlew (*Numenius borealis*) is endangered and is close to extinction, but sporadic sightings are still reported throughout their former range from Canada to Argentina. It has not been documented in Alaska since the turn of the century. The Alaska breeding Steller's Eider (*Polysticta stelleri*) is presently being considered for listing as threatened. This species occurs in low numbers in the Prudhoe Bay area and likely occurs occasionally in the study area. The Arctic Peregrine Falcon (*Falco peregrinus tundrius*) had been listed as threatened, but the U.S. Fish and Wildlife Service removed it from the list as of October 5, 1994 (59 *Federal Register* 50796).

The Spectacled Eider was listed as threatened under the Endangered Species Act effective 9 June 1993 (58 *Federal Register* 27474). The status, distribution, and population trends of this species in the Prudhoe Bay area are summarized in Warnock and Troy (1992), TERA (1993b), and TERA (1994b). In northern Alaska, Spectacled Eiders nest



BP EXPLORATION (ALASKA) INC.

LOCATION OF KNOWN ACTIVE AND INACTIVE ARCTIC FOX DENS AND POLAR BEAR DENS IN THE BADAMI STUDY AREA

DATE:	SCALE:	FIGURE:
JAN. 1995	1" = 2.25 MILES	4-11

on the Arctic Coastal Plain at least as far east as the Okpilak River delta (Garner and Reynolds 1987). During the breeding season they favor wet coastal tundra — in particular, areas of shallow water with emergent vegetation such as occurs in drained lake basins. Within the study area, Spectacled Eiders are known to breed in the Sagavanirktok River delta (TERA 1994b) and between the Kadleroshilik and Shaviovik rivers (Nickles et al. 1987, Field et al. 1988, TERA 1994c). Suitable habitat for this species appears to become progressively more restricted from west to east through the study area. Surveys conducted in NPRA have found Spectacled Eiders more than 50 miles inland (Larned and Balogh 1994), in the Prudhoe Bay area (Warnock and Troy 1992; TERA 1993b 1994b, 1994c). Spectacled Eiders occur within at least 12 miles of the coast (the width of the survey area); but between the Sagavanirktok and the Shaviovik rivers, the range narrows rapidly, with Spectacled Eiders restricted to within 8 miles of the coast (Figure 4-12). Farther to the east, the coastal fringe occupied by Spectacled Eiders probably continues to narrow.

During surveys for Spectacled Eiders in 1994 (TERA 1994c), many sightings of this species were made on the coastal plain south of Foggy Island Bay; however, Spectacled Eiders were scarce east of the Shaviovik River. Ground surveys confirm these findings. Spectacled Eiders were not recorded on study plots in the Badami area but were present in the Kadleroshilik study area, where three nests were located. Aerial surveys undertaken in 1993 as part of other investigations also indicate relatively high use of the Foggy Island Bay coastal plain but markedly less use of areas east of the Shaviovik River (Figure 4-12, Larned and Balogh 1994, Byrne et al. 1994).

Two areas of Spectacled Eider concentration were detected: the portion of the survey area near the Sagavanirktok River delta and the area between the Kadleroshilik and Shaviovik rivers. Of these areas, only the area near the Sagavanirktok River delta was found to harbor many duck broods during a July 1994 survey. The paucity of broods in the Kadleroshilik-Shaviovik area reflects the low nest success documented by the plot studies in that region. Hatching success on duck nests monitored east of the Kadleroshilik River was approximately 5 percent.

4.7.6 Marine Benthos

Most nearshore, shallow-water areas of the Beaufort Sea (i.e., areas with water depths of 1.8 to 6 meters [~6 to 20 feet]) contain relatively diverse, predictable benthic communities year-round (Busdosh 1984; Busdosh and Robilliard 1979, 1982; Carey 1991; Feder et al. 1976; Feder and Jewett 1982; Grider et al. 1977, 1978; Robilliard and Busdosh 1979, 1983; Robilliard and Colonell 1983; Robilliard et al. 1978, 1988; Woodward-Clyde Consultants 1979, 1983). These benthic communities are subjected to a wide array of natural events previously described in Section 4.2 and 4.3, including storm waves during the open-water season, ice gouging and scour during breakup and freeze-up, large volume inflow of fresh water during breakup and occasionally during the summer, and deposition of sediment and organic material following high river discharges. The biota have adapted to these natural disturbances.

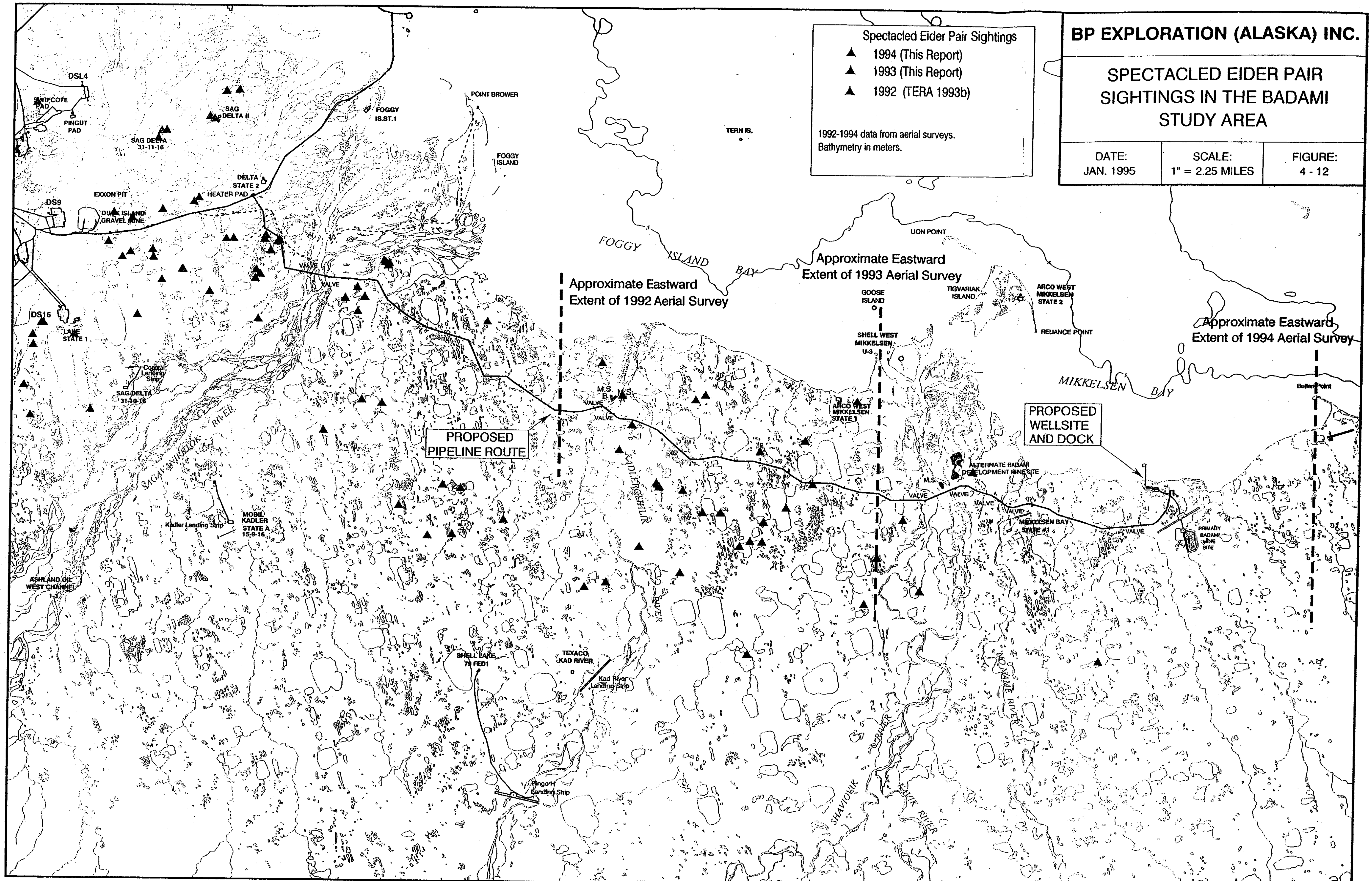
There are fluctuations in the number, distribution, and abundance of species on seasonal, annual, and longer-term bases. The type, cause, duration, magnitude, and direction of these fluctuations are not always predictable, but fluctuations can be anticipated on a year-to-year basis (ENSR 1991). The benthic infauna populations in the 1.8- to 3-meter (~6- to 10-foot) depth range are more species-diverse and abundant in the ice-free season than they are immediately after sea-ice breakup (Grider et al. 1977). During winter, the nearshore area is covered by bottomfast ice to a depth of 2 meters (~6 feet), and it is recolonized each summer by planktonic polychaete and clam larvae and more mobile epifauna such as amphipods (Envirosphere 1988).

Studies of marine benthos conducted as part of the Endicott National Pollutant Discharge Elimination System (NPDES) monitoring program from 1986 through 1990 were reviewed by Jewett et al. (in press). These studies identified 99 taxa of marine macrobenthos within the sampling area. Faunal composition changed from year to year and was related to water depth and bottom sediment composition. Faunal diversity was typically low during the 5-year study. This low diversity is characteristic of shallow, ice-stressed benthic systems in the Arctic (Dunbar 1968, Feder and Schamel 1976 in Jewett et al. in press). The marine benthic community in the Endicott study area was dynamic and subject to disturbances due to storm activity, ice gouging, and outflow from the Sagavanirktok River.

Epibenthic invertebrates were sampled in Foggy Island Bay to the west of Mikkelsen Bay in 1985 and 1986 as part of the Endicott Monitoring Program (Envirosphere 1987, 1990). Average biomass in Foggy Island Bay (range 0.4 to 0.8 grams per square meter, g/m^2) was comparable to areas to the west such as the Sagavanirktok Delta (0.1 to 1.2 g/m^2) and Gwydyr Bay (0.5 to 0.7 g/m^2). Invertebrate abundance was generally correlated with water temperature and salinity, with higher abundance in areas subject to mixing of fresh and marine waters.

4.8 CULTURAL RESOURCES

Historic and cultural resources include archaeological sites, places, and artifacts. These resources can be prehistoric or historic in nature, the differentiation relating to the time of occupation or use. Several periods of human cultural and historical development are presently recognized for northern Alaska. The Alaska Heritage Resource Survey (AHRS) file indicates that cultural resource sites located in the study area are mostly historic in age. Aerial reconnaissance of the well pad location for the Badami No. 1 exploration well in 1990 failed to find locations of potential cultural resource sites (Lobdell 1991). A baseline reconnaissance of the area between the Sagavanirktok and



BP EXPLORATION (ALASKA) INC.
SPECTACLED EIDER PAIR SIGHTINGS IN THE BADAMI STUDY AREA
DATE: JAN. 1995
SCALE: 1" = 2.25 MILES
FIGURE: 4 - 12
Spectacled Eider Pair Sightings
1994 (This Report)
1993 (This Report)
1992 (TERA 1993b)
1992-1994 data from aerial surveys.
Bathymetry in meters.
Approximate Eastward Extent of 1992 Aerial Survey
Approximate Eastward Extent of 1993 Aerial Survey
Approximate Eastward Extent of 1994 Aerial Survey
PROPOSED PIPELINE ROUTE
PROPOSED WELLSITE AND DOCK
FOGGY ISLAND BAY
MIKKELSEN BAY
POINT BROWER
FOGGY ISLAND
TERN IS.
LION POINT
GOOSE ISLAND
TIGVARIAK ISLAND
RELIANCE POINT
Bullen Point
DSL4
SURFCOTE PAD
PINGUT PAD
SAG DELTA 31-11-16
SAG DELTA II
FOGGY IS.ST.1
DELTA STATE 2
HEATER PAD
EXXON PIT
DS9
DUCK ISLAND GRAVEL MINE
DS16
LAKE STATE 1
SAG DELTA 31-10-16
SAGAVANIRKTOK RIVER
MOBIL KADLER STATE A 15-9-16
Kadler Landing Strip
ASHLAND OIL WEST CHANNEL
SHELL LAKE 78 FED1
TEXACO KAD RIVER
Kad River Landing Strip
Pingo'H' Landing Strip
KADLEROSHILIK RIVER
VALVE
M.S.
SHELL WEST MIKKELSEN U-3
ARCO WEST MIKKELSEN STATE 1
ARCO WEST MIKKELSEN STATE 2
ALTERNATE BADAMI DEVELOPMENT MINE SITE
MIKKELSEN BAY STATE #1
PRIMARY BADAMI MINE SITE
SHAVIOVIK RIVER
KAVIK RIVER
NO NAME RIVER

ex12492.dgn

Shaviovik rivers was conducted during the summer of 1993, while a more detailed reconnaissance was conducted in the summer of 1994 (Lobdell 1994).

In summer 1994, the pipeline route being considered at the time, potential material sources, and production facilities locations were surveyed by helicopter. When features of interest were seen, surface examinations were conducted. This survey resulted in the discovery of a previously unknown archaeological site of probable prehistoric age near the pipeline route and material source zone. This site (49-XPB-042) is located just east of the material source zone. The site was not tested but can be recognized by small exposures of fire-cracked rocks typical of near-surface archaeological sites throughout the region.

One previously located site, Mikkelsen Bay Village (49-XBP-028), is more than 1 mile west of the proposed project facilities. This site, which is an historic-period village site on the shore of Mikkelsen Bay, contains at least five sod house ruins, plus numerous tether posts, ice cellars, and two standing structures. During the reconnaissance, the probable ruins of an historic structure were identified just to the south of Mikkelsen Bay Village. This feature, which will not be impacted by the project, should be included in 49-XPB-028.

Two sites are located near the proposed pipeline route in the vicinity of the Sagavanirktok River crossing: a small historic structure on the east bank of the river (49-XPB-020) upstream of the pipeline crossing and a small historic boat (49-XPB-021) downstream of the crossing. The route differs slightly from that surveyed in the summer of 1994, and the sections missed will be checked in the summer of 1995.

4.9 SOCIO-ECONOMICS

Communities closest to the study area are Deadhorse, which is adjacent to the Prudhoe Bay Unit on the west, and the village of Kaktovik, located on Barter Island on the Beaufort Sea coast approximately 85 miles east of the proposed Badami well pad and 120 miles east of Deadhorse. The village of Nuiqsut on the Colville River is about 60 miles west of Deadhorse and 20 miles south of the Beaufort Sea coast. The only facility in the study area with housing is the U.S. Air Force Distant Early Warning (DEW) line station at Bullen Point. Public airports are located at Deadhorse and Kaktovik, and the James Dalton Highway terminates in Deadhorse, with no public access to the Prudhoe Bay Unit. During the ice-free season in late summer, barges can access coastal areas.

The study area is entirely within the North Slope Borough, which contains eight communities recognized under the Alaska Native Claims Settlement Act, the unincorporated community of Deadhorse, and small military installations along the coast. A home-rule borough encompassing 85,000 square miles, the North Slope Borough was incorporated July 1, 1972; and in 1992, the resident population was 8,578 (Alaska Dept. of Community and Regional Affairs, Municipal and Regional Assistance Div. 1993). The majority of residents are Inupiat Eskimos; and most live in Barrow, approximately 200 miles west of Deadhorse. Kaktovik and Nuiqsut are second class cities, with 1992 populations of 224 and 354, respectively. The population of Deadhorse and the adjacent oil field community, consisting primarily of non-residents, is variable, but in September 1993 was estimated at 2,500 to 3,000. During new construction projects, an additional 500 to 600 people may be present.

Much of the Borough's resident population is dependent on subsistence hunting and fishing (see Section 4.9.1). The oil and gas industry has been the primary employer near the study area since construction started on the Trans Alaska Pipeline in 1974. In 1993, half of ARCO Alaska, Inc.'s and BPXA's employees worked at North Slope facilities. An estimated 1,500 people work in two one- or two-week shifts. By the early 1980's, two-thirds of the North Slope Borough revenue was obtained from property taxes paid by the owner companies in the Prudhoe Bay area (U.S. Army Corps of Engineers, Alaska District and Environmental Research and Technology, Inc. 1984). In 1993, about 85 percent of the State of Alaska's revenues were obtained from taxes and royalty interests collected on oil production.

4.9.1 Land Use

Subsistence has been the traditional land use in the study area. Nuiqsut residents and some Barrow and Kaktovik residents use the Sagavanirktok River area for hunting, trapping, and whaling activities (U.S. Army Corps of Engineers, Alaska District and Environmental Research and Technology, Inc. 1984). Caribou are hunted in the delta area in late summer/early fall and upriver in winter. Nuiqsut residents use the coastline along the entire study area during the whaling season.

Kaktovik residents fish and trap along the Shaviovik and Canning river valleys (Craig 1989b). Approximately 30 percent of the onshore subsistence area used by Kaktovik residents is located on state lands throughout the study area (Clough et al. 1987). Caribou are harvested from early July to late August in the vicinity of the Canning River delta. In some years, half the caribou harvested during summer are taken from the Central Arctic Herd in this area.

Recreation and tourism occur in limited parts of the study area, and there are few participants and minimal revenues derived from these activities. Oil field workers are not allowed to hunt or hike over tundra during summer. Fishing is allowed with a fishing license. Tourists can drive or fly to Deadhorse, but can only access the Prudhoe Bay Unit and adjacent unitized operating areas with approved tour operators. Public access is allowed on state lands that are not in unitized operating areas, but there are no facilities. River rafting occurs on the Canning River east of the study area (Clough et al. 1987, U.S. Fish and Wildlife Service 1993).

Oil and gas exploration and production are the primary land uses in the study area. The North Slope Borough has zoned the proposed Badami pipeline corridor and the Mikkelsen Bay Unit as part of the Resource Development District. The rest of the study area is in the Conservation District.

4.9.2 Land Ownership

The entire study area, as shown on Figure 1-1, is patented to the State of Alaska. The state owns both the surface and subsurface (mineral) estates and has issued a number of oil and gas leases in the area. Under the terms of state oil and gas leases, the mineral lessee has a right to use as much of the surface as is reasonably necessary to develop and produce the minerals. The surface estate is reserved by the state, and such reservation allows for the issuance of road and pipeline rights-of-way to the extent that such rights-of-way do not interfere with the rights of the underlying mineral owner.

The proposed pipeline route and well pad are, for the most part, free from land status encumbrances. There are, however, four encumbrances in the study area:

- *DEW Line Site, United States Survey (USS) 4307:* Federal Public Land withdrawal pursuant to Public Land Order 1769 for land located within Section 31 (S31), Township 10 North (T10N), Range 21 East (R21E), Umiat Meridian (UM) and S4 and S5, T9N, R21E, UM. These lands are owned by the United States and are located at Bullen Point.
- *Native Allotment Applications:* These lands are tentatively approved for patent to the State of Alaska. The Bureau of Land Management is currently seeking title recovery from the state so that the lands can be certificated to the applicant. Native allottees are granted surface rights only. Underlying minerals remain the property of the State of Alaska. These lands are described as follows:
  1) *U.S. Bureau of Land Management, Fairbanks District File (F) 12053 USS8120:* Land located within S24, T10N, R17E, UM and S19 and S30, T10N, R11E, UM on the Beaufort Sea coast, about 2 miles west of the mouth of the Kadleroshilik River.
  2) *F11943 USS 9490:* Land located within S25, T10N, R18E UM on the Beaufort Sea coast, about 4 miles east of the mouth of the Kadleroshilik River.
  3) *F17445 USS 9128:* Land located within S20, S28 and S29, T8N, R18E UM. The site is on the west shore of a lake half a mile east of the Kadleroshilik River.

The study area is located within the boundaries of the North Slope Borough, and all corridors are located within the boundary of the North Slope Borough coastal zone. The western boundary of the Arctic National Wildlife Refuge is located approximately 25 miles east of the Badami area.

5. ENVIRONMENTAL CONSEQUENCES

In this section, the potential environmental impacts of the proposed Badami Development Project are described. Avoidance and mitigation measures for these impacts are discussed in Section 6. Table 5-1 summarizes the potential impact areas of the proposed development, which consist of:

- Offshore gravel placement for a dock;
- Onshore gravel placement for the drilling pad, production pad, airstrip, road, and valve pads;
- Onshore material site;
- Construction of a buried pipeline with buried river crossings; and
- Construction of a heater pad and pig receiver at the connection with the Endicott sales oil pipeline.

In addition, the potential impacts of the following project alternatives are considered:

- Elevated pipeline with elevated river crossings,
- Construction of gravel access road paralleling the pipeline route,
- Offshore gravel drilling and production island, and
- Buried subsea pipeline.

5.1 NEARSHORE STRUCTURE

A solid-fill gravel docking structure will extend approximately 2,400 feet into the nearshore portion of Mikkelsen Bay. Such a structure may have impacts on the local oceanography, fish, and marine benthos.

5.1.1 Oceanographic

The gravel fill for the dock will extend into the Littoral Zone, resulting in colder ground temperature below the sea floor, which will prevent the degradation of subsea permafrost. The surface of the dock will be elevated approximately 15 feet above sea level, which will be sufficient to provide protection from storm surges.

TABLE 5-1
SUMMARY OF POTENTIAL IMPACTS
BADAMI DEVELOPMENT PROJECT

	OFFSHORE GRAVEL PLACEMENT	ONSHORE GRAVEL PLACEMENT	BURIED PIPELINE	ELEVATED PIPELINE	GRAVEL ROAD	OFFSHORE ISLAND	BURIED SUBSEA PIPELINE
Oceanography	X					X	X
Hydrology		X			X		
Wetland Vegetation		X	X		X		
Fish	X	X	X		X	X	X
Birds		X			X		
Mammals		X		X	X		
Marine Benthos	X					X	X
Threatened & Endangered Species		X			X		
Cultural Resources		X	X	X	X		

The dock will cover 23.8 acres of seabed within the nearshore zone. Modifications to circulation patterns caused by the dock could consist of minor changes to current speed and direction of, as has been seen with the Endicott and West Dock causeways, formation of a wake eddy on the downwind side of the structure during periods of persistent east or west winds. However, unlike the Endicott and West Dock causeways, the proposed Badami structure will not cause changes to the local temperature and salinity regimes.

The Endicott and West Dock causeways are located in areas where marine and fresh water masses can interact to produce distinct temperature and salinity gradients. The structures interact with the two different water masses (fresh and marine) to accentuate the gradients or to enhance mixing of marine water with fresher water from the Sagavanirktok River, resulting in a decrease in temperature and an increase in salinity in an area adjacent to the structure. This is not expected to be the case within Mikkelsen Bay. Due to the uniform characteristics of the water mass within the bay, the structure will cause few, if any, changes to water temperature or salinity. Alterations to current flow of wake eddy formation could cause localized upwelling and perhaps outcropping of bottom water downstream of the structure. Because the water column within Mikkelsen Bay tends to be uniform, both horizontally and vertically, through the water column, formation of a wake eddy would mix waters with similar temperature and salinity characteristics. Bottom water that upwelled to the surface would have the same general properties as the surface water. Thus, strong temperature-salinity gradients will not be created, and water influenced by the wake eddy will not become colder or more saline.

Because minimal freshwater influx will occur in Mikkelsen Bay only under westerly winds, the proposed dock might be expected to sustain a small (<1–2 ppt) salinity difference across its length, due to its interruption of alongshore flow. However, any such salinity difference would soon be dissipated by a wind change, and the bay could be expected to return to essentially uniform marine conditions. Monitoring studies of the Endicott Causeway have identified similar minor and intermittent localized effects on temperature and salinity near the causeway (Morehead et al. 1993). Thus, oceanographic effects of the proposed dock will be minimal, quite localized, and therefore benign (see Section 4.5).

5.1.2 Fish

Minimal project impacts on fish in the nearshore zone are anticipated. Monitoring studies of the longer Endicott Causeway (2 miles vs. approximately 2,400 feet for the Badami offshore structure) have shown minor, localized impact on fish distribution and abundance within the region (Gallaway et al. 1991). It is likely that the Badami site is at or near the eastern limit of the dispersal ranges of both broad whitefish and least cisco populations (Fechhelm et al. 1994). Because both species seem to be intolerant of high salinities (de March 1989; Fechhelm et al. 1989, 1994), the brackish-to-marine nature of

Mikkelsen Bay would probably render it an unsuitable foraging habitat. The potential effect of the development on both populations is, therefore, expected to be minimal.

Because of the general uniformity of the water within Mikkelsen Bay, any alterations to circulation due to placement of the proposed Badami structure in the nearshore environment should not create conditions that would potentially block or delay movements of fish. Movements of large fish (i.e., large Arctic cisco, least cisco, Dolly Varden charr) are generally not altered by causeway-induced changes to temperature and salinity distribution patterns (Gallaway et al. 1991). Monitoring data suggest that small least cisco may be blocked at West Dock following a shift from westerly to easterly winds (Fechhelm et al. 1989); this occurs infrequently and has had no impact on least cisco populations (Fechhelm et al. 1994) (see Section 4.7.2). Small Arctic cisco are transported to and past Prudhoe Bay during years when northeast winds are of sufficient intensity and duration to move these fish into Alaskan waters from the Mackenzie River in Canada (Fechhelm and Griffiths 1990, Schmidt et al. 1991) (see Section 4.7.2). There is no evidence to suggest that their movements have been impacted by either the West Dock or Endicott causeways (Gallaway et al. 1991). In addition, because there is little evidence that the river systems east of Mikkelsen Bay serve as major overwintering sites for Arctic cisco, the Badami area would likely not represent a prime migratory pathway for Arctic cisco age 1 and older.

5.1.3 Benthos

Approximately 23.8 acres of the littoral zone extending from the shoreline to the 10- to 12-foot depth would be covered by placement of gravel for the proposed Badami nearshore structure. Effects on benthos inhabiting the nearshore area from the shoreline to the 6-foot depth contour would be expected to be minor because this area is recolonized annually and is subject to frequent disturbances because of storm-induced wave action and ice movements during the open-water season (see Section 4.7.6). Between the 6-foot and 10- to 12-foot depth contours, some benthos would be permanently impacted, but given the low density and diversity within the nearshore zone characteristic of the Beaufort Sea coast (see Section 4.7.6), this will not have a significant negative effect on benthos within Mikkelsen Bay. Total coverage within the nearshore zone in the bay would be less than 0.18 percent (23.8 acres/13,580 acres) of the total bottom area of Mikkelsen Bay (see Section 4.3).

Based on the results of a five-year study of drilling discharges from the Endicott drilling islands (ENSR 1991), it is anticipated that benthos in adjacent areas are not likely to be affected by changes in depositional and erosion patterns that may result from the presence and maintenance of the proposed structure.

Although they tend to be localized and more intense, activities such as those listed below cause physical changes that are similar to those caused by natural events.

- Dredging and dredged material disposal for placement of docks, manmade islands, and causeways;
- Placement of gravel-fill structures, such as docks and causeways, that alter local water-flow patterns, and thus the deposition (or erosion) of sediment and organic material;
- Maintenance of gravel-fill structures by placement of sand and gravel, some of which is eroded and then deposited in the nearby benthic community each open-water season; and
- Tug-and-barge movement during the open-water season.

5.2 ONSHORE FACILITIES REQUIRING GRAVEL PLACEMENT

Onshore facilities requiring gravel placement include the drilling pad, production pad, airstrip, road, and valve pads. The working surface for these structures will be elevated 5 feet or more above ground level depending on local topography. The active layer beneath the gravel will be reduced to a narrow zone near the existing ground surface. This reduction of annual thaw into the ice-rich soils removes the risk of thaw settlement under the gravel fill. The potential for thermal erosion due to blockage of surface-water flow can be minimized with proper culvert design and facility layout.

Development of the East Badami Creek material site will result in loss of tundra wetlands that will be replaced by a large, deep, freshwater lake.

5.2.1 Hydrology

Blockage of Flow

There will be minimal impacts on rivers and floodplains because the Badami pipeline will be underground. In addition, the pads, airstrip, the short access road between the material source and the Badami facilities, and the pipeline trench cap will be designed and built to avoid drainage problems. The potential impacts are (1) blockage of natural drainages by road embankments and the trench cap, resulting in ponding upstream and drying downstream; (2) concentration of flow by culverts and berm breaks and subsequent erosion of disturbed ground; and (3) scour at culvert and berm break outlets.

There is a potential for the road and trench cap to block overland sheet flow and flow in defined drainages. Sheet flow must be collected into channelized flow and conveyed under the road embankments and through the trench cap. For small drainages this is accomplished with culverts and berm breaks, which can be installed to prevent ponding of water along the upstream side of embankments. To eliminate or minimize the effects of blockage of minor waterways, all drainages will be identified as part of the road and trench design so that culverts and berm breaks may be properly located.

Culverts and berm breaks tend to concentrate flow that would otherwise be dispersed over a wider area. There is no practical way to redisperse flow once it is conveyed through a road or berm. This concentrated flow tends to erode, forming a new channel if the flow intensity is higher than the erosion resistance capability of receiving terrain. Soils within the study area tend to be ice-rich sands and silts that are highly erodible.

Culverts for the road will be designed to limit headwater and water velocities to non-eroding limits. Erosion by concentrated flow may be further reduced by placing an erosion prevention mat (such as a 6- to 12-inch-thick grout-filled fabric apron) on the streambed downstream of the culvert outlet, by choosing an alignment with well-defined existing drainages, or by providing sufficient culverting so that concentration of flow is minimized. Berm breaks will be installed in the pipeline trench cap at intervals designed to limit, to the extent possible, interruptions to surface flow during the first year after pipeline construction. Settlement and maintenance of the cap during the first and subsequent summers to the final design height of about 6 inches above the tundra surface will reduce the potential for blockage of cross-trench flow during breakup and following significant storm events during late summer. Additional details on the maintenance and revegetation of the pipeline trench cap are included in the Badami Pipeline Right-of-Way Application.

Concentration of flow at culverts in streams has the potential to create a scour hole immediately downstream of the outlet. Impacts on fish are discussed in Section 5.2.3. Scour at culverts can be reduced by placing an erosion prevention mat over the area of anticipated scour downstream of the culvert outlet.

Development of the primary Badami material site will disturb parts of the stream channel and adjacent tundra at "East Badami Creek." Rehabilitation of this site (see Section 3.7) will result in creation of a small (approximately 72 acres) fresh water lake with a depth of up to 40 feet, depending on the gravel quantity and quality. Several small gravel extraction sites at the Shaviovik and Kadleroshilik rivers will disturb some stream bed within and adjacent to the active channels in these rivers; however, these small sites are expected to be flooded during breakup following construction.

Water Quality

Erosion and scouring in streams cause sediments to be transported downstream. Measures discussed above to reduce erosion and scouring resulting from concentrated flow of water through culverts will also protect water quality.

All work at river crossings will be conducted during winter. River crossing sites will be surveyed to determine the depth of water and ice prior to commencing work. It is anticipated that no free water will be encountered at any of the minor stream crossings or at the crossing sites for the Kadleroshilik, Shaviovik, and No Name rivers because of the extremely low water levels in most North Slope streams and rivers at the time of freeze-up. Due to the depth of the channel, the crossing site for the east channel of the Sagavanirktok River will likely have flowing water. Construction of the pipeline trench will result in significant disturbance to the river bed and alterations of water quality within the construction area. All these impacts will be highly localized, however, and changes to water quality downstream of the construction site are expected to be minor due to the shallow nature of the braided channel system of the Sagavanirktok River.

5.2.2 Vegetation and Wetlands

The proposed onshore gravel structures include a drilling pad, production pad, an airstrip, an access road connecting the material site to the airstrip and drilling and production pads, and a total of nine valve pads. Development of the East Badami Creek material site will also result in disturbance to tundra wetlands. Total acreages of tundra wetlands covered by these facilities are summarized in Table 5-2 (the acreages exclude the coverage by valve pads, which are shown later in Table 5-3). As shown on Table 5-2, IV (moist/wet tundra complex) and V (moist or dry tundra) are the primary wetland types affected by the approximately 175 acres of gravel coverage for facilities and disturbance for the material sites (exclusive of valve pads and heater pad). These two types represent over 74 percent of the area covered.

5.2.3 Fish

None of the segments of the proposed Badami access roads crosses streams that are likely to support significant numbers of either fresh water or anadromous fish. However, culverts will be designed to meet the fish passage requirements of the Alaska Department of Fish and Game as determined by site-specific conditions (G.N. McDonald and Associates 1994).

As discussed in Section 4.7.1, charr is considered the only major anadromous fish species in the region between the Sagavanirktok and the Canning rivers, and Arctic grayling is the most common resident species. Measures taken to insure fish passage by charr should also protect Arctic grayling. Based on currently available information (Griffiths and Gallaway 1982; Biosonics 1984; Critchlow 1983; Griffiths et al. 1983; Woodward-Clyde Consultants 1983; Moulton et al. 1986; Cannon et al. 1987; Glass et al. 1990; Reub et al. 1991; LGL 1990, 1991, 1992, 1993a), it is doubtful that the Dolly Varden charr populations of study-area rivers will be affected by the Badami Development.

TABLE 5-2
SUMMARY OF VEGETATION COVERAGE BY GRAVEL FILL
BADAMI DEVELOPMENT PROJECT*
(Acres)

FACILITY	VEGETATION TYPE (WALKER ET AL. 1983)												
	Ia	IIId	IVa	Va	Vd	Ve	IXb	IXc	Xa	BS	XIc	TOTAL	% OF TOTAL
AIRSTRIP			1.51	25.35	11.45	1.43						39.75	22.81
CPF	0.04		2.41	11.24								13.69	7.86
MATERIAL SITE													
Development	6.6		43.97	2.53	2.19		15.01	0.29	1.10			71.68	41.13
Maintenance			0.74	4.90								5.64	3.24
Overburden	0.02		0.23	6.06	2.13	2.84	0.38	0.33				12.00	6.88
TOTAL MATERIAL SITE	6.62		44.95	13.49	4.32	2.84	15.39	0.62	1.10			89.32	51.26
ROADS													
Airstrip to CPF		0.44		1.73	1.16	0.16						3.49	2.00
Airstrip to Maint. Pit				1.54								1.54	0.88
Well Pad to Dock				0.83						0.07		0.90	0.52
Well Pad to CPF		1.87		0.66								2.53	1.45
TOTAL ROADS		2.31		4.76	1.16	0.16				0.07		8.46	4.86
WELL PAD	2.01	16.71	0.16	3.80							0.37	23.04	13.22
TOTAL	8.67	19.02	49.02	58.64	16.92	4.44	15.39	0.62	1.10	0.07	0.37	174.26	100.00*
% of TOTAL	4.98	10.92	28.13	33.65	9.71	2.55	8.83	0.36	0.63	0.04	0.21	100.00*	

*Exclusive of valve pads and heater pad (see Table 5-3)

5.2.4 Birds

The primary impacts to birds are expected to be loss of habitat, disturbance, and decreased nest success. Impacts are expected to be of greatest concern during the breeding season. Habitat loss includes direct loss from gravel placement and secondary changes to adjacent areas resulting from altered drainage, dust deposition, or thermokarsting. In most studies, it is impossible to isolate bird response to these factors individually and the additional factor of disturbance from vehicles and activities on the facilities; therefore, all are treated as a composite "habitat" impact.

During the pre-nesting season, dust from roads creates an early melt zone that increases habitat availability for birds, and high bird use is generally found during the brief period of snowmelt (e.g., Troy 1988). Anderson et al. (1992) found that shifts in distribution of waterfowl attributable to avoidance of increased noise are only apparent during prenesting. During the post-breeding season, bird use of roadside areas tends to be higher than areas away from facilities (TERA 1993a); therefore, impacts at this time of year are not of concern.

Several studies have documented avoidance of oil field roads and pads by birds (e.g., Troy and Carpenter 1990, Troy 1993, TERA 1993a). As a group, shorebirds appear more sensitive to oil field structures than are waterfowl (Murphy and Anderson 1993, Troy 1993, TERA 1993a). Except for special cases in which deep and permanent impoundments preclude nesting, the worst-case impact for species such as Semipalmated Sandpiper is approximately a 50 percent reduction in nest densities within 330 feet of roads (such as the Spine Road) (TERA 1993a). However, in developments where relatively little habitat is lost due to roads and small pads, it appears that birds displaced by gravel deposition and changes in adjacent habitat remain to nest in nearby areas (Troy and Carpenter 1990). Therefore, there are no apparent population consequences of this habitat loss. Impacts from the proposed Badami Development are expected to be localized to the immediate vicinity of the gravel fills and result in minor displacement of breeding birds, with no population-level impacts expected.

There is concern that oil fields result in increased Arctic fox abundance, due primarily to supplemental food availability, and that this results in decreased nest success of tundra-breeding birds because of increased predation from these foxes. While this series of linkages is plausible, only the criteria that foxes take advantage of supplemental food and that they can be important nest predators have been unequivocally established.

5.2.5 Mammals

The proposed onshore gravel facilities for the Badami Development will not affect movements of large mammals (e.g., bears, caribou, muskoxen, and moose), although there may be some avoidance of the area by some species due to operations and drilling-related disturbance. However, some species may be attracted to facilities to seek relief from insect harassment (caribou) or because of availability of attractants such as food (bears, foxes). Additional detail on potential impacts to large mammals is presented below.

Caribou

The major potential impacts of the project on Central Arctic Herd (CAH) caribou are displacement of maternal caribou from a portion of their calving grounds and blockage of caribou movement during the insect season. While use of calving areas varies greatly among years, the northern portion of the traditional calving grounds located east of the study area is used less frequently. The coastal location for the pipeline route has little potential for interference with caribou during the calving period, because it intersects only the most northern portion of the traditional calving grounds. Potential disturbance to caribou is associated with the presence of traffic on adjacent roads, rather than an isolated pipeline (especially one that is buried).

Muskoxen

Potential impacts to muskoxen are displacement during calving and blockage of movement, particularly along riparian corridors. As described in Section 4.7.4, calving areas and wintering areas are south of the study area. The proposed buried pipeline will not interfere with muskoxen movements along, or use of, riparian areas.

Moose

Because relatively few moose are found in the project area, major impacts to this species are not anticipated.

Brown Bear

Potential impacts of the project on grizzly bear use of the area include: (a) attraction of bears to facilities and construction activities, and subsequent elimination of the bears; (b) disturbance of bears during denning; and (c) increased access for bear harvest.

Bears attracted to project facilities and activities might be killed in defense of life or property or might consume toxic substances such as antifreeze or lubricants. Although some, usually subadult, grizzly bears may be attracted out of curiosity, the primary attraction is food such as putrescible garbage. Some bears may have previous experience obtaining such food elsewhere (such as around Prudhoe Bay) and may be attracted to the site because of their learned association of human activity with food. Even without anthropogenic food sources, bears can destroy enough essential property such as power or communication cables or monitoring equipment that the bear would have to be eliminated. Because the current plans call for a continuously, but minimally manned facility, there will be the potential for a continuous source of attractants for bears. Special efforts will be made to eliminate availability of garbage and other anthropogenic substances that bears may ingest.

Bears may also be attracted to facilities that artificially enhance populations of a preferred prey such as ground squirrels. In the existing oil fields, the abundance of gravel pads and putrescible waste has had a secondary effect of providing denning habitat and food to artificially elevate ground squirrel populations (D. Shideler, ADF&G, pers. obs.). Facilities such as permanent gravel pads at the Badami site will be limited in extent; therefore, artificial increases of ground squirrel densities would have a potential but negligible effect on bear populations in the area.

Den disturbance could have the relatively low-intensity effect of increased energy loss as bears are aroused more or the high-intensity effect of den abandonment. Increased arousal would likely affect only bears that enter hibernation in poor physical condition or that experience greater energy loss over winter, such as females giving birth. Severe disturbance could cause bears to abandon dens. A bear abandoning a den during the early denning period may be able to successfully establish a new den. Later in the denning period, abandonment would be more critical, especially to pregnant females, which give birth to cubs in late December or early January and which cannot move newborn cubs to new sites.

Aircraft overflights, pipeline construction and seismic activities, and processing facilities in the Badami area are potential sources of noise that may disturb denning bears. The latter is unlikely to have an effect because processing is year round, and bears sensitive to the level of disturbance can avoid the area during den selection. Aircraft overflights could cause a chronic but low level of disturbance, but flight paths can be established to avoid known dens to the extent practicable for safety and operational reasons, as has been done with several exploration drilling projects in the region. Construction activity can cause short-duration but intense disturbance for bears denning very near the center of activity. Evidence to date suggests that most denned bears are very tolerant of construction and seismic activities more than 0.5 to 1.0 miles away, and some bears have not abandoned dens in response to disturbances at much shorter distances. Although unlikely to affect more than a few bears, such activities could be significant to those individuals.

Access to the Badami area by potential bear hunters in fixed-wing aircraft is presently restricted to a few airstrips left from previous exploration projects. An increase in such facilities, such as the road from the gravel mine to the processing site, has the potential to increase access by aircraft during operations and after abandonment. This could result in a minor increase in harvest, but would have a negligible impact on the bear population in the region.

Arctic Fox

Arctic foxes have been shown to be extremely tolerant of human activities associated with oil development at Prudhoe Bay (Garrott et al. 1983). They have been able to occupy the Prudhoe Bay area and successfully reproduce there, concurrent with extensive development (Eberhardt et al. 1982, Garrott et al. 1983, Burgess and Banyas 1993). Arctic foxes have shown little avoidance of heavily traveled roads or noisy equipment (Eberhardt et al. 1982). The pipeline route has the potential for coming into close contact with existing fox dens; however, features with high potential for denning habitat, such as pingos and cut banks, will be avoided. Measures will be implemented to avoid increasing the population by artificially increasing the food supply.

Polar Bear

Most polar bears seen will be casual visitors to the study area. Potential impacts are loss of denning habitat, encounters with humans, and ingestion of harmful substances. There is no indication that elevated pipelines by themselves are a disturbance to polar bears, and there is no reason to believe that a buried pipeline will have any impact on these animals. Measures will be implemented for minimizing polar bear/human encounters and ingestion of harmful materials. There are no consistently used polar bear dens near the proposed Badami wellsite. The proposed pipeline route avoids areas of marked topography which could serve as suitable polar bear denning habitat. The effects of disturbance of denning polar bears are the same as those described for denning brown bears. Four dens identified in the study area have each only been used once (in 1912, 1981, 1992, and 1993). An additional den site used in 1986 was identified in the Sagavanirktok River delta just west of the study area.

5.2.6 Threatened and Endangered Species

Spectacled Eiders are subject to the same types of concerns generally afforded other species of birds on the North Slope. These concerns include the potential for decreased populations (or impediment to recovery) due to habitat loss, disturbance of birds, and decreased productivity. Decreased productivity is generally a secondary effect arising from increased predator populations reducing nest success. Protection measures can be expected to be applied more conservatively in areas harboring Spectacled Eiders than other tundra-breeding birds in general, because these birds are currently listed as threatened under the Endangered Species Act. The U.S. Fish and Wildlife Service has developed preliminary protection guidelines for new developments within the breeding range of Spectacled Eider. These measures include:

- Prohibiting high-noise facilities, such as gathering centers and airports, within 0.6 mile of nest sites;

brood-rearing geese, swans, and other waterfowl such as Spectacled Eiders should not be altered by the elevated pipeline (e.g., Johnson 1991, TERA 1994b).

An elevated onshore pipeline would not alter natural tundra drainage patterns, and no, or very limited, habitat restoration would be required following pipeline construction.

Caribou

Pipeline elevation is the design feature that would allow free passage of caribou during north/south movements across the route, as well as movements parallel to the coast. The pipeline would have an average elevation of 5 feet from the ground surface to the bottom of the pipeline, depending on local topography; and the pipeline would be buried at major river crossings. With the use of these mitigation measures, no CAH population-level impacts or changes in calving distribution or access to insect relief habitat are anticipated. The CAH caribou are in contact with roads and facilities in the Prudhoe Bay area, and the herd has grown for 14 years at rates exceeding or equal to herds not in contact with oil development (Ballard and Cronin 1994). The CAH has continued to grow to the present, although the rate of growth has decreased since about 1990 (Cameron 1993).

Muskoxen

The elevated pipeline would be buried at river crossings; and few impacts to riparian vegetation are expected to result from construction activities. There is some uncertainty how muskoxen will respond to an elevated pipeline; however, limited experience in existing North Slope oil fields suggests that muskoxen will move freely beneath elevated pipelines.

Moose

It is possible that the pipeline may interfere with north-south movements by moose; but because moose tend to use river drainages as travel corridors, the buried river crossings should facilitate free passage by moose.

5.5.2 Elevated River Crossings

Elevated river crossings would be constructed using strengthened vertical support members (VSMs). These VSMs would not significantly alter river flow; there may be some slight adjustments to flow as gravels and other debris as the active channel is reworked during the breakup following construction. The pipeline would be elevated such that there would be no impacts to movements of caribou or muskoxen within the river channels.

Bridges to be used to carry the elevated pipeline across major channels of the Sagavanirktok, Kadleroshilik, Shaviovik, and No Name rivers would be designed to provide fish passage.

5.5.3 1,200-Foot Dock

An alternative to the 2,400-foot dock, which will reach water depths sufficient for the barges that will bring production modules to Badami, is a 1,200 foot dock, which would require dredging to maintain a channel deep enough for the barges. The impacts of the shorter dock are similar to the longer one, with the additional impacts of the dredging and spoil disposal.

Dredging causes a physical change similar to ice scouring, but dredging probably moves more sediment and "gouges" a deeper furrow than does the sea ice on a local scale in shallow water. Dredging a channel to the proposed Badami dock will probably cause such a disturbance; however, studies of benthic infauna along the Beaufort Sea coast indicate that the communities are resilient and tolerant of such changes. Under natural conditions, the area between the shoreline and the 2-meter (~6-foot) isobath will likely contain bottomfast ice each winter, and such areas are recolonized each year (Envirosphere 1988). Thus, no extensive, permanent damage to the benthic habitat is likely to occur as a result of dredging or disposal of dredge spoils. However, short-term turbidity impacts would occur. Dredging and dredge spoil disposal are estimated to impact about 30 acres of seabed within Mikkelsen Bay in the immediate vicinity of the 1,200 foot dock.

5.5.4 Offshore Production/Drilling Island

The option of building a man-made gravel production/drilling island at the end of the Badami dock would result in impacts similar to those of the dock itself, but with the additional coverage of approximately 26 acres of seabed.

5.5.5 Buried Subsea Pipeline

Construction of a buried subsea pipeline from Badami production facilities in Mikkelsen Bay to the existing oil transportation system at Endicott would result in short-term impacts similar to those caused by dredging. A corridor of seabed approximately 50 feet wide and 25 miles long would be excavated for pipeline placement and refilled with gravel and spoil materials. Local benthos present along the construction corridor would be destroyed, but the area would be recolonized rapidly following completion of construction activities. No permanent alterations to local community structure would be anticipated for this highly dynamic and resilient area.

5.6 GENERAL IMPACT

The following discussion addresses impacts that are common to all project alternatives. These impacts include cultural, socio-economic, land use, land ownership, air quality, solid waste, contaminated sites, and hazardous waste.

5.6.1 Cultural Resources

The results of the cultural resources reconnaissance survey of the proposed Badami pipeline and facilities were negative within the proposed use area. No archaeological, historical, or physical properties of ethnographic sites were noted. The Mikkelsen Bay village site (49-XPB-028), which might be deemed significant under criteria of the National Register of Historic Places, can be avoided easily. The reconnaissance suggests that the project will be more than a mile east of this site. The pingo locality discovered during the reconnaissance (49-XPB-042) is to the north of the pipeline route and to the east of a material source area. Two other sites are located near the pipeline alignment at the Sagavanirktok River. These sites (49-XPB-020 and 49-XPB-021) can be avoided easily.

No surface sites or indications of buried cultural sites were noted in the project footprint. Further discovery efforts for any deeply buried cultural resource sites are not advisable because deep and large-scale subsurface testing would result in thermokarst damage to the tundra. Additionally, the probability of finding such archaeological resources is low.

If cultural resources are discovered during construction, any work that may damage these resources will be halted, and the State Historic Preservation Officer and the North Slope Inupiaq History, Language, and Culture Commission will be contacted. Following consultation, a decision will be made to avoid, protect, or remove the resource, utilizing appropriate scientific excavation, recording, or testing.

Secondary impacts to cultural resources include damage to cultural resources and the heritage resource record from unauthorized visitation to, increased pedestrian traffic upon, looting of, or contamination of cultural resources sites. Secondary impacts may occur to sites not directly in the path or footprint of a project, but in close enough proximity to be damaged by the aforementioned activities. All project personnel will receive training on the importance of cultural resources and will be instructed to avoid these sites. The lack of a permanent access road along the pipeline route means that year-round access will not be available.

Cumulative effects to cultural resources in general are more difficult to determine and depend completely on projected primary and secondary effects coupled to proposed mitigation measures. In accordance with state permit stipulations, cultural resource sites will be avoided, protected, or removed utilizing appropriate scientific excavation, recording, or testing. As a result, there should be no cumulative effect to the record of cultural resources.

For the proposed project, no restrictions have been recommended for future development and planning.

5.6.2 Socio-Economic Impacts

The Badami Development would provide significant economic benefits to the North Slope Borough, the State of Alaska, and the United States. The State of Alaska stands to benefit directly by the infusion of capital expenditures into the economy, leading to the creation of jobs. Over the estimated life of the project, additional benefits will accrue to the State through the payment of royalty, severance tax, income tax, and ad valorem tax, some of which would accrue to the North Slope Borough.

The benefits will occur at a time when State revenue, heavily dependent on production from the large North Slope oil fields, such as Prudhoe Bay, Kuparuk, and Endicott, will be declining. Badami will not by itself offset these declines, but it will mitigate the severity of the decline.

5.6.3 Land Use

The proposed project is consistent with existing oil and gas exploration and production activities in and adjacent to the study area. At the request of BPXA and following Planning Commission review and public hearings, the North Slope Borough has rezoned the Badami Unit and the proposed pipeline corridor from a Resource Conservation District to a Resource Development District and Transportation Corridor District.

Subsistence use of the area will not be affected by the project. The project will provide no additional access to the area for non-residents who might fish and hunt and thus affect the resources used for subsistence (see Badami Pipeline Right-of-Way application for additional details on protection of public property and subsistence uses).

5.6.4 Land Ownership

None of the proposed project facilities will be constructed on the DEW Line site at Bullen Point or in the areas for which applications have been submitted for native allotments. All proposed facilities are on state land.

5.6.5 Air Quality

Air emissions for the Badami project will be evaluated to determine if they exceed Prevention of Significance Deterioration (PSD) levels. For any pollutant that exceeds significance levels, the permit application will demonstrate that anticipated project emissions will be below applicable National Ambient Air Qualitv Standards and PSD increments. The assessment of air quality effects will be conducted using the dispersion model approved by the U.S. Environmental Protection Agency. Air quality-related values (AQRV) such as visibility, local vegetation, threatened and endangered species, and population growth will also be reviewed; and as required, a Best Available Control Technology (BACT) assessment will be conducted on emissions sources.

5.6.6 Solid Waste

Solid wastes generated during construction and operation of the Badami Development will be disposed of on site and/or backhauled to the Prudhoe Bay oil field for disposal. Drilling wastes (spent muds and cuttings) will be ground and injected on site or if necessary, backhauled to the CC-2A facility at Prudhoe Bay for disposal. Other construction waste, such as wood debris, insulation, and scrap metal, will be taken to Prudhoe Bay for recycling or disposal at North Slope Borough-operated facilities. Food wastes will be stored in animal-proof containers prior to disposal on-site or at an approved facility at Prudhoe Bay.

5.6.7 Contaminated Sites

The proposed pipeline route and wellsite do not appear to contain any contaminated sites. If abandoned airstrips or gravel pads are used for camps, staging, and transportation during construction, they will be inspected and any existing contamination will be documented prior to use. Potential contamination will be reported to the appropriate agencies as required.

5.6.8 Hazardous Waste

Very small volumes of hazardous waste are likely to be generated during construction and operation of the Badami Development. All hazardous wastes will be properly identified, labeled, packaged, and then shipped to approved disposal facilities in accordance with all applicable regulations. Measures will be implemented to minimize spills of hazardous substances.

5.7 CUMULATIVE IMPACTS OF OTHER DEVELOPMENTS

The proposed Badami development will be the first oil and gas production east of the Sagavanirktok River, and it will extend oil field infrastructure approximately 30 miles to the east of the existing North Slope fields. Because of the project design, specifically the lack of an access road, the compact nature of the facilities, and the remote location of the proposed Badami project relative to existing North Slope oil fields, additional cumulative impacts from construction and operation of the project are expected to be minor.

The most significant impacts will include coverage of tundra and nearshore seabed with gravel, surface disturbance from excavation and backfill of the pipeline trench, development of the East Badami Creek material site, and minor localized disturbance related to construction and operations activities. These impacts will be mitigated through pre-project planning and design and by application of standard North Slope operating procedures. The primary habitat enhancement feature will be creation of approximately 72 acres of overwintering habitat for freshwater and, possibly, anadromous fish, following reclamation of the East Badami Creek material site.

Some potential exists that development of this field could increase the economic feasibility of other regional oil and gas prospects due to construction of infrastructure in a previously undisturbed area. Because the proposed Badami Pipeline will be operated as a common carrier, it must accept petroleum from other sources for transportation to market. Once this pipeline is constructed and in operation, previously uneconomical oil or gas fields may become economically viable. BPXA and other oil and gas companies have dedicated a considerable amount of effort to find new oil and gas reserves in the general area east of Prudhoe Bay. BPXA drilled two exploration wells (Sourdough and Yukon Gold) in 1994 and is likely to continue exploration of this area. The Kuvlum prospect lies offshore and northeast of the Badami field, and the western boundary of the Point Thomson Unit, which is a high-pressure gas field, is about 6 miles east of Badami.

The cumulative impacts of any potential future activities are difficult to define in the absence of project-specific alternatives and reconnaissance data. In the absence of any conclusive information that indicates development is reasonably likely near or beyond the Badami development area, additional impacts, other than those identified in the proposed plan, would be speculative at this time. However, continued exploration and development of other eastern North Slope prospects will require numerous state, federal, and local approvals. These review processes would evaluate the cumulative impact of future exploration and development.

6. MITIGATION

This section describes the mitigation measures considered in the design of the proposed Bàdami Development Project. Overall project impacts have been minimized through careful design and planning of the project. These design measures are summarized in Table 6-1. Mitigation and avoidance measures during construction and operation are listed in Table 6-2, and details on these measures are discussed in Sections 6.1 and 6.2 below.

The primary design features of the proposed Badami Development that in most cases eliminate or that significantly reduce project impacts include:

- Production of a nearshore reservoir from a single onshore production well pad,
- No access road paralleling the sales oil pipeline (elimination of gravel fill in over 350 acres of tundra wetlands),
- Minimal fill placement in higher-value habitats,
- Minimal facility size,
- A dock for site access, and
- Incorporating pre-construction environmental assessment information into project design.

6.1 MITIGATION OF CONSTRUCTION IMPACTS

To minimize environmental impacts, all construction involving on-tundra activities will take place during winter. These include pipeline construction from ice roads and ice pads, burying the pipeline at the four major river crossings, access to and development of the gravel source in the vicinity of the Badami wellsite, and construction of the pads, airstrip, in-field access road, and dock. By conducting all major construction activities in winter, disturbance of wildlife will be negligible, and impacts to tundra, other than those specifically authorized by permit, will be minimized. Appraisal and development drilling on the Badami well pad will be conducted year around in the same manner as for wells in the other North Slope oil fields. Minor displacement of some breeding birds due to placement of fill for the pads and road and to noise and activity associated with the drilling and production operations will occur at the Badami

TABLE 6-1
BADAMI DEVELOPMENT PROJECT
AVOIDANCE AND MINIMIZATION OF ENVIRONMENTAL IMPACTS

DESIGN

ACTION	BENEFIT
Minimized facility size; initial 35' wellhead spacing, probably reduced; directional drilling	Minimize impacts to tundra wetlands
Eliminated gravel access road paralleling pipeline	Minimize impact to tundra wetlands: avoid coverage of over 350 acres of wetlands
Designed facility for zero discharge of drilling wastes; no reserve pits	Reduce pad size and impacts to tundra wetlands; eliminate potential for contaminant release from reserve pits
Evaluated need to pre-stage spill response equipment at strategic locations on pipeline route, especially river crossings	Minimize response time in the event of a release from the pipeline; reduce impacts to tundra wetlands, rivers, streams and other waterbodies
Examined options for pipeline route and operational mode (e.g., pipeline buried in tundra, pipeline buried in roadbed, offshore buried pipeline, elevated pipeline to a minimum of 5 feet above tundra)	Minimize or eliminate impacts to tundra wetlands; optimize facility siting; reduce potential impacts to wildlife
Minimized in-field access-road crown width; used 2:1 side slopes	Reduce impacts to tundra wetlands
Evaluated gravel sources within floodplains of rivers	Minimize impacts to tundra wetlands; facilitate immediate rehabilitation of gravel source to wildlife habitat consistent with Alaska Department of Fish and Game guidelines
Eliminated the need for caribou crossing ramps	Eliminate impacts to tundra wetlands due to direct coverage with gravel
Conducted hydrological assessments of access road routes and river crossings	Optimize siting of road and river crossings; reduce alterations to natural drainage patterns at freeze-up and breakup, and during normal summer flow conditions; provide initial assessment of spill response requirements; minimize restrictions to movements of freshwater or anadromous fish
Buried pipeline between river crossings	Eliminated potential for interference to wildlife movements
Buried pipeline at river and stream crossings	Eliminated structures in floodplains of rivers
Identified potential culvert requirements for in-field access roads and incorporated into project design	Reduce alterations to surface drainage patterns
Obtained block aerial photography coverage (true color) of access routes and development sites	Use most up-to-date information in project design, facility siting, and environmental assessment

TABLE 6-1 (Cont'd)
BADAMI DEVELOPMENT PROJECT
AVOIDANCE AND MINIMIZATION OF ENVIRONMENTAL IMPACTS

DESIGN

ACTION	BENEFIT
Obtained low-altitude CIR aerial photography of proposed development site and pipeline corridor	Optimize facility siting; avoid and minimize impacts to higher-value wetlands; enhance environmental assessment and spill response planning
Prepared maps at scale appropriate (1"=500') to current project design requirements	Update 1955 base maps to 1993 standards for accuracy; improved assessment of impacts and better design criteria; consistent with existing North Slope developments
Obtained habitat maps for proposed project area; contacted North Slope Borough, U.S. Fish and Wildlife Service regarding sources of information and "preferred" classification methodologies	Produce preliminary impact assessment using classifications accepted by resource and regulatory agencies
Prepared vegetation maps for potential development sites based on current aerial photography	Identify low- and high-value habitats within the project area; avoid where practicable and minimize impacts overall
Reviewed historical data on wildlife use within the proposed project area	Identify critical issues early in project design
As feasible, incorporated design changes suggested by regulatory and resource agencies into final design	Reduce project impacts
Met with federal and state agencies early and frequently in project development to reaffirm critical issues and develop familiarity with project	Verify critical issues early in project design; establish agency involvement early in process
Reviewed and summarized existing data on nearshore oceanographic conditions and potential alterations due to construction of a dock in Mikkelsen Bay	Identify potential project and cumulative impacts; minimize impacts within project design and operational constraints
Conducted nearshore hydrographic surveys in vicinity of proposed dock	Provide limited baseline data on temperature and salinity patterns
Reviewed and summarized existing data on use of nearshore Mikkelsen Bay by anadromous and freshwater fish to assess potential impacts related to construction of a dock	Identify potential project and cumulative impacts; minimize impacts within project design and operational constraints
Collected baseline data from field surveys of large mammals (caribou and muskoxen) and birds (tundra-breeding birds, Snow Geese, Brant, Tundra Swans, and Spectacled Eiders)	Develop multi-year baseline data for use in road and facility siting to minimize impacts on wildlife within the project area; avoid or minimize use of areas used by Spectacled Eiders (a threatened species)
Coordinated with U.S. Fish and Wildlife Service on Spectacled Eider surveys since 1991	Ensure protection of a threatened species

TABLE 6-1 (Cont'd)
BADAMI DEVELOPMENT PROJECT
AVOIDANCE AND MINIMIZATION OF ENVIRONMENTAL IMPACTS

DESIGN

ACTION	BENEFIT
Identified potential sources of fresh water for ice road and ice pad construction and for domestic and industrial use	Minimize impacts to fish-bearing lakes, ponds, rivers, and streams
Incorporated part of material-site access road into airstrip	Reduce number of facilities; reduce coverage of tundra wetlands

TABLE 6-2
BADAMI DEVELOPMENT PROJECT
AVOIDANCE AND MINIMIZATION OF ENVIRONMENTAL IMPACTS

CONSTRUCTION AND OPERATION

ACTION	BENEFIT
Use ice roads to access Badami project and temporary water sources	Eliminate impacts to tundra wetlands
Construct pipeline during winter from ice roads	Eliminate impacts to wildlife; eliminate impacts to tundra wetlands from a permanent access road
House pipeline construction workers in existing facilities in Deadhorse	Reduce temporary facilities on site; reduce potential for wildlife disturbance or attraction
Designate fuel storage and transfer locations away from river crossings and sensitive wetlands; use secondary containment	Avoid water pollution from spills
Strictly enforce speed limits within project construction areas	Reduce potential for impacts to wildlife; reduce accidents both on road surface and onto tundra
Prohibit work in streams during fish spawning runs	Reduce impact to fish
Coordinate with Alaska Department of Fish and Game on studies of fish and grizzly bears within project area	Minimize interactions with bears; identify important fish resources in project area
Coordinate with U.S. Fish and Wildlife Service on historic and recent locations of polar bear den sites	Avoid actions that would disturb denning polar bears
Mine gravel for roads and pads during winter according to approved mining plan	Minimize impacts to fish overwintering areas; facilitate abandonment and reclamation of mine site
Conduct all major activities (e.g., pipeline construction, gravel mining, facilities construction) during winter	Eliminate impacts to tundra wetlands; eliminate impacts to wildlife
Maintain continual on-site environmental presence during construction to ensure compliance with permit requirements	Minimize variances from permitted activities
Prevent icing of culverts by method of installation and by blocking with plywood	Avoid flooding during breakup
Prohibit hunting by project personnel and restrict public access	Protect wildlife
Train personnel in interactions with wildlife	Reduce potential for harassment of wildlife

production site. However, these changes are not expected to influence either breeding success or population dynamics of the species involved (see Troy and Carpenter 1990). Similarly, caribou may be displaced from some parts of the Badami production site; however, experience from the North Slope oil fields indicates that caribou will use gravel pads and other facilities as insect relief habitat because insect abundance is often lower on gravel pads compared to undisturbed tundra (LGL 1993b, Pollard and Noel 1994).

6.1.1 Gravel Mining

The Alaska Department of Fish and Game's North Slope gravel pit performance guidelines (McLean 1993) will be used where practicable for siting and restoration of the gravel sources required for the proposed project. Areas that will not be excavated include wetland sites supporting *Arctophila fulva*, drained lake basins, and known fish overwintering pools. Disturbances in vegetated areas of river floodplains, which provide nesting habitat for birds and food and cover for moose and muskoxen, will be avoided or minimized. Where possible, mines will be located so that fish overwintering and rearing habitat can be created. If sites are covered with organic material, overburden will be removed and stockpiled for reuse. Disturbed areas will be cleaned up and restored, if necessary. For more details, refer to BPXA's Badami Development Project Mine Site Rehabilitation Plan.

6.1.2 Ice Roads

Ice roads will be used for temporary access during construction. They can be breached at river and stream crossings if necessary prior to breakup, and they will melt during breakup.

6.1.3 Water Quality Protection

There is a risk of spills of fuel or lubricating oil or of other harmful materials during construction. A major spill potential is associated with fueling of construction equipment. To minimize risks from this type of spill, fueling locations will be at designated locations removed from river crossings and non-palustrine wetlands. Best Management Practices approved by the Alaska Department of Environmental Conservation for fuel transfer in the Prudhoe Bay and Duck Island units will be followed. These include use of impermeable liners with sorbent materials beneath all fuel line connections.

6.1.4 Wetlands

BPXA has used the following approach to reduce or eliminate impacts to wetlands in the Badami project area:

1) Identify wetlands of known or potential high value during project design;
2) Avoid, to the extent practicable, specific wetlands habitats, including drained lake basins and areas identified by resource and regulatory agencies as having high value;
3) Conduct all on-tundra operations during winter from ice roads or ice pads; and
4) Minimize the total acres of all types of wetlands directly covered by gravel.

Mapping was used to identify small lakes and ponds, drained lake basins, *Arctophila*-covered areas, and other important habitats to aid in avoiding these habitats to the extent practicable and minimize construction-related disturbances in riparian and estuarine areas.

Total coverage of wetlands by the access road from the material site will be minimized by using, wherever possible, an alignment that follows dry, level terrain, so that the base of the roadbed is limited to approximately 50 feet (the width required for a 30-foot-wide, 5-foot-high road with sideslopes of 2:1). Detailed mapping and route surveying will be required to determine fill requirements for the selected access road route.

Upgradient impoundments have the potential to alter wetland plant species composition in consistently flooded locations. Design features for both the in-field gravel roads and pads and the pipeline trench the first year following construction (see Section 3.6) will reduce the formation of impoundments during spring breakup and thus help maintain the characteristics of wetlands adjacent to the pipeline and roadbed. Some downgradient drying of wetlands is unavoidable but will be minimized by culverts and berm breaks designed to reduce alterations to normal surface drainage patterns.

Although impoundments alter the vegetation, many impoundments within the Prudhoe Bay oil field are highly productive. In temporarily flooded areas and in shallow, permanent impoundments, enhanced primary production is often the most noticeable effect during the growing season (Walker et al. 1987, Kertell and Howard 1992). Enhanced primary production may be partially responsible for high invertebrate production in some impoundments. At Prudhoe Bay, numbers of macroinvertebrates (chironomid larvae, oligochaetes, trichopterans, plecopterans, and gastropods) averaged greater in impoundments (Kertell and Howard 1992, Kertell 1993); some of the differences between ponds and impoundments were significant. Waterfowl, in turn, appear to respond to high secondary production. Although differences were not significant, ducks (all species combined) were more abundant on impoundments than ponds during the breeding season at Prudhoe Bay (Kertell 1993).

6.1.5 Fish

Spawning runs of fish in the project area occur in late summer and early fall. There will be no in-water work during this period. There are currently no plans to cross streams in the project area that would require placement of culverts; however, if such crossings are required they will follow the design criteria developed by G.N McDonald & Associates (1994). Overwintering habitat for fresh water fish will be enhanced significantly following flooding of the East Badami Creek mine site and to a lesser extent at the gravel extraction sites in the Shaviovik and Kadleroshilik rivers.

6.1.6 Birds

Most gravel hauling and construction activity will take place during winter when few or no birds will be present. During the following summers, some activity is anticipated as drilling and related construction work continue. Disturbance of birds by this activity would be expected to be greater during construction than during operations. There is little detailed information on bird responses to construction disturbances, in part because safety concerns preclude detailed study during periods of intense construction activity. Murphy and Anderson (1993) found that swan and goose use of the Lisburne development was unaffected by construction or operation. However, Anderson et al. (1992) reported that Spectacled Eiders avoided noise resulting from the GHX-1 facility at Prudhoe Bay. Hence, this species may be expected to avoid areas of busy construction activity. Snow Geese were not adversely affected by activities associated with construction and operations at Endicott (SAIC 1994).

Habitat changes due to impoundments along the in-field access road should be at their maximum during the first year or two of the development until optimal culvert locations have been identified and culverts installed. The size and extent of these impoundments are difficult to predict, but they could result in the temporary loss of nesting habitat for some species. Because Spectacled Eiders readily use impoundments (Warnock and Troy 1992), they are not expected to have adverse impacts on this species. As discussed in Section 5.2.4, ducks (all species combined) were more abundant on impoundments than ponds during the breeding season at Prudhoe Bay (Kertell 1993).

Minor habitat changes may occur adjacent to the pads if snow accumulates during winter due to drifting or to removal from the pads for operations or safety reasons. These changes are likely to be small in areal extent and have no impact on local breeding bird populations.

BPXA has been conducting surveys in the North Slope oil fields since 1991, before Spectacled Eiders were listed as threatened under the Endangered Species Act. In 1993, radio packages were placed on some eiders to track their movements during migration to wintering grounds, and this effort continued in 1994. Each year, the survey area has been expanded, and in 1994, it extended from Milne Point on the west to Bullen Point in the east. As in the past, BPXA will share survey data with the U.S. Fish and Wildlife Service and will continue close coordination throughout the planning, construction, and operation phases of the Badami Development.

6.1.7 Mammals

Measures for reducing disturbance to caribou and muskoxen are summarized in Tables 6-1 and 6-2. There is a low potential for brown bears to be attracted to artificial food sources (i.e., dumpsters, handouts) during construction since major work will be conducted during winter and all pipeline construction workers will be housed in Deadhorse and transported to the construction site daily. Other measures to reduce potential conflicts with grizzly bears include site layout and facility design to increase visibility and reduce potential bear hiding places, physical barriers to prevent bear access under elevated buildings, protection of cable systems that supply remote power and monitoring of the wellsite, and emphasis on good lighting to eliminate hiding places for bears.

Studies conducted in the Prudhoe Bay oil field have suggested that availability of artificial food sources (refuse and feeding by oil field personnel) in developed areas results in increased fox productivity, increased density, and dampened population fluctuations (Eberhardt et al. 1982, 1983). Artificially high fox populations increase the potential risk of exposure of oil field workers to rabies and may lead to abnormally high predation of tundra bird populations. Proper handling and disposal of garbage in appropriate animal-proof dumpsters, coupled with enforceable restrictions on feeding wildlife, will minimize the likelihood of detrimental animal/human interactions during Badami Development. No food wastes will be stored outside or kept in areas accessible to foxes, bears, or other wildlife.

There is no evidence that noise associated with construction or operations disturbs polar bears, although they probably avoid extremely loud noise sources. In fact, bears have commonly approached industrial sites in the Canadian Beaufort Sea (Stirling 1988). Human/bear encounters have the potential to cause injury on both sides. Polar bears are extremely curious and opportunistic hunters, and they have been known to approach facilities in search of food. As with brown bear and foxes, all operations in the project area will be conducted to minimize the attractiveness of the construction sites to polar bears and to prevent their access to garbage, food, or other potentially edible or harmful materials. BPXA will coordinate all activities associated with polar bears in the region with the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Trained personnel have authority under Section 112(c) of the Marine Mammal Protection Act to haze polar bears under certain circumstances involving the protection of life.

6.1.8 Personnel Training

All BPXA and contract personnel will receive environmental training which identifies physical, biological, and human resource concerns of the project area and explains BPXA's policies for addressing these concerns. This training program will include, but not be limited to, BPXA's Achieving Environmental Excellence training and polar bear, brown bear, and fox awareness training. Construction personnel will be strictly forbidden to feed wildlife. Selected personnel will receive training for polar bear deterrence to meet the requirements of Section 112(c) of the Marine Mammal Protection Act. This training will be under the supervision of the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game.

6.2 MITIGATION OF OPERATIONS IMPACTS

Measures for protecting water quality and controlling garbage during construction will also be used as appropriate during project operation. All personnel will be strictly forbidden to feed wildlife. Operations features and mitigation measures include the following.

6.2.1 Snow Control

Snow will tend to accumulate on the downwind sides of well houses and associated facilities and the Badami pad. Snow removal and control (i.e., snow fences) will be evaluated and incorporated into project operations consistent with current procedures on the North Slope.

6.2.2 Dust Control

Dust from the in-field access road will darken the adjacent tundra surface and decrease the albedo of the ground surface. As with snow, more dust will collect on the downwind side of the road embankment. This can also result in a slight thickening of the active layer and in wetter ground conditions, which can cause a change in vegetation types. Dust deposition on wetland vegetation will likely be minimal because of the small size of the project and the lack of regular vehicle traffic.

Breeding-bird use of areas near roads during periods of relatively high levels of disturbance due to vehicles and dusting was discussed in Section 5.2.4.

6.2.3 Culvert Icing Prevention

Even when properly installed, culverts can cause temporary flooding when blocked by ice during the spring thaw. Therefore, active intervention may be necessary to remove ice from culverts as snowmelt begins to accumulate each spring. Where required, culverts may be blocked with plywood prior to freeze-up; and in some cases, snow may be excavated from culvert openings prior to breakup. BPXA will institute a program for monitoring, tracking, and maintenance of all culverts. This program will be modeled on that currently in place for the Prudhoe Bay oil field.

6.2.4 Ice Roads

During most winters, an ice road will be built just offshore from the base of the Endicott Causeway to the wellsite for winter access during operations. Some years when necessary for pipeline work, the ice road may be built onshore along the pipeline route. Onshore ice roads can be breached at river and stream crossings if necessary prior to breakup, and they will melt during breakup.

6.2.5 Wildlife Protection

Project personnel will not be allowed to hunt in the project area, and access, by virtue of a roadless project design, will be restricted to essential personnel only. All project personnel will receive environmental training, and they will be strictly forbidden from feeding wildlife. Firearms kept on location for protection from polar bears and grizzly bears will be stored in locked cabinets and access to them restricted to trained personnel only.

6.3 OTHER ON-SITE MITIGATION

During pre-project planning and design for the Badami Development, BPXA evaluated several options that would take advantage of existing gravel structures or other previously developed sites in the area to reduce overall project impacts. In all cases, BPXA attempted to address mitigation of project impacts within the immediate vicinity of the proposed Badami Development rather than examine mitigation options not directly related to the Badami project. These included:

- Use of the Mikkelsen Bay State #1 airstrip as part of the Badami access road,
- Use of the Mikkelsen Bay State #1 airstrip as a facility site for Badami development,
- Use of the Mikkelsen Bay State #1 airstrip as a gravel source for Badami Development facilities, and
- Use of the existing flooded material site on the Shaviovik River.

None of the above-listed options has been included in the final project design due to technical and other reasons described below.

6.3.1 Airstrip as Part of Access Road

The original design for a gravel access road connected to either the Endicott access road or to Prudhoe Bay Unit Drill Site 16 attempted to incorporate the Mikkelsen Bay State #1 airstrip into the road. This created several design problems including less-than-optimal locations for the proposed bridged river crossings and placement of the road east of the airstrip in a drained lake basin. This option was excluded from consideration when the Badami access road was eliminated.

6.3.2 Airstrip as Facility Site

The Mikkelsen Bay State #1 airstrip was initially evaluated as a potential facility site for the Badami Development Project. However, this site was not acceptable due to its distance from the Badami reservoir.

6.3.3 Airstrip as Gravel Source

The Mikkelsen Bay State #1 airstrip was constructed of gravel obtained from the Shaviovik River and was considered as a potential gravel source for Badami facilities. However, because the current condition of the gravel at the airstrip is unknown, especially in terms of potential contamination, this site was not considered further.

6.3.4 Existing Shaviovik Material Site

A material site was excavated near the eastern bank of the Shaviovik River in the early 1980's to support construction of exploration sites. This pit is up to 35 feet deep and is currently filled with water. Use of this site for the Badami Development would require draining the pit, which would in turn require a National Pollutant Discharge Elimination System (NPDES) permit from the U.S. Environmental Protection Agency. Because of uncertainties regarding the time and resolution of technical issues required to obtain an NPDES permit, the difficulties in working in a previously flooded material site, and the distance of this material site from the location of the proposed Badami facilities, this development option was excluded from further consideration.

7. CONSULTATION AND COORDINATION

7.1 AGENCY COORDINATION

As an integral part of project planning, BPXA has worked very closely with various federal and state agencies and the North Slope Borough. This coordination included individual meetings with representatives from each agency involved in the project review and approval process, a series of topical workshops, and pre-application meetings and follow-up.

Meetings with individual agencies were held to informally discuss proposed project plans, project alternatives, design concepts, and environmental, geotechnical, hydrological, and engineering data collection programs. Comments from agency personnel on project scope, project alternatives, environmental concerns, permitting requirements, and data gaps were actively sought during these meetings. Table 7-1 lists each of these meetings.

Informal workshops were also conducted as part of the pre-application process. Workshop topics included Beaufort Sea fisheries and causeway studies, pipeline design criteria, spill prevention planning, pipeline operation and maintenance considerations, and pipeline design concepts. Workshops are also listed on Table 7-1.

A formal pre-application meeting was held on December 12, 1994. Appendix B includes a listing of meeting attendees. As a follow-up to the meeting, BPXA distributed a set of notes summarizing agencies' concerns about the project.

7.2 PUBLIC EDUCATION

In addition to close agency coordination, BPXA also conducted a public education effort. This program included a series of meetings with the North Slope Borough officials and residents in Barrow and Kaktovik, a series of meetings with key community groups in Fairbanks, a general information meeting conducted in Anchorage on December 12, 1994, and a series of meetings with interested environmental interest groups in Anchorage and Fairbanks. Table 7-1 lists all of these meetings, and Appendix B includes a list of attendees at the Anchorage general information meeting.

7.3 PREVIOUS PERMIT APPLICATIONS

On July 14, 1994, BPXA submitted a permit application package for what was then termed Phase I of the Badami Development Project. That package requested approvals for permits needed to drill two appraisal wells in the winter of 1994-1995 and to construct gravel pads for field facilities during the winter of 1995. Based on procedural issues raised by federal agencies, these permit applications were withdrawn on August 22, 1994.

Shortly after withdrawing the original set of applications, BPXA resubmitted applications needed to drill two Badami appraisal wells during the winter of 1994-1995. Those permits were issued and drilling-related activities were initiated in December 1994.

TABLE 7-1
SUMMARY OF AGENCY AND PUBLIC MEETINGS

DATE	AGENCY	MAJOR TOPICS DISCUSSED
December 8, 1993	Alaska Department of Fish and Game; Alaska Department of Natural Resources, Division of Land; U.S. Fish and Wildlife Service	General project concept
March 29, 1994	North Slope Borough	General project issues and concerns
March, 1994	Alaska Department of Environmental Conservation	Spill planning issues and concerns
March 16, 1994	U.S. Army Corps of Engineers	Project permit requirements, NEPA review
May 2, 1994	National Marine Fisheries Service	Impacts of and justification for dock, Mikkelsen Bay oceanographic data needs
May 4, 1994	Alaska Department of Natural Resources, Division of Land, Northern Region	Project permit requirements, including land use authorizations for facilities and pipeline and competitive mineral material sale
May 4, 1994	U.S. Fish and Wildlife Service; Alaska Department of Fish and Game - Fairbanks	Biological concerns related to project development, including river crossings and dock, Mikkelsen Bay oceanographic data needs
May 5, 1994	Alaska Department of Natural Resources, Division of Oil and Gas	Project permitting requirements, general issues and concerns
May 13, 1994	U.S. Army Corps of Engineers	Project permitting requirements, general issues and concerns
May 16, 1994	Alaska Division of Governmental Coordination	State of Alaska permitting requirements, coastal consistency review, project permitting process
May 31, 1994	Alaska Division of Governmental Coordination, Alaska Department of Natural Resources - SPCO	Badami pipeline permitting requirements
June 8, 1994	U.S. Environmental Protection Agency	Project permit requirements, data adequacy, general issues and concerns, NEPA review
June 14, 1994	Pre-application conference (Appendix B)	Pre-application conference
June 21, 1994	Causeway monitoring workshop (Appendix B)	Causeway monitoring workshop
June 24, 1994	Alaska Department of Natural Resources	Badami pipeline permitting, unitization
June 28, 1994	Alaska Department of Natural Resources, Division of Oil and Gas	Lease Plan of Operations approval requirements
June 29, 1994	U.S. Army Corps of Engineers	Review of draft permit application

TABLE 7-1 (Cont'd)
SUMMARY OF AGENCY AND PUBLIC MEETINGS

DATE	AGENCY	MAJOR TOPICS DISCUSSED
June 29, 1994	Alaska Department of Natural Resources, Division of Oil and Gas, and Alaska Division of Governmental Coordination	Project permitting requirements
July 7, 1994	Environmental Groups	Issues and Concerns
July 11, 1994	Alaska Department of Natural Resources, Division of Oil and Gas	Site visit
July 15, 1994	North Slope Borough	Rezoning pre-application meeting
July 20, 1994	Alaska Department of Environmental Conservation	Air permitting requirements
August 15, 1994	U.S. Army Corps of Engineers and U.S. Coast Guard	Section 10/Section 9 Coordination
August 16, 1994	U.S. Army Corps of Engineers	Permit process
August 17, 1994	U.S. Coast Guard, Alaska Department of Environmental Conservation	Site visit
August 19, 1994	U.S. EPA	Site visit
August 26, 1994	North Slope Borough	Planning Commission public hearing
August 29, 1994	U.S. EPA	Dock alternatives
September 1, 1994	U.S. Army Corps of Engineers	Site visit
September 8, 1994	Alaska Department of Natural Resources	Pipeline permitting
September 9, 1994	Alaska Department of Fish and Game	River crossings
September 14, 1994	U.S. EPA, U.S. Army Corps of Engineers, Alaska Division of Governmental Coordination, Alaska Division of Oil and Gas	Badami dock alternatives
September 22, 1994	Alaska Department of Natural Resources	Pipeline permitting
September 29, 1994	U.S. EPA, U.S. Army Corps of Engineers, U.S. Department of Transportation, U.S. Coast Guard, Alaska Department of Fish and Game, Alaska Division of Governmental Coordination, Alaska Department of Natural Resources, North Slope Borough	Pipeline design criteria crossings workshop
October 4, 1994	National Wildlife Federation	Issues and concerns
October 17, 1994	U.S. EPA, NMFS	Offshore alternative issues and concerns
October 17, 1994	U.S. Army Corps of Engineers	Offshore alternative issues and concerns

TABLE 7-1 (Cont'd)
SUMMARY OF AGENCY AND PUBLIC MEETINGS

DATE	AGENCY	MAJOR TOPICS DISCUSSED
October 19, 1994	Alaska Division of Governmental Coordination, Alaska Department of Natural Resources, Alaska Department of Environmental Conservation	Offshore alternative issues and concerns
October 21, 1994	Alaska Department of Fish and Game, Alaska Department of Natural Resources, U.S. Fish and Wildlife Service	Offshore alternative issues and concerns
November 3, 1994	U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, Alaska Department of Natural Resources (Div. of Lands)	Mine site development
November 4, 1994	Division of Governmental Coordination, U.S. Environmental Protection Agency, Alaska Department of Environmental Conservation, Alaska Department of Natural Resources (SPCO and Div. of Oil and Gas)	Mine site development
November 8, 1994	U.S. Environmental Protection Agency, U.S. Army Corps of Engineers	Project design
November 21 and 22, 1994	Fairbanks Chamber of Commerce, Doyon Drilling, Fairbanks North Star Borough, North Alaska Environmental Center, Alaska Outdoor Council, Tanana Valley Sportsman's Association, Alaska Support Industry Alliance, interested individuals	General issues and concerns
December 5, 1994	U.S. Environmental Protection Agency	Pipeline issues and concerns
December 12, 1994	(see Appendix B)	Pre-application conference
December 12, 1994	(see Appendix B)	Anchorage public meeting
December 13, 1994	Alaska Department of Environmental Conservation, Alaska Department of Natural Resources, Colt Engineering	Pipeline issues and concerns
December 13, 1994	North Slope Borough, Colt Engineering	Pipeline issues and concerns
December 13 and 14, 1994	U.S. Environmental Protection Agency, Colt Engineering	Pipeline issues and concerns
December 14, 1994	U.S. Environmental Protection Agency, Corps of Engineers, National Marine Fisheries Service, Alaska Division of Governmental Coordination	Permitting process
December 21, 1994	U.S. Environmental Protection Agency, Corps of Engineers, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Alaska Division of Governmental Coordination, Alaska Department of Natural Resources	Permitting process

TABLE 7-1 (Cont'd)
SUMMARY OF AGENCY AND PUBLIC MEETINGS

DATE	AGENCY	MAJOR TOPICS DISCUSSED
January 3, 1995	Alaska Division of Governmental Coordination, Alaska Department of Natural Resources	Permitting process
January 5, 1995	Kaktovik residents	General project information

8. STUDIES AND DESIGN

This section describes BPXA plans for continued environmental, geotechnical, and hydrological data gathering in the Badami area, and also describes how detailed engineering will proceed.

As described in Section 4, a thorough data collection program was initiated early in the project planning process. Work completed to date includes:

- Color aerial photography at a scale of 1 inch equals 1500 feet (1993).
- Color infrared aerial photography at a scale of 1 inch equals 600 feet (1994).
- Detailed mapping of the project corridor at a scale of 1 inch equals 500 feet with 4-foot contour intervals (1994).
- Survey of the proposed and alternative pipeline corridors (1994).
- Geotechnical investigation of potential material sites at East Badami Creek, West Badami Creek, and the Shaviovik River (1994).
- Geotechnical investigation of proposed river crossing locations at the No Name River, the Shaviovik River, the Kadleroshilik River, and the East Channel of the Sagavanirktok River. Work included depth profiles and borings to determine the characteristics of soils in the channel, including the extent of thawed soils. Due to a late summer flood, incomplete data was gathered for the East Channel of the Sagavanirktok River (1994).
- Hydrological reconnaissance investigations to determine optimum river crossing locations, including acquisition of stream stage and discharge data (1994).
- Hydrographic surveys across five 1-mile-long transects of Mikkelsen Bay to measure temperature, salinity, and depth (1994).
- Field assessment of littoral transport in Mikkelsen Bay (1994).
- Monitoring of large-mammal and predator distribution, including polar bear and fox den location and summer distribution of grizzly bears (1993, 1994).

- Breeding-pair surveys to build up the database of probable nesting areas for Spectacled Eiders, as well as brood surveys to locate known brood-rearing areas (1993, 1994).
- Surveys of tundra-breeding birds to identify known nesting and brood-rearing areas (1993, 1994).
- Preparation of wetlands vegetation map of the Badami project area.
- Completion of a reconnaissance of the proposed pipeline route and drilling pad for archaeological and historical sites (1993, 1994).
- BPXA-funded ADF&G fish surveys in East and West Badami creeks (1994).
- BPXA-funded ADF&G grizzly bear survey of Badami area (1994).

These studies provided the foundation for project planning and were designed to provide the level of information needed to support the permitting and conceptual design processes. Some additional environmental data acquisition is planned for 1995 and 1996, and an extensive geotechnical/hydrological data program will also be conducted.

8.1 CONTINUING ENVIRONMENTAL STUDIES

Two additional field environmental programs are planned before project construction begins. These include continuing archaeological surveys of the area and a fish survey of Mikkelsen Bay.

A final archaeological survey of the pipeline corridor will be conducted in 1996, after final detailed routing of the pipeline has been completed. The intent of this program is to confirm the results of earlier reconnaissance surveys indicating that there is a low probability of locating previously unknown cultural or historic resources in the corridor.

BPXA will also conduct a hydrographic and fish data collection program in Mikkelsen Bay during the summer of 1995. This program is designed to verify predictions regarding the effects of the proposed Badami dock on fish and hydrography within Mikkelsen Bay. The program will include using fyke nets to capture and count fish. The lengths of the four key anadromous species will be measured. Water temperature and salinity will be measured throughout the water column at the cod end of each fyke net and 100 meters offshore each day. Arctic grayling will be dye-marked to track movements in the study area. In addition, hydrographic surveys will be conducted every other day during the fish sampling program. Frequency of sampling may be adjusted to coincide with significant changes in wind speed and direction. Surveys will generally follow the same protocols used in the 1994 Mikkelsen Bay program except that sampling equipment will be upgraded significantly. The transect locations may be modified or the number of transects adjusted to accommodate design changes for the proposed Badami dock.

In addition, BPXA will conduct a bathymetric survey of the proposed dock site in Mikkelsen Bay.

8.2 GEOTECHNICAL/HYDROLOGICAL PROGRAM

BPXA plans an extensive geotechnical and hydrological data collection program in 1995. The primary purposes of this program will be to confirm assumptions made based on reconnaissance-level data, and to obtain the detailed site-specific information needed to complete final design of the pipeline and field facilities.

Data collected will include:

- Soils borings along the pipeline route. Data collected will include soils type, moisture content, and ice content.
- Temperature readings from thermistor strings placed in boreholes.
- River crossing profiles.
- Thaw depth at river crossing locations.
- Identification and staking of all minor creek and stream crossings.
- Identification of needed locations for berm breaks and ditch plugs.
- Identification of temporary water sources.
- Continued stage and discharge measurements at river crossing locations.

8.3 DESIGN PROCESS

Information to support the permitting process has been developed on the basis of conceptual engineering, the results of 1993 and 1994 environmental and engineering data collection, and general background knowledge of operating conditions on the North Slope. This data base and engineering approach provide a sound framework for proceeding with project permitting review. BPXA believes that sufficient information about the project is available to understand the basic design concepts, extent of disturbance, predicted impacts on the environment, and means to mitigate any adverse impacts.

Detailed, site-specific design information about the pipeline is not available at this time. However, the Application for Right-of-Way Lease and the supporting Appendix A provide a substantial discussion of the design concept, design standards, and required codes and standards. This application fully describes how site-specific data will be used in the final design process. Thus, while detailed engineering of the pipeline system will not be available during the permitting timeframe (exclusive of the Right-of-Way Lease process), the applications provide the level of detail needed to allow project review. For example, the concept of the trench excavation and backfill design is explained in detail. Information is also provided concerning a range of designs depending on site-specific soils information. After this site-specific information is available, this design concept will be applied to conditions at that project location to develop a final design.

Preliminary and detail design engineering will begin in January 1995. The engineering design work will be conducted by the Badami Alliance, which is made up of contractors who have specific skills and experience in arctic and cold region technology complemented by operations and drilling. This information will be coordinated with the results of appraisal well drilling to develop final design. Through these design processes, information about the project proposal will continue to evolve. However, it is expected that there will be no significant changes in the basic design concepts, location of facilities, or project operational concept. In a few instances, uncertainty regarding locations or design concepts has been acknowledged in the permit applications (for example, the alternative southern crossing of the Shaviovik River, or a contingent Shaviovik River material source).

The final design process is intended to focus on developing plans for a final pipeline route, refinement of the river crossing designs (particularly depth of burial and sagbend setbacks), individual designs for creek and stream crossings, and site-specific trench and backfill designs.

9. REFERENCES

AEIDC (Arctic Environmental Information and Data Center, University of Alaska). 1974. Alaska regional profiles. Vol. II, Arctic region. Anchorage, AK.

Abbott, S.M. (ed.). 1993. Federal aid in wildlife restoration management report of survey inventory activities 1 July 1990 – 30 June 1992. Caribou. Projects W-23-5 and W-24-1, Study 3.0. Alaska Dept. of Fish and Game, Division of Wildlife Conservation, Juneau, AK. 233 pp.

Alaska Dept. of Community and Regional Affairs, Municipal and Regional Assistance Div. 1993. Community/borough map. Anchorage, AK. 1 sheet.

ADF&G (Alaska Dept. of Fish and Game). 1992. Catalog of waters important for spawning, rearing or migration of anadromous fishes. Arctic Region Resource Management, Region V, Juneau, AK. 55 pp.

Amstrup, S.C., and D.P. DeMaster. 1988. Polar bear, *Ursus maritimus*. Pp. 39–56 *in* J.W. Lentfer (ed.). Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Amstrup, S.C., I. Stirling, and J.W. Lentfer. 1986. Past and present status of polar bears in Alaska. Wildl. Soc. Bull. 14:241–254.

Anderson, B.A. 1992. Abundance and distribution of waterbirds in the GHX-1 study area. Final report. Report by Alaska Biological Research, Inc. for ARCO Alaska, Inc., Anchorage, AK.

Anderson, B.A., S.M. Murphy, M.T. Jorgenson, D.S. Barber, and B.A. Kugler. 1992. GHX-1 waterbird and noise monitoring program. Report by Alaska Biological Research, Inc. and BBN Systems and Technologies Corp. for ARCO Alaska, Inc., Anchorage, AK. 132 pp.

AOGA (Alaska Oil and Gas Association). 1988. A compilation and description of industry research projects in Alaska frontier OCS areas. Lease Planning and Research Committee, Alaska Oil and Gas Association, Anchorage, AK.

Ballard, W.C., and M.A. Cronin. 1994. Alaska Arctic caribou herds in relation to oil field development. *In* Proceedings of the 6th Symposium on Issues and Technology in the Management of Impacted Wildlife. Thorne Ecological Institute, Boulder, CO. In Press.

Barnes, P.W., D.M. Schell, and E. Reimnitz (eds.). 1984. The Alaskan Beaufort Sea: Ecosystems and environments. Academic Press, Inc., New York, NY. 466 pp.

Bendock, T. 1979. Beaufort Sea estuarine fishery study. *In* Environmental assessment of the Alaskan continental shelf. Bureau of Land Management and National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Boulder, CO. Final Report 4:670–729.

Bergman, R.D., R.L. Howard, K.F. Abraham, and M.W. Weller. 1977. Water birds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish and Wildlife Service Research Publication 129, Washington, D.C.

Biosonics, Inc. 1984. Prudhoe Bay Waterflood Project fish monitoring program. 1983. Report for Department of Army, Alaska District, Corps of Engineers, Anchorage, AK. 161 pp.

Brewer, M.C. 1987. Surficial geology, permafrost, and physical processes. Chap. 5 *in* K.J. Bird and L.B. Magoon (eds.). Petroleum geology of the northern part of the Arctic National Wildlife Refuge, northeastern Alaska. U.S. Geological Survey. Bulletin 1778.

Burgess, R.M., and P.W. Banyas. 1993. Inventory of arctic fox dens in the Prudhoe Bay region, 1992. Report by Alaska Biological Research, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK. 104 pp.

Busdosh, M. 1984. Infaunal monitoring program. Chapter 4 *in* Prudhoe Bay Waterflood Project. Environmental monitoring program 1983. Vol. 2. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Busdosh, M., and G.A. Robilliard. 1979. Benthic ecology. *In* Environmental studies associated with the Prudhoe Bay dock: Physical, oceanographic, and benthic ecology. Final report for ARCO Oil and Gas Company, Anchorage, AK. 145 pp.

Busdosh, M., and G.A. Robilliard. 1982. Beaufort Sea benthic studies near the Sagavanirktok River delta. *In* Duck Island Development: Marine environmental studies. Final report for Exxon Company, U.S.A., Los Angeles, CA. 11 pp.

Byrne, L.C., R.J. Ritchie, and D.A. Flint. 1994. Spectacled Eider and Tundra Swan surveys: Kuvlum corridor, Sagavanirktok River to Staines River. Unpublished Draft Report for ARCO Alaska, Inc., Anchorage, Alaska.

Cameron, R.D. 1993. Distribution and productivity of the Central Arctic caribou herd in relation to petroleum development: Case history studies with a nutritional perspective. Progress report (Research). Project No. W-24-1, Study No. 3.35, 1 July 1992 – 30 June 1993. U.S. Fish and Wildlife Service, University of Alaska Fairbanks.

Cameron, R.D., and K.R. Whitten. 1978. Third interim report on the effects of the Trans-Alaska Pipeline on caribou movements. Joint State/Federal Fish and Wildlife Advisory Team, Anchorage, AK. Special Report 22. 29 pp.

Cameron, R.D., and K.R. Whitten. 1980. Influence of the Trans-Alaska Pipeline corridor on the local distribution of caribou. Pages 475-484 *in*: E. Reimers, E. Gaare, and S. Skjenneberg (eds.). Proc. 2nd Int. Reindeer/Caribou Symp., Røros, Norway. 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

Cameron, R.D., W.T. Smith, and S.G. Fancy. 1989. Distribution and productivity of the Central Arctic caribou herd in relationship to petroleum development. Federal Aid in Wildlife Restoration. Progress Report, Project W-23-1 and W-23-2, Study 3.35. Alaska Dept. of Fish and Game, Juneau, AK. 52 pp.

Cannon, T.C., B.A. Adams, D. Glass, and T. Nelson. 1987. Fish distribution and abundance. Pp. 1–129 *in* Endicott environmental monitoring program, final reports, 1985. Vol. 6. Report by Envirosphere Co. for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Carey, A.G., Jr. 1991. Ecology of North American arctic continental shelf benthos: A review. Continental Shelf Research 11(8-10):865–883.

Carruthers, D.R., R.D. Jakimchuk, and S.H. Ferguson. 1984. The relationship between the Central Arctic caribou herd and the Trans-Alaska Pipeline. Report by Renewable Resources Consulting Services, Ltd., Sidney, B.C., for Alyeska Pipeline Service Co., Anchorage, AK. 207 pp.

Chesemore, B.S. 1967. Ecology of the Arctic fox in northern and Western Alaska. M.S. thesis, Univ. of Alaska, Fairbanks. 148 pp.

Church, M. 14) and fluvial characteristics of rivers in northern Alaska and northern Yukon Territory. Report for Mackenzie Valley Pipe Line Research, Ltd. by Dept. of Geography, Univ. of British Columbia, Vancouver, B.C. 200 pp.

Clough, N.K., P.C. Patton, and A.C. Christiansen (eds.). 1987. Arctic National Wildlife Refuge, Alaska, coastal plain resource assessment. Report and recommendation to the Congress of the United States and final legislative environmental impact statement. Vol. 1. Report. U.S. Fish and Wildlife Service, U.S. Geological Survey, and Bureau of Land Management, Washington, D.C. 1 vol.

Colonell, J.M., and A.W. Niedoroda. 1993. Coastal oceanography of the Alaska Beaufort Sea. *In* 1991 Endicott Development fish monitoring program. Vol. I: Synthesis. Final Report. Report by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska), Inc., Anchorage, AK, and North Slope Borough, Barrow, AK.

Connors, P.G., J.P. Myers, and F.A. Pitelka. 1979. Seasonal habitat use by arctic Alaskan shorebirds. Stud. Avian Biol. 2:101–111.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C. Publication FWS-OBS-79/31. 131 pp.

Craig, P.C. 1977a. Ecological studies of anadromous and resident populations of Arctic char in the Canning River drainage and adjacent coastal waters of the Beaufort Sea, Alaska. Arctic Gas Biological Report Series 41. 116 pp.

Craig, P.C. 1977b. Fisheries research in the Shaviovik drainage, Alaska, with emphasis on Arctic char in the Kavik River. Arctic Gas Biological Report Series 41. 28 pp.

Craig, P.C. 1984. Fish use of coastal waters of the Beaufort Sea: A review. Transactions of the American Fisheries Society 113:265–282.

Craig, P.C. 1989a. An introduction to anadromous fishes in the Alaskan Arctic. Biol. Pap. Univ. Alaska 24:27–54.

Craig, P.C. 1989b. Subsistence fisheries at coastal villages in the Alaskan Arctic, 1970–1986. Biol. Pap. Univ. Alaska 24:131–152.

Craig, P.C., and W.B. Griffiths. 1981. Studies of fish and epibenthic invertebrates in the coastal waters of the Beaufort Sea. *In* Environmental assessment of the Alaskan continental shelf, Bureau of Land Management and National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Boulder, CO. Annual Report 1:73–145.

Craig, P.C., and L. Haldorson. 1981. Beaufort Sea barrier-island-lagoon ecological process studies: Final report, Simpson Lagoon (Part 4, Fish). Pp. 384–678 *in* Environmental assessment of the Alaskan Continental Shelf, final reports of principal investigators. Vol. 7. Bureau of Land Management and National Oceanic and Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

Craig, P.C., and G.J. Mann. 1974. Life history and distribution of Arctic cisco *(Coregonus autumnalis)* along the Beaufort Sea coastline in Alaska and the Yukon Territory. Arctic Gas Biological Report Series 20. 27 pp.

Craig, P.C., and P. McCart. 1974. Fall spawning and overwintering areas of fish populations along routes of proposed pipeline between Prudhoe Bay, AK, and the Mackenzie Delta. Arctic Gas Biological Report Series 15. 36 pp.

Craig, P.C., and P.J. McCart. 1975. Classification of stream types in Beaufort Sea drainages between Prudhoe Bay, Alaska, and the Mackenzie Delta, N.W.T., Canada. Arctic and Alpine Research 7(2):183–198.

Craig, P.C., and V. Poulin. 1974. Life history and movements of grayling (*Thymallus arcticus*) and juvenile Arctic char (*Salvelinus alpinus*) in a small tundra stream tributary to the Kavik River, Alaska. Arctic Gas Biological Report Series 17(2). 53 pp.

Critchlow, K. 1983. Fish report, Prudhoe Bay Waterflood Project environmental monitoring program, 1982. Report by Woodward-Clyde Consultants for Department of Army, Alaska District, Corps of Engineers, Anchorage, AK. Vol. 3, Chap. 5. 327 pp.

Cronin, M.A., W.B. Ballard, J.C. Truett, and R.H. Pollard. 1993. Mitigation of the effects of oil development and transportation corridors on caribou. Draft report by LGL Alaska Research Associates, Inc. for Alaska Oil and Gas Association, Anchorage, AK. 1 vol.

De March, B.G.E. 1989. Salinity tolerance of larval and juvenile broad whitefish (*Coregonus nasus*). Can. J. Zool. 67:2392–2397.

Derksen, D.C., T.C. Rothe, and W.D. Eldridge. 1981. Use of wetland habitats by birds in the National Petroleum Reserve-Alaska. U.S. Fish and Wildlife Service Research Publication 141, Washington, D.C.

Eberhardt, B.S. 1977. The biology of Arctic and red foxes on the North Slope. M.S. thesis, Univ. of Alaska, Fairbanks. 125 pp.

Eberhardt, L.E., R.A. Garrott, and W.C. Hanson. 1983. Den use by arctic foxes in northern Alaska. J. Mamm. 64(1):97–102.

Eberhardt, L.E., W.C. Hanson, J.L. Bengtson, R.A. Garrott, and E.E. Hanson. 1982. Arctic fox home range characteristics in an oil-development area. J. Wildl. Manage. 46(1):183–190.

Elison, G.W., A.G. Rappoport, and G.M. Reid (eds.). 1986. Report of the caribou impact analysis workshop, Arctic National Wildlife Refuge, November 19–20, 1985. U.S. Fish and Wildlife Service, Fairbanks, AK. 39 pp.

ENSR Consulting and Engineering. 1991. Endicott Development Project NPDES monitoring program Permit No. AK-003866-1. Sediment quality and benthic macroinvertebrate monitoring, 1990 studies. Final report. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and U.S. Environmental Protection Agency, Region 10. 1 vol.

Envirosphere Company. 1987. 1985 Final Report for the Endicott Environmental Monitoring Program. 7 Volumes. Prepared by Envirosphere Company, Anchorage, AK for the U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.

Volume I: Executive Summary; Introduction; Integration and Assessment
Volume II: Meteorology; River Discharge
Volume III: Oceanographic Monitoring
Volume IV: Oceanographic Monitoring Appendices
Volume V: Breach Monitoring; Ice Breakup/Freeze-up; Sedimentation and Erosion
Volume VI: Fish Distribution and Abundance; Mark-Recapture Study
Volume VII: Fish Food Habits; Fish Prey Survey; Age, Growth, and Condition of Anadromous Fish; Over-wintering Study; Surveys of Domestic and Commercial Fisheries in the Central and Eastern Beaufort Sea; Snow Geese

Envirosphere Company. 1988. Prudhoe Bay Waterflood Project comprehensive marine report. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK. 2 vols.

Envirosphere Company. 1990. 1986 Final Report for the Endicott Environmental Monitoring Program. 8 Volumes. Prepared by Envirosphere Company, Anchorage, AK for the U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.

Volume I: Executive Summary; Introduction; Integration and Assessment
Volume II: Meteorology; River Discharge; Oceanography
Volume III: Oceanography Appendices
Volume IV: Breach Monitoring; Numerical Modeling; Ice Breakup/Freeze-up; Sedimentation and Erosion Monitoring
Volume V: Fish Distribution and Abundance
Volume VI: Fish Food Habits; Fish Prey Survey; Age, Growth, and Condition of Anadromous Fish

Volume VII: Pilot Study for Fish Habitat Sampling; Habitat Utilization of Invertebrate Organisms; Fish Habitat Suitability Estimates; Preliminary Fish Habitat Accounting Model
Volume VIII: Snow Geese

Envirosphere Company. 1991. 1987 Final report for the Endicott environmental monitoring program. Vol. 3. Report for U.S. Department of the Army, Alaska District, Corps of Engineers, Anchorage, AK.

Envirosphere Company. 1992. Endicott Environmental Monitoring Program, Final Report - 1987. Prepared by Envirosphere Company, Bellevue, Washington, for the U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.
Volume 1: Executive Summary; Introduction; Integration and Assessment
Volume 2: Meteorology; River Discharge
Volume 3: Oceanographic Monitoring
Volume 4: Oceanographic Monitoring
Volume 5: Breach Monitoring; Ice Breakup/Freeze-up; Sedimentation and Erosion Monitoring
Volume 6: Fish Distribution and Abundance; Mark-Recapture Study
Volume 7: Fish Food Habits; Fish Prey Surveys; Age, Growth, and Condition of Anadromous Fish; Over-wintering Study; Surveys of Domestic and Commercial Fisheries in the Central and Eastern Beaufort Sea; Snow Geese; Caribou

Everett, K.R., D.A. Walker, and P.J. Webber. 1981. Prudhoe Bay oilfield geobotanical master maps: scale 1:6,000. Report for Sohio Alaska Petroleum Co., Anchorage, AK. 23 map sheets.

Fechhelm, R.G., and W.B. Griffiths. 1990. The effect of wind on the recruitment of Canadian Arctic cisco (*Coregonus autumnalis*) into the central Beaufort Sea. Can. J. Fish. Aquat. Sci. 47:2164–2171.

Fechhelm, R.G., W.H. Neill, and B.J. Gallaway. 1983. Temperature preference of juvenile Arctic cisco (*Coregonus autumnalis*) from the Alaskan Beaufort Sea. Biol. Papers Univ. Alaska 21:24–38.

Fechhelm, R.G., J.G. Baker, W.B. Griffiths, and D.R. Schmidt. 1989. Localized movement patterns of least cisco (*Coregonus sardinella*) and Arctic cisco (*C. autumnalis*) in the vicinity of a solid-fill causeway. Biol. Pap. Univ. Alaska 24:75–106.

Fechhelm, R.G., J.D. Fechhelm, C.J. Herlugson, and D.K. Beaubien. 1991. Bioassay tests of acute temperature and salinity shock to Arctic cisco. Amer. Fish Soc. Symposium 11:109–118.

Fechhelm, R.G., R.E. Dillinger, Jr., B.J. Gallaway, and W.B. Griffiths. 1992. Modeling of in situ temperature and growth relationships for yearling broad whitefish in Prudhoe Bay, Alaska. Trans. Amer. Fish. Soc. 121:1–12.

Fechhelm, R.G., J.D. Bryan, W.B. Griffiths, W.J. Wilson, and B.J. Gallaway. 1994. Effect of coastal winds on the summer dispersal of young least cisco (*Coregonus *sardinella*) from the Colville River to Prudhoe Bay, Alaska: a simulation model. Can. J. Fish. Aquat. Sci. 51:890-899.

Feder, H.M., and S. Jewett. 1982. Prudhoe Bay Waterflood Project infaunal monitoring program. Appendix C *in* Prudhoe Bay Waterflood Project. Environmental monitoring program 1981. Vol. 3. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Feder, H.M., D.G. Shaw, and A.S. Naidu. 1976. The arctic coastal environment of Alaska, Vol. 1: The nearshore marine environment in Prudhoe Bay, Alaska. Institute of Marine Science, University of Alaska, Fairbanks, AK. Rept. R-76-7.

Feulner, A.J., J.M. Childers, and V.W. Norman. 1971. Water resources of Alaska. Alaska District, Water Resources Div., U.S. Geological Survey. Open File Report. 60 pp.

Field, R., F. Gerhardt, J. Tande, G. Balogh, R. McAvinchey, and J. Bart. 1988. Bird-habitat associations on the North Slope, Alaska. Progress report 1987. Alaska Investigations, U.S. Fish and Wildlife Service, Anchorage, AK.

Fine, B.A. 1980. Ecology of Arctic foxes at Prudhoe Bay, Alaska. M.S. thesis. Univ. of Alaska, Fairbanks. 76 pp.

Gallaway, B.J., R.G. Fechhelm, W.B. Griffiths, and J.G. Cole. In prep. Broad whitefish (*Coregonus nasus*) population dynamics in the Prudhoe Bay region of Alaska - causeway effects or density dependence? Proc. Sympos. Arctic Fish Ecol. No. America. May, 1992, Fairbanks, AK. American Fisheries Society.

Gallaway, B.J., W.J. Gazey, J.M. Colonell, A.W. Niedoroda, and C.J. Herlugson. 1991. The Endicott Development Project - preliminary assessment of impacts from the first major offshore oil development in the Alaskan Arctic. Am. Fish. Soc. Symp. 11:42–80.

Gallaway, B.J., W. Griffiths, P. Craig, W. Gazey, and J. Helmericks. 1983. An assessment of the Alaskan stock of Arctic cisco (*Coregonus autumnalis*) - Migrants from Canada? Biol. Pap. Univ. Alaska 21:4–23.

Gallaway, B.J., W.J. Gazey, and R.G. Fechhelm. 1995. Estimating abundance of arctic anadromous fish in the coastal Beaufort Sea during summer — Is an open population model necessary? Proc. Symposium of Arctic Fish Ecol. in North Amer., Fairbanks, AK. American Fisheries Society. In press.

Garner, G.W., and P.E. Reynolds (eds.). 1987. 1985 update report of baseline study of the fish, wildlife and their habitat. U.S. Fish and Wildlife Service, Anchorage, AK.

Garrott, R.A., L.E. Eberhardt, and W.C. Hanson. 1983. Arctic fox den identification and characteristics in northern Alaska. Can. J. Zool. 61:423–426.

Gavin, A. 1983. Spring and summer caribou movements, Prudhoe Bay, Alaska, 1969–1979. Report for Atlantic Richfield Co., Los Angeles, CA. 50 pp.

Glass, D., C. Whitmus, and M. Prewitt. 1990. Fish distribution and abundance. Vol. 5. Endicott environmental monitoring survey, 1986. Report by Envirosphere Company for U.S. Army Corps of Engineers, Anchorage, AK. 188 pp.

G.N. McDonald & Associates. 1994. Stream crossing design procedure for fish streams on the North Slope coastal plain of Alaska. Prepared for BP Exploration (Alaska)

Inc. Anchorage, AK and Alaska Department of Environmental Conservation, Juneau, AK.

Grider, G.W., Jr., G.A. Robilliard, and R.W. Firth, Jr. 1977. Environmental studies associated with the Prudhoe Bay dock: Coastal processes and marine benthos. Final report by Woodward-Clyde Consultants for Atlantic Richfield Company, Anchorage, AK.

Grider, G.W., Jr., G.A. Robilliard, and R.W. Firth, Jr. 1978. Environmental studies associated with the Prudhoe Bay dock: Coastal processes and marine benthos. Final report by Woodward-Clyde Consultants for Atlantic Richfield Company, Anchorage, AK.

Griffiths, W.B., and B.J. Gallaway. 1982. Prudhoe Bay Waterflood fish monitoring program 1981. Pp. D1–D98 *in* Prudhoe Bay Waterflood environmental monitoring program. Vol. 4. Report by LGL Alaska Research Associates, Inc., for Woodward-Clyde Consultants and Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Griffiths, W.B., P.C. Craig, G.L. Walder, and G.J. Mann. 1975. Fisheries investigations in the coastal region of the Beaufort Sea (Kaktovik Lagoon, Barter Island, AK). Arctic Gas Biological Report Series 40. 190 pp.

Griffiths, W.B., D.R. Schmidt, B.J. Gallaway, R.E. Dillinger, Jr., W.H. Neill, W. Gazey, and J.S. Baker. 1983. Fish ecology. Vol. 3. *In* B. Gallaway and R. Britch (eds.). Environmental summer studies (1982) for the Endicott Development. Report for Sohio Alaska Petroleum Company, Anchorage, AK. 323 pp.

Griffiths, W.B., B.J. Gallaway, W.J. Gazey, and R.E. Dillinger, Jr. 1992. Growth and condition of Arctic cisco and broad whitefish as indicators of causeway-induced effects in the Prudhoe Bay region, Alaska. Trans. Amer. Fish. Soc. 121(5):557–577.

Hale, D.A. 1990. A description of the physical characteristics of nearshore and lagoonal waters in the eastern Beaufort Sea. Ocean Assessments Division, National Oceanic and Atmospheric Administration, Anchorage, AK. 73 pp. + app.

Hampton, P.D., L.C. Orr, and L. Byrne. 1988. An evaluation of the effects of noise on waterfowl in the vicinity of CPF-3, Kuparuk Field, Alaska. Vol. I, 1985–1986. Report by Environmental Science and Engineering, Inc. for ARCO Alaska, Inc. and Kuparuk River Unit, Anchorage, AK.

Hazen, B., D.L. Miller, and W.S. Powell. 1993. Insulated ice drilling pad feasibility study report. Report by Duane Miller & Associates for BP Exploration (Alaska) Inc., Anchorage, AK. 1 vol.

Hearn, J.K and M. Robb. 1991. Coastal processes. In: Prudhoe Bay Waterflood Project environmental monitoring program 1987. U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.

Hemming, C. 1994. Badami field trip report, August 27-31, 1994. Habitat and Restoration Division, Alaska Department of Fish and Game, Fairbanks, AK.

Hemming, C. and A. Ott. 1994. Badami field trip report, July 30 to August 2, 1994. Habitat and Restoration Division, Alaska Department of Fish and Game, Fairbanks, AK.

Jakimchuk, R.D., S.H. Ferguson, and L.G. Sopuck. 1987. Differential habitat use and sexual segregation in the central arctic caribou herd. Can. J. Zool. 65:534–541.

Jewett, S.C., H.M. Feder, A. Blanchard, and L.A. Gardner. In press. Macrobenthos associated with the Endicott drilling islands and a causeway in the Beaufort Sea, Alaska.

Johnson, S.R. 1991. The status of Snow Geese in the Sagavanirktok River Delta area, Alaska: a 12-year summary report: 1980-1991. Prepared by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK.

Johnson, S.R. 1994a. The status of Lesser Snow Geese in the Sagavanirktok River delta area, Alaska, 1980–1993. Report by LGL Alaska Research Associates, Inc., for BP Exploration (Alaska) Inc., Anchorage, AK.

Johnson, S.R. 1994b. The status of Black Brant in the Sagavanirktok River delta area, Alaska, 1991–1993. Report by LGL Alaska Research Associates, Inc., for BP Exploration (Alaska) Inc., Anchorage, AK.

Johnson, S.R., and D.R. Herter. 1989. The birds of the Beaufort Sea. BP Exploration (Alaska) Inc., Anchorage, AK. 372 pp.

Kemnitz, R.T., K.M. Novcaski, R.L. Rickman, W.C. Swaner, and K.C. Linn. 1993. Water resources data for Alaska - water year 1992. U.S. Geological Survey. Water-Data Report AK-92-1. 417 pp.

Kertell, K. 1993. Macroinvertebrate production and waterbird use of natural ponds and impoundments in the Prudhoe Bay oil field, Alaska. Report by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK.

Kertell, K., and R. Howard. 1992. Secondary productivity of impounded wetlands in the Prudhoe Bay oil field: Implications for waterbirds. Report by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK.

Larned, W.W., and G.R. Balogh. 1994. Eider breeding population survey Alaska Arctic Coastal Plain 1993. U.S. Fish and Wildlife Service, Migratory Bird Management Project, Anchorage, AK.

Lawhead, B.E. 1990. Caribou study, 1989. *In* Endicott environmental program, draft reports, 1989. Report by Envirosphere Co. for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Lawhead, B.E., and J.A. Curatolo. 1984. Distribution and movements of the Central Arctic herd, summer 1983. Report by Alaska Biological Research, Inc. for ARCO Alaska, Inc., Anchorage, AK. 52 pp.

Lentfer, J.W. 1974. Discreteness of Alaska polar bear populations. International Congress of Game Biologists 11:323–329.

LGL Alaska Research Associates, Inc. 1990. The Endicott Development fish monitoring program—analysis of 1988 data. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and the North Slope Borough, Barrow, AK.

LGL Alaska Research Associates, Inc. 1991. The Endicott Development fish monitoring program—analysis of 1989 data. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and the North Slope Borough, Barrow, AK.

LGL Alaska Research Associates, Inc. 1992. The Endicott Development fish monitoring program—analysis of 1990 data. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and the North Slope Borough, Barrow, AK.

LGL Alaska Research Associates, Inc. 1993a. The Endicott Development fish monitoring program—analysis of 1991 data. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and the North Slope Borough, Barrow, AK.

LGL Alaska Research Associates, Inc. 1993b. Parasitic insect abundance and microclimate on gravel pads and tundra, and observations of caribou in the Prudhoe Bay oil field, Alaska, summer 1992. Prepared for BP Exploration (Alaska) Inc., Anchorage, AK.

LGL Alaska Research Associates, Inc. 1994. The Endicott Development fish monitoring program — analysis of 1993 data. Report for BP Exploration (Alaska) Inc., Anchorage, AK, and North Slope Borough, Barrow, AK.

Lobdell, J.E. 1991. Badami D&E exploration well sites, archaeological and cultural resource reconnaissance, North Slope, Alaska. Report by Lobdell & Associates, Inc. for Conoco, Inc., Anchorage, AK.

Lobdell, J.E. 1994. Badami production facilities and access corridor archaeological and cultural resources reconnaissance, North Slope, Alaska. Report by Lobdell & Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

Lockwood, S.F., B.T. Seavey, R.E. Dillinger, Jr., and J.W. Bickham. 1991. Variation in DNA content among age classes of broad whitefish, *Coregonus nasus*, from the Sagavanirktok River delta. Can. J. Zool. 69:1335–1338.

Mangarella, P.A., J.K. Harper, and T.G. Weingartner. 1982. Physical processes monitoring program. Appendix A *in:* Prudhoe Bay Waterflood Project Environmental Monitoring Program. Vol. 2 of 4. Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Martin, P.D., and C.S. Moitoret. 1981. Bird populations and habitat use, Canning River delta, Alaska. Unpubl. report. U.S. Fish and Wildlife Service, Arctic National Wildlife Refuge, Fairbanks, AK.

McCart, P. 1980. A review of the systematics and ecology of Arctic char, *Salvelinus alpinus*, in the western Arctic. Can. Tech. Rep. Fish. Aquat. Sci. No. 935. 89 pp.

McDonald, G.N. 1984. Breakup 1984 - Sagavanirktok and Putuligayuk rivers, Prudhoe Bay, Alaska. Report for ARCO Alaska, Inc., Anchorage, AK. 1 vol.

McLean, R.F. 1993. North Slope gravel pit performance guidelines. Habitat and Restoration Division, Alaska Dept. of Fish and Game, Fairbanks, AK. Technical Report 93-9. 1 vol.

Michel, B. 1978. Ice mechanics. Les Presses de l'Universite' Laval, Quebec. 499 pp.

Moitoret, C.S., P.A. Miller, R.M. Oates, and M.A. Masteller. 1985. Terrestrial bird populations and habitat use on coastal plain tundra of the Arctic National Wildlife

Refuge. ANWR Progress. Rept. USDI Fish and Wildlife Service. Number FY85-13.

Morehead, M.D., J.T. Gunn, G.D. Pollard, C.B. Wilson, and R.K. Dewey. 1993. Oceanography. Vol. II in 1988 Endicott environmental monitoring program final report. Report by Science Applications International Corp. for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK. 1 vol.

Morrow, J.E. 1980. Freshwater fishes of Alaska. Alaska Northwest Publishing Co., Anchorage, AK. 248 pp.

Mortensen, T.W., and P.J. Cannon. 1982. Flood hazard potential of five selected arctic rivers, Arctic Coastal Plain. Report by Mineral Industry Research Laboratory, Univ. of Alaska, Fairbanks for North Slope Borough Coastal Management Program. 56 pp.

Moulton, L.L., B.J. Gallaway, M.H. Fawcett, W.B. Griffiths, K.R. Critchlow, R.G. Fechhelm, D.R. Schmidt, and J.S. Baker. 1986. 1984 central Beaufort Sea fish study. Waterflood monitoring program fish study. Report for U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.

Murphy, S.M., and B.A. Anderson. 1993. Lisburne terrestrial monitoring program: The effects of the Lisburne Development Project on geese and swans 1985–1989. Report by Alaska Biological Research, Inc. for ARCO Alaska, Inc., Anchorage, AK. 202 pp.

Nickles, J.R., R. Field, J. Parker, R. Lipkin, and J. Bart. 1987. Bird-habitat associations on the North Slope, Alaska. Progress report 1986. Alaska Investigations, U.S. Fish and Wildlife Service, Anchorage, AK.

Oates, R.M., D.C. Douglas, M. McWhorter, and C.A. Babcock. 1987. Terrestrial bird populations and habitat use in coastal plain tundra of the Arctic National Wildlife Refuge. ANWR Progress Rept. Number FY86-14.

Pollard, R.H. and L.E. Noel. 1994. Caribou distribution and parasitic insect abundance in the Prudhoe Bay oil field, summer 1993. Report by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK.

Pollard, R.H., R. Rodrigues, and R.C. Wilkinson. 1990. Wildlife use of disturbed habitats in arctic Alaska: 1989 final report. Report by LGL Alaska Research Associates, Inc. for BP Exploration (Alaska) Inc., Anchorage, AK.

Reimnitz, E. and D.K. Maurer. 1979. Effects of storm surges on the Beaufort Sea coast, northern Alaska. Arctic 32(40):329–344.

Reub, G.S., D.R. Glass, and J.W. Johannessen. 1991. Habitat use and abundance of overwintering fish. Vol. 7, Part IV, Chap. 5 *in* Endicott environmental monitoring program, final reports, 1987. Report by Envirosphere Co. for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK. 46 pp.

Reynolds, P. 1992. Potential effects of petroleum exploration and development on muskoxen using the 1002 area. Pp. 130–147 *in* T.R. McCabe, B. Griffith, N.E. Walsh, and D.D. Young (eds.). Terrestrial research: 1002 area, Arctic National Wildlife Refuge, interim report, 1988–1990. U.S. Fish and Wildlife Service, Anchorage, AK. 432 pp.

Robilliard, G.A., and M. Busdosh. 1983. Oliktok Point and vicinity: 1981 Infauna study. Report for ARCO Alaska, Inc., Anchorage, AK. 42 pp.

Robilliard, G.A., and J.M. Colonell. 1983. Environmental impacts of a 4-km causeway at Prudhoe Bay, Alaska: How could government and industry benefit? Oceans '83 Conference, San Francisco, CA. 5 pp.

Robilliard, G.A., R.W. Firth, Jr., and D.W. Chamberlain. 1978. Effect of a dock on marine benthic organisms at Prudhoe Bay, Alaska. Proceedings Energy/Environment '78 Symposium by Society of Petroleum Industry Biologists, Los Angeles, CA. 21 pp.

Robilliard, G.A., R.W. Smith, and J.M. Colonell. 1988. Prudhoe Bay Waterflood Project benthic infauna and water quality components of the NPDES monitoring program May 1986. Report for ARCO Alaska, Inc. and the Prudhoe Bay Unit, Anchorage, AK. 157 pp.

Rodrigues, R., R.O. Skoog, and R.H. Pollard. 1994. Inventory of Arctic fox dens in the Prudhoe Bay oil field, Alaska. Final report prepared by LGL Alaska Research Associates, Inc., for BP Exploration (Alaska) Inc., Anchorage, AK 25 pp. + Appendix.

SAIC (Science Applications International Corporation). 1993a. 1988 Endicott Environmental Monitoring Program Final Report. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Volume 1: Integration and Assessment
Volume 2: Oceanography
Volume 3: Breaches, Modeling, Sedimentation and Erosion
Volume 4: Ice Breakup/Freezeup, Meteorology, River Discharge, Caribou
Volume 5: Snow Goose

SAIC (Science Applications International Corporation). 1993b. 1989 Endicott Environmental Monitoring Program Final Report. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Volume 1: Integration and Assessment
Volume 2: Oceanography
Part 1 Oceanography - Main Report
Part 2 Appendices A-F
Part 3 Appendices G-J
Part 4 Appendices K-V
Volume 3: Breaches, Circulation Modeling, Sedimentation and Erosion
Volume 4: Ice Breakup/Freezeup, Meteorology, River Discharge
Volume 5: Caribou, Snow Goose

SAIC (Science Applications International Corporation). 1994. Endicott 1992 environmental monitoring program. Snow geese. Final report. Report for Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Savoie, M. and D.E. Wilson. 1983. Physical processes monitoring program. Chapter 3 *in:* Prudhoe Bay Waterflood Project Environmental Monitoring Program. Vol. 2 of 5. Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Savoie, M. and D.E. Wilson. 1984. Physical processes 1983. Chapter 2. *in:* Prudhoe Bay Waterflood Project Environmental Monitoring Program. Vol. 2 of 3. Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Savoie, M. and D.E. Wilson. 1986. Physical oceanographic processes. Chapter 2 *in:* Prudhoe Bay Waterflood Project Environmental Monitoring Program. Vol. 1 of 4. Alaska District, U.S. Army Corps of Engineers, Anchorage, AK.

Schmidt, D.R., W.B. Griffiths, and L.R. Martin. 1989. Overwintering biology of anadromous fish in the Sagavanirktok River Delta, Alaska. Biol. Pap. Univ. Alaska 24:55–74.

Schmidt, D.R., W.B. Griffiths, D.K. Beaubien, and C.J. Herlugson. 1991. Movement of young-of-the-year Arctic ciscoes across the Beaufort Sea coast, 1985-1988. Amer. Fish. Soc. Symposium 11:132–144.

Scott, K.H. 1978. Effects of permafrost on stream channel behavior in Arctic Alaska. U.S. Geological Survey. Professional Paper 1068. 19 pp.

Shannon and Wilson, Inc. 1991. Geotechnical field and laboratory studies, North Alaska warning system. Report for Unisys Defense Systems, Inc., Great Neck, NY. 1 vol.

Sharma, G. 1979. The Alaskan shelf: Hydrographic, sedimentary, and geochemical environment. Springer-Verlag, New York, NY. 498 pp.

Smits, C.M.M., C.A.S. Smith, and B.G. Slough. 1988. Physical characteristics of arctic fox (*Alopex lagopus*) dens in northern Yukon Territory, Canada. Arctic 41(1):12–16.

Stickney, A.A., R.J. Ritchie, B.A. Anderson, and D.A. Flint. 1994. Tundra Swan and Brant surveys on the Arctic Coastal Plain, Colville River to Sagavanirktok River, Alaska, 1993. Report by Alaska Biological Research, Inc. for ARCO Alaska, Inc. and the Kuparuk River Unit, Anchorage, AK.

Stirling, I. 1988. Attraction of polar bears *Ursus maritimus* to off-shore drilling sites in the eastern Beaufort Sea. Polar Record 24(148):1–8.

TERA (Troy Ecological Research Associates). 1992. Bird use of coastal tundra: 1991 report. Report for BP Exploration (Alaska) Inc., Anchorage, AK. 28 pp.

TERA (Troy Ecological Research Associates). 1993a. Bird use of the Prudhoe Bay oil field. Report for BP Exploration (Alaska) Inc., Anchorage, AK. 58 pp.

TERA (Troy Ecological Research Associates). 1993b. Distribution and abundance of Spectacled Eiders in the vicinity of Prudhoe Bay, Alaska: 1992 status. Report for BP Exploration (Alaska) Inc., Anchorage, AK. 22 pp.

TERA (Troy Ecological Research Associates). 1993c. Preliminary characterization of the breeding-season bird community in the vicinity of the Yukon Gold ice pad. Unpublished report for BP Exploration (Alaska) Inc., Anchorage, AK. 10 pp.

TERA. (Troy Ecological Research Associates). 1994a. Bird use of coastal tundra at Prudhoe Bay, Alaska: 1991–1992. Prepared by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

TERA. (Troy Ecological Research Associates). 1994b. Distribution and abundance of Spectacled Eiders in the vicinity of Prudhoe Bay, Alaska: 1991-1993 status. Draft report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

TERA. (Troy Ecological Research Associates). 1994c. Preliminary characterization of summer bird use of the proposed Badami development area. Unpublished report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK.

Thorsteinson, L.K., L.E. Jarvela, and D.A. Hale. 1990. Arctic fish habitat investigations: Nearshore studies in the Alaskan Beaufort Sea, summer 1988. U.S. Department of Commerce and U.S. Department of the Interior, Outer Continental Shelf Environmental Assessment Program. Final Report 71:349–485.

Thorsteinson, L.K., L.E. Jarvela, and D.A. Hale. 1991. Arctic fish use habitat investigations: Nearshore studies in the Alaskan Beaufort Sea, summer 1990. National Ocean Service, Office of Ocean Resources Conservation and Assessment, National Oceanic and Atmospheric Administration. Annual Report. 166 pp.

Troy, D.M. 1988. Bird use of the Prudhoe Bay oil field during the 1986 nesting season. Report by LGL Alaska Research Associates, Inc. for Alaska Oil and Gas Association, Anchorage, AK. 96 pp.

Troy, D.M. 1991. Bird use of disturbed tundra at Prudhoe Bay, Alaska: Bird and nest abundance along the abandoned peat roads, 1988–1989. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK. 57 pp.

Troy, D.M. 1992. Tundra birds. Chapter IV *in* Prudhoe Bay Waterflood Project: Tundra bird monitoring program 1987. U.S. Army Corps of Engineers, Alaska District, Anchorage, AK.

Troy, D.M. 1993. Tundra birds. Appendix IV *in* Prudhoe Bay Waterflood Project environmental monitoring program, 1987. Alaska District, U.S. Army Corps of Engineers, Anchorage, AK. 103 pp.

Troy, D.M., and T.A. Carpenter. 1990. The fate of birds displaced by the Prudhoe Bay oil field: The distribution of nesting birds before and after P-Pad construction. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK. 51 pp.

Urquhart, D.R. 1973. Oil exploration and Banks Island wildlife: a guideline for the preservation of caribou, musk ox, and Arctic fox populations on Banks Island, NWT. Game Management Division Report, Government of the Northwest Territories. 105 pp.

U.S. Army Corps of Engineers, Alaska District and Environmental Research and Technology, Inc. 1984. Endicott Development Project. Final environmental impact statement. Vol. II: Technical discussion. Anchorage, AK. 1 vol.

U.S. Fish and Wildlife Service. 1993. Arctic National Wildlife Refuge river management plan and environmental assessment (draft). U.S. Fish and Wildlife Service. Fairbanks, AK.

U.S. Fish and Wildlife Service. No Date. National wetlands inventory notes to the user for North Slope 1:63,360 scale maps.

Wahrhaftig, C. 1965. Physiographic divisions of Alaska. U.S. Geological Survey. Professional Paper 482. 50 pp.

Walker, D.A. 1983. A hierarchical tundra vegetation classification especially designed for mapping in northern Alaska. Pp. 1332–1337 *in*: Permafrost: fourth international conference proceedings, July 17–23, 1983, Fairbanks, AK. National Academy Press, Washington, D.C.

Walker, D.A. 1985. Vegetation and environmental gradients of the Prudhoe Bay region, Alaska. CRREL Report 85-14, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH, 239 pp.

Walker, D.A., and P.J. Webber. 1983. Vegetation studies, 1:63,360-scale mapping and an accurate check of the 1:250,000-scale Landsat-derived map in the Arctic National Wildlife Refuge, Alaska. Institute of Arctic and Alpine Research, Boulder, CO. 151 pp.

Walker, D.A., and W. Acevedo. 1987. Vegetation and a Landsat-derived land cover map of the Beechey Point Quadrangle, Arctic Coastal Plain, Alaska. CRREL Report 87-5, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH. 72 pp.

Walker, D.A., W. Acevedo, K.R. Everett, L. Gaydos, J. Brown, and P.J. Webber. 1982. Landsat-assisted environmental mapping in the Arctic National Wildlife Refuge, Alaska. CRREL Report 82-37, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH. 59 pp.

Walker, D.A., P.J. Webber, E.F. Binnian, K.R. Everett, N.D. Lederer, E.A. Nordstrand, and M.C. Walker. 1987. Cumulative impacts of oil fields on northern Alaskan landscapes. Science 238:757–761.

Ward, D., and P.C. Craig. 1974. Catalogue of streams, lakes and coastal areas in Alaska along routes of the proposed gas pipeline from Prudhoe Bay, Alaska to the Alaskan/Canadian border. Volume 19. Arctic Gas Biological Report Series.

Warnock, N.D., and D.M. Troy. 1992. Distribution and abundance of Spectacled Eiders at Prudhoe Bay, Alaska: 1991. Report by Troy Ecological Research Associates for BP Exploration (Alaska) Inc., Anchorage, AK. 21 pp.

Whitten, K.R., and R.D. Cameron. 1980. Nutrient dynamics of caribou forage on Alaska's arctic slope. Pages 159-166 *in*: E. Reimers, E. Gaare, and S. Skjenneberg (eds.). Proc. 2nd Int. Reindeer/Caribou Symp., Røros, Norway. 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

Whitten, K.R., and R.D. Cameron. 1985. Distribution of caribou calving in relation to the Prudhoe Bay oil field. Pp. 35–39 *in* A.M. Martell and D.E. Russell, (eds.). Proceedings of the First North American Caribou Workshop. Can. Wildl. Serv. Spec. Publ., Ottawa, Canada.

Woodward-Clyde Consultants. 1979. Benthic ecology. *In* Prudhoe Bay Waterflood Project. Biological effects of impingement and entrainment from operation of the proposed intake: Summer 1978. Report for Prudhoe Bay Unit, Anchorage, AK.

Woodward-Clyde Consultants. 1983. Lisburne Development area: 1983 environmental studies. Final report. Report for ARCO Alaska, Inc., Anchorage, AK. 722 pp.

Woodward-Clyde Consultants. 1994. Mikkelsen Bay oceanography and coastal processes. Report for BP Exploration (Alaska) Inc., Anchorage, AK.

APPENDIX A
SPILL PREVENTION AND RESPONSE

This appendix provides general information on spill prevention and response considerations for the Badami Development Project to facilitate assessment of the impacts of the project. This information is not intended to be complete; a full Oil Discharge Prevention and Contingency Plan (ODPCP) will be prepared for the project once final engineering is available. The ODPCP will be submitted to the Alaska Department of Environmental Conservation (ADEC) and other appropriate agencies in time for approval before start-up of operations at Badami.

BPXA's policy is to prevent spills in the first place through facility design and personnel training. If a spill occurs, BPXA has its own resources to call upon, as well as those of the Mutual Aid organization of North Slope operators and of Alaska Clean Seas. BPXA is already working under an approved exploration ODPCP for the Badami appraisal wells in the winter of 1994-95. This plan, along with the Endicott and Prudhoe Bay ODPCP's, will provide the basis for the Badami operational plan.

A.1 SPILL PREVENTION

BPXA has adopted Best Management Practices for spill prevention which were established through guidelines and operating procedures. Following is a summary of some of the spill prevention considerations for the Badami development.

A.1.1 Badami Drillsite and Main Production Facilities

A detailed description of the Badami wellsite and production facilities is provided in Section 3 of the Project Description/Environmental Assessment. Full production facilities will include:

- Multi-stage oil, water, and gas separation;
- Crude oil chilling, pumping, and metering;
- Gas conditioning, compression, and reinjection;
- Flare and pressure relief systems;
- Produced water treatment and reinjection;

- Electrical power generation; and
- Utility provision.

Fuel Transfer Procedures

BPXA requires the use of its North Slope Fluid Transfer Guidelines by employees and contractors. In addition, the use of surface liners at all inlet and outlet points in a fuel transfer operation became mandatory for transfer operations on April 2, 1993, with the North Slope Unified Operating Procedure (UOP) for Surface Liner/Drip Pan Use. This procedure was signed and issued by all North Slope Field Managers. The UOP mandates the use of liners for vacuum trucks, fuel trucks, sewage trucks, chemical delivery units, chemical transfer units, and fluid transfers within facilities. Surface liners, also known as drip liners, protect the ground surface from contamination during fuel and chemical transfers. BPXA Environmental personnel place facility tags to identify areas requiring a liner during transfer. BPXA supplies contractors with liners and training in their proper use.

Off-pad and remote-site operations are conducted in accordance with BPXA Best Management Practices approved by ADEC in 1993.

Secondary Containment

Specific tankage to be located at the drillsite and production pad is unknown at this time. The ODPCP submitted to ADEC for review and approval for operation of these facilities will include an inventory for tanks containing chemical or petroleum products. This inventory will include the tank identification number, location, capacity, contents, secondary containment, and the year the tank was built. All tanks will be constructed with arctic-grade materials in accordance with BPXA engineering requirements. A complete tank inventory containing detailed information regarding tank design and construction parameters will be available from the Environmental and Regulatory Affairs Department. A corrosion prevention and tank maintenance program will be implemented to ensure the integrity of all storage tanks.

Secondary containment sufficient to contain 110 percent of the tank capacity will be provided for all tanks containing hazardous substances and storage tanks with capacities greater than 660 gallons. Fuel storage tanks located at the wellsite will be placed in bermed, lined containment areas sufficient to contain 110 percent of the tank capacity.

Contaminated fluids within secondary containment structures will be collected by a system of drains and channels leading to a common sump. Vacuum trucks will collect fluids from temporary storage. Storage tanks and sumps will be provided with high level alarms and automatic shutoff devices.

In-Situ Burning. The Badami operations ODPCP will contain information on the use of in-situ burning as a response technique under the appropriate conditions. ACS can provide the requisite technical and logistical support.

Wildlife Protection

Wildlife protection strategies for Badami area spill response will be consistent with the strategies currently employed at other BPXA facilities on the North Slope. These procedures will be defined in the Badami ODPCP.

A.3 ENDICOTT SPILL HISTORY

The tables on the following pages present the history of spills reported at Endicott from 1986 through 1994. This history was used in evaluating the spill potential for Badami operations.

TABLE A-4
BPXA ENDICOTT SPILL SUMMARY: 1986

DATE	AMOUNT (GAL)	PRODUCT	PRIMARY LOCATION	SECONDARY LOCATION	CAUSE
3/21/86	5	Diesel/Hydraulic oil	Causeway		Drips and leaks; lack of attention to prevention
8/31/86	840	Oil-based mud	MPI		Return line under mud tank broke
9/3/86	20	Ethylene glycol (60-40)	MPI	Mod 605	Hole accidentally drilled in line
9/7/86	7	Diesel	MPI		Hose on fuel trucks broke during installation of insulation
9/11/86	30	Crude & diesel	MPI	Skid 20&21	Line purging
9/18/86	15	Crude	MPI	Skid 301	Operator opened wrong valve
9/18/86	3	Crude	MPI		Leak from ball valve shipped from NS
9/22/86	1	Diesel	MPI	Mod 610	Defective fuel filter
9/27/86	100	MEG	MPI	Skid 19	Heat trace failure on new KO drum
9/27/86	37	35 gal diesel; 1.5 gal hyd. fluid	MPI		From rig fire
9/28/86	20	Ethylene glycol	MPI	Pipe rack	Vent line valve inadvertently opened
9/29/86	5	TEG & crude	MPI	Skid 20	Reboiler overpressured; PSV valve popped

TABLE A-5
BPXA ENDICOTT SPILL SUMMARY: 1987

DATE	AMOUNT (GAL)	PRODUCT	PRIMARY LOCATION	SECONDARY LOCATION	CAUSE
3/14/87	7	MEG	Endeavor Island	Skid 12	Glycol sump line vented
3/22/87	2	Battery acid	Endeavor Island	DS-14	Batteries fell off truck
8/4/87	50 yds^3	Drilling fluids	MPI		Overtopped pit walls
8/7/87	5	Crude	MPI	Warehouse	Oil residue from tubing
8/16/87	2100	Crude	MPI	Flare	Release through flare stack
8/17/87	42	Crude/Hydrochloric Acid	MPI	Skid 54	Truck control valve left open
8/21/87	84	MEG	MPI	Skid 408	Vessel overfilled; "cold down load"
8/24/87	50	Crude	MPI	Skid 452	Oil trapped in line between valve and blind
8/24/87	35	Diesel	MPI	Fuel Ramp	Vented while line being bled
8/26/87	100 lb	Borax	MPI	Well 21	Valve left open
8/27/87	30	MEG	MPI		Valve left open
9/2/87	65	MEG	MPI	Sk 304-302	PSV valve relieved into unwelded fl_____
9/9/87	4	Antifreeze	MPI		Broken heater hose on bus
9/11/87	Sheen	Diesel	MPI		
9/12/87	25	Crude	MPI	Skid 54	Loose flange: flow line leak
9/14/87	40	Crude oil/Well returns	MPI		High winds blew returns from well

TABLE A-6
BPXA ENDICOTT SPILL SUMMARY: 1988

DATE	AMOUNT (GAL)	PRODUCT	PRIMARY LOCATION	SECONDARY LOCATION	CAUSE
4/22/88	60	Diesel	End. SDI	Rig 7	Butterfly valve btwn f. and r. tanks leaked through
5/1/88	40	Methanol	Endeavor Is. - End Sag 10		Vac truck so full it drove liquid into vent pipe
5/2/88	20 bbl	Crude	Endeavor Is.	Skid 454	Leak developed in dike liner holding fluids
5/3/88	50	Diesel	Endicott	Well 30	Heater misbalanced and lost fuel from tank
5/5/88	3	Crude	Endicott	Well 3-1	Possible well maint. equip. hose/coupling failure.
5/7/88	80	Diesel	Endicott	Well 9	During rig disassembly prior to rig move
5/11/88	15	Diesel	Endicott SDI	Well 20	Camlock fitting vibrated loose during stim work
5/11/88	5	Hydraulic fluid	Endicott SDI	Well 1	Filter blew off the PTO unit of Camco 5th wheel
5/13/88	25	Hydraulic fluid	Endicott SDI		Snow removing loader ran into buried pipe.
9/11/88	5	Crude	MPI	Skid 56	Hose failed while transferring crude from skid to tank
9/14/88	2	Diesel/Water	MPI		Bleed barrel overflowed - liquids left - wind sprayed
9/14/88	4	Diesel	MPI	Well 9	Leaked onto pad during well work
9/14/88	5	Diesel	MPI	Well 32	Leaked onto pad during well work
9/14/88	5	Diesel	MPI	Well 25	Fuel escaped out filler neck of heater
9/14/88	5	Diesel	MPI	Well 5	Leaked onto pad during well work

TABLE A-7
BPXA ENDICOTT SPILL SUMMARY: 1989

DATE	AMOUNT (GAL)	PRODUCT	PRIMARY LOCATION	SECONDARY LOCATION	CAUSE
1/1/89	18	Antifreeze/ automotive	MPI	Module 604	Lower radiator hose ruptured on Kobelco forklift
1/4/89	2	Hydraulic fluid	Causeway	At breach	Ruptured hydraulic line on APC snow blower
1/7/89	1.5	Crude oil	Causeway		Paint bucket fell off vehicle on causeway near gravel pit
2/17/89	2	Lightweight motor oil	Causeway	Intersection	Probable: Vehicle w/ruptured line sprayed oil
3/15/89	2	Anti-freeze	MPI		Water pump failure on the Natchiq Cat forklift
6/23/89	Trace	Suspected oil sheen	SDI	West side	Snow melt
	0.0625	Diesel fuel	(Revision 1:)	East side	
6/30/89	Trace	Unknown	MPI	West side	Snow melt from parking/pad; sheen leached out
	0.125	Automotive oil			
7/1/89	Sus.	Oil sheen/ Hydraulic fluid	SDI	West side	Snow melt
	0.125				Melt on ice road
7/3/89	?	Crude oil	MPI	West side	Plant upset resulted in liquid carryover to flare with incomplete combustion. Variable winds 10-16 mph from SE carried light residue across flare pond, roadway and offshore
	20				
7/4/89	3	Crude and water	MPI	Well 2-2	While transferring liquids to the injection well, (?) failed to bleed (??) and the liquid blew out of the gravel
7/9/89	20	Seawater	MPI	Module 401	Fiberglass pipe joint failure
8/24/89	10	Diesel	Endeavor Is.		Unknown. Spill was discovered while in process of moving dunnage (timbers) that had been in place over 2-1/2 years
9/26/89	4	Transmission fluid	Endicott Causeway		Natchiq road grader had a leaking transmission line at the gear box. Leaked fluid along the Endicott Causeway while in motion.
9/27/89	20	Diesel fuel	MPI		Auto shutoff nozzle did not operate per design
9/30/89	0.5	Motor oil, 30 wt.	SDI		Oil filter on the manlift developed a leak. Was noticed by electricians and shut off
10/12/89	50	Seawater	MPI	Module 401	Joint on outlet spool of E-1901B seawater heater failed.

TABLE A-7 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1989

DATE	AMOUNT (GAL)	PRODUCT	PRIMARY LOCATION	SECONDARY LOCATION	CAUSE
11/1/89	84	Crude oil and diesel, 50/50	SDI	Well 3-15	Coiled tubing parted while pulling out of Well 3-15
	126				
11/5/89	3	Anti-foam	MPI	Module 305	Centrifugal pump on bulk delivery tanker failed to operate due to blockage in pneumatic actuator line. The bulk storage tank valve was cracked open to prevent dead heading pump and liquid from storage tank backfeed into tanker and overflowed through vent before operator could get the storage tank valve closed. Delivery tank was already completely full on arrival.
11/10/89	1	Diesel - Arctic grade	MPI	Fuel pump	Fuel dispensing nozzle failed to shut off
11/18/89	20	Diesel	SDI	Well 3-15	Well that had previously been killed broke through (burped) during process of removing damaged tubing from well
	& 10	& Seawater/NaCl brine			
	80	Seawater (Revision)			
12/5/89	1	Crude	SDI	Well 3-33	O-ring failed on lubricator

TABLE A-8
BPXA ENDICOTT SPILL SUMMARY: 1990

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
1/19/90	20	MEG	Outside Mod 305	Valve didn't seat properly
1/21/90	1	Hydraulic fluid	Well 3-23 SDI	Suspected vehicle leak
3/14/90	0.5	H.P. wellhead grease	Well Row 4, SDI	Suspected lube seal failure
3/16/90	3	Crude oil	Well 4-8, SDI	Leaking 3" Camlock plug
3/28/90	1	Diesel fuel	Well Slot 1-31	
3/28/90	1	Crude oil	Endicott SDI	
4/03/90	3	Gasoline (unleaded)	Endicott MPI	Unattended nozzle
4/14/90	2	Glycol	Bullrail 603	Probably vehicle radiator leak
4/16/90	1	Crude oil	Well 3-39 SDI	Oil came off wireline pulley
4/28/90	2	Hydraulic fluid,	Fuel storage	Ruptured hose
4/28/90	1	Gasoline	Fuel Storage	Leaking valves
5/06/90	5	Corrosion inhibitor	Module 305	
5/12/90	5	Diesel fuel	Tool Services	Parked on incline
5/24/90	2	Diesel fuel	Tool Services	Parked on incline
6/21/90	1	Diesel fuel	Fuel pumps	Probably over filled vehicle
6/25/90	1.5	Crankcase oil	Endicott	
7/03/90	10	Diesel fuel	Well 4-48	Gasket on tiger tank malfunctioned
7/11/90	2	Crude oil/water mix	Well 2-02 MPI	Operator failed to close intake valve
7/28/90	10	Crankcase oil	MPI Pad	Forklift hit bump; drum fell off and spilled
8/14/90	100	Crude oil & water mix	Under 303	Pulling blind from 1st stage oil inlet
8/20/90	1	Crude oil	Well 2-34	Leaking valve
8/20/90	Unk-Sheen	Diesel	Mile 10	Discharge of oily residue from vac truck.
8/31/90	2	Hydraulic fluid	MPI pad	Vehicle overfilled; leaked onto pad.
9/04/90	5	Diesel	MPI Pad	Bleeding down wireline lubricator into bleed tank too fast.
9/26/90	Trace	WR-6 (soap) w/crude	M 401	Transfer w/contaminated hose
10/01/90	30	TEG	Mod 305	Operator not paying attention
10/04/90	1	Crude oil	SDI Well 3-39	Failure to insure lubricator was completely bled down prior to removing it from the tree.
11/16/90	33	Produced water containing approx. 2 gallons crude.	MPI Mod 401	Wastewater injection pump seized up and pump ruptured.
11/18/90	20	Diesel	MPU U-606	While attempting to fill tank of vehicle the valve stuck in closed position. Tank on truck did not seal off completely and allowed fuel to overflow the center tank which was already full.

TABLE A-8 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1990

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
11/18/90	1	Methanol	MPI U-305	Failed to drain all liquids from suction hose prior to storing hose back on truck.
11/29/90	3100	Crude/oil mix 100 gal. crude; 3,000 gal. water	MPI Mod 401	Camlock fitting at melt tank recirculation pump broke in half. Pump continued pumping and product went over side of tank onto ground.
12/02/90	100	Seawater	MPI Mod 401	Malfunction of seawater filters backwash valves. Seawater leak into air scour vent line during backwash cycle.
12/05/90	8	Hydraulic fluid	603 Southside	Vehicle hydraulic filter failed.
12/01/90	1	Motor oil	401 Southside	Most likely cause found to be a ruptured oil coolant line.
12/01/90	25	Biocide	305 Southside	Hose hook up backward to truck. Discharge hose from pump to IMO tank.

TABLE A-9
BPXA ENDICOTT SPILL SUMMARY: 1991

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
01/07/91	25	Diesel	Mod 603	Level instrument failure on diesel day tank, causing to over fill.
01/07/91	10	Diesel	Diesel fuel tank	While filling the unit with diesel, the spare valve was partially open and the cap not secured. When the pump was engaged the fuel bled by the valve onto the snow.
01/07/91	50	Gray water	BOC	Gray water tank developed a leak, due to corrosion.
01/28/91	15	Hydraulic fluid	Bridge - Big Skookum	Ruptured main motor drive 2" hose
02/04/91	2 qts.	Motor oil	MPI	977 Cat engine block damaged due to piston rod failure.
02/24/91 (rig spill)	2	Glycol	Well 3-25	Sight glass broke on boiler spilling glycol onto deck where it migrated onto snow. Leak was found after rig was moved.
02/27/91	5	Diesel	Well 2-44	Withdrawing 1/2" wireline. Seal faulty; not complete. Diesel expelled into the air onto the snow.
05/09/91	2	Crude oil	Module 401	Pump failed to pump down crude level. Oil level was high in bin and high winds caused oil to slope over the side.
05/16/91	≥15	Diesel	Wellhouse 1-11	BJ Titan Nitrogen pumper fueled without incident. Spill noticed after departure of fuel truck.
06/15/91	1	Crude oil	Module 303	Separation of a nipple on 1st stage separator
6/17/91	20	Seawater & produced water	Wellhouse 2-2	Broken flange on 8 in. line.
7/6/91	2	Gasoline	Bulk storage area on MPI	Was unloading a shipment of gasoline and the transfer hose ruptured.
7/22/91	1	Diesel	MPI	During a refueling operation some fuel leaked out of the nozzle.
07/25/91	5	Diesel fuel	Wellhouse 2-68	Opr was pressure testing wing valve flange and choke leaked. Bleed hose was attached to sample port and valve was open.
09/24/91	50	80% crude and 20% produced wWater	Outside Mod 401	Using vac truck to pump from the CPI but hose was not connected at the other end.
10/10/91	10	Salt water/ Brine	Wellhouse 2-06	An HB&R unit was going to break a hose down and did not bleed-off the fluid before disconnecting hose.
10/12/91	25	75/25 water/crude oil	Wellhouse 2-02	While pumping into the injection well the relief valve lifted. It drained into the well cellar and over filled ii causing the mixture to exit the wellhouse onto the pad.

TABLE A-9 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1991

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
11/1/91 (rig spill)	30	Oil/Diesel	Well Row 2	Overflow of wellhouse cellar.
11/19/91	110	Oil/Diesel	Wellhouse 1-35	Failure of 6-inch air actuated valve on HB&R hot oil truck.
12/10/91 (rig spill)	20	Antifreeze	Drill rig laydown area	Rig radiator leak.
12/31/91	10-20	Crude oil/ Produced water	Between flare and Skid 303	Flare carryover.

TABLE A-10
BPXA ENDICOTT SPILL SUMMARY: 1992

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
02/03/92	1	Motor oil	SDI	Breather line froze, oil discharged out the dipstick housing
02/07/92 (rig spill)	less than 10	Diesel	SDI	Prep Well 3-15 for workover. Depressuring annulus, diesel was carried out of vent.
2/15/92	150	Seawater (1-1/2 gal crude oil)	SDI	Squeeze job being done on Well 4-02 when well burped causing tank to overflow
03/10/92	3	MEG	Storage Rack TS Building	Pallet caked with snow. Forklift missed pallet. Barrel punctured
03/14/92	55	50% MEG 50% water	Flare	Methanol being used in flare line to thaw ice blew out flare stack.
5/13/92	2	Diesel	Bulk fuel loading rack	Overfill truck.
5/21/92	0	Crude oil	Under Skid 303	Drain line from repair clamp plugged causing oil to leak from seal.
5/28/92	10	Crude oil/ Diesel mix	SDI/East end, Row-4	While attempting to vacuum out a bleed tank, pressure was applied to the hose instead of a vacuum.
7/9/92	1	Glycol/ Diesel mix	Behind Well 2-20	Block valve leaked about a gallon of glycol/diesel mix into an upcapped line allowing fluid to leak onto pad.
7/19/92	Initial report 15; final report .15 (Corrected)	Crude oil	Between Skid 401 & 603	While emptying the wastewater tank into tiger tank a loose inspection plate on tiger tank caused oil leakage.
7/18/92	6 oz.	Biocide	Chemical Loading Station	Operator thought sample point drain was hooked back into truck but drain line was designed to flow to the ground.
7/20/92	25	Hydraulic oil	Well 4-44	A high pressure hydraulic line (coil tubing unit) ruptured while working on the well.
7/26/92	1/2	Crude oil/Diesel mix	Bleed down trailer near Well 5-01	When testing a SSSV on 5-01, the pressure was bleed down into a bleed down trailer to fast causing carry over of fluids in the tank
8/14/92	15-20	Scale inhibitor	SDI Pipe rack	A valve stem packing leaked causing scale inhibitor to leak onto pad.
8/15/92	Approx. 2	Diesel	Diesel storage tank	Hose used to hook to diesel supply tankers sprang a leak and drained contents of hose onto ground.
8/18/92	1	Gasoline	East of BOC under sky bridge	Unknown
8/27/92	2 qts.	Hydraulic fluid	SDI gravel pad	P & H mobile crane, hydraulic line that leaked appeared to have rubbed on the transmission housing wearing a hole in the line, thus causing the spill.

TABLE A-10 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1992

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
9/11/92	2	Crude	Under Skid 401	Deluge drain: It appears that someone dumped crude oil into the fire water deluge drain, enough that the floor trap opened and dumped oil on the ground under the module.
9/20/92	1/2	Scale inhibitor	Under SDI Pipe Rack #245A	Packing leak on block valve lines leading to Wells 3-49 and 4-08.
11/4/92	1	Antifreeze	604 bullrail	Green maint. truck has a plastic tee that connects 3 heater hoses. It broke and spilled antifreeze onto the ground.
11/19/92	3	Scale inhibitor	Under SDI Pipe Rack #245A	Scale Inhibitor supply line to Well 3-49. Failure in a fitting.
11/19/92	1 qt.	Diesel	Mile 11 on causeway	A coupling connecting two fuel tanks on the 44-passenger bus failed.
11/29/92	1 qt.	Crude oil	Outside Wellhouse 3-47	While bleeding an annulus on Well 3-47 into a P.E bleed trailer, trailer was left unattended for a period of time. Personnel returned to trailer just as fluid was overflowing the trailer tank and containment pan.
12/11/92	2	Scale inhibitor	Behind Well 2-08	Chemical feed to well, A ball valve outside the wellhouse was found leaking.
12/14/92	1	Diesel	Well slot 3-03	On a Tioga Space Heater, a schedule 40 1/4" X 2" nipple failed. allowing fuel to be spilled onto the ground

TABLE A-11
BPXA ENDICOTT SUMMARY: 1993

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
1/16/93	5	Diesel	SDI, 75 ft. in front of 3-25	While fueling a coil tubing unit, the fueler walked away momentarily to check the truck. The fuel nozzle did not shut-off when the tank fill was complete.
1/22/93	2	Hydraulic fuid	North end of row four	Vehicle had been in for service; new hydraulic oil filter installed in warm shop. When taken out into -40•F weather, metal and gasket shrunk, jarred loose and leaked.
2/15/93 (rig spill)	4	Vehicle antifreeze	Construction Office bull rail	Mi-Drilling Fluids Truck 24, had a failure of the lower radiator hose allowed antifreeze to spill onto the ground.
4/9/93	100	Produced water	SDI Well 3-45 injection header	Injection Header for Water Injection Well 3-45 developed a leak.
4/27/93	5	60/40 methanol/ seawater	Outside Wellhouse 4-02	Chicksan piping was prepared for well work. When pressure tested, one connection leaked, causing a mist of methanol/seawater to be discharged. Containment pit had been placed under the connection and caught some of the fluid.
4/28/93	45	60/40 methanol/ seawater (27 gallons of methanol)	Outside Wellhouse 4-02	After transferring a tank of methanol/seawater mix, a valve that did not have a good seal began dripping fluid into an enclosed secondary containment pit. After a few hours, pit overflowed into the tank farm building and began running out the door.
5/01/93	5	Annulus fluid (dead crude oil)	SDI Well 3-41	PE bleed trailer was overfilled by an operator bleeding the pressure off the 9 5/8" annulus.
5/8/93	6	Crude oil	Well 2-14	A coiled tubing unit was trouble shooting Well 2-14. While running in the hole, the tubing broke through a hydrate plug causing the wellhead pressure to rise from 250 psi to approx. 1,500 psi. The "Pack Off" had been set for 250 psi and did not hold the higher pressure. Oil sprayed onto the back of the coiled tubing unit about 450 square feet behind the wellhouse.
5/23/93	2	Diesel fuel	Outside Skid 302, Door 302-S	An Atlas Compco Compressor had a "cross-over" fuel line between the two fuel tanks that was probably plugged. Fuel was being pulled from one tank while excess fuel was being returned to other tank, causing the tank to overfill.
6/15/93	1/2	Crude oil	241 pipe rack	A grease fitting worked itself loose allowing oil to leak around the threads.
6/17/93	1/2	Diesel	Fuel pumps	Person not parked completely on containment area and allowed his tank to overflow onto the gravel at edge of containment pit area.

TABLE A-11 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1993 (CONT'D)

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
6/23/93	1/2	Hydraulic fluid	Outside 302 Module	Hydraulic tank on the 90-ton crane was topped off with outriggers extended. When outriggers were retracted oil in line caused the tank to overflow.
7/5/93	1/2	Outboard motor oil	Endeavor Island	An outboard motor was pulled, the oil injection line was plugged. The plug developed a leak and allowed a half gallon to spill on the gravel.
7/11/93	2	Scale Inhibitor	SDI Pipe rack	Packing leak; packing gland not tight enough.
8/2/93	Less than 5	Hydrocarbon sheen	Endicott Road	A 2-4 foot wide hydrocarbon sheen was found on Endicott Road from 100 yds south of the Big Skookum Bridge to start of the road near Drill Site 9. At this time, investigation is not able to determine the source.
8/10/93	1	Emulsion polymer (antifoam)	Outside Skid 401	Thought to be empty barrel. Summer hires were picking up some empty barrels to take to barrel crusher. One of the barrels had some product in it and didn't have bungs screwed into them. Barrel tipped over and spilled product onto ground.
8/11/93	50	Produced water	Outside Skid 401	Wastewater tank was almost full; Vac truck was called to hook up to tank and bring level down. Level gauge malfunctioned and head pressure from tank rapidly filled Vac truck with product and overflowed tank on truck through PSV onto ground.
8/27/93	0.25	Motor oil	MPI Dock	While running a small engine, the engine oil drain plug vibrated out of place dumping 1 quart of motor oil on to the pad.
9/27/93	.50	Type F transmission fluid	Endicott Access Road Mile Marker 7.5	A Baker Oil tool truck (Tk#2625) driven by John Swanson was leaving from delivery at Rig 15 when the fan belt broke and tore the transmission fluid coolant line.
9/30/93	20	80% seawater / 20% crude	Endicott SDI	While working on well squeeze job, vac truck operator decided to use pressure from one truck to force liquid from another vac truck. A valve leaked allowing fluid from one truck into the other and overflowing onto ground.
11/3/93	1/8	60/40 MEG	Well Row #2	Most likely cause was a vehicle overheating.
11/4/93	3	Transmission fluid	Well Row #2	PTO gear box cracked on vehicle.
11/29/93	1/2	60/40 methanol/ water mix	Injection Skid	HB&R truck driver changing out pump on truck and spilled contents onto ground under truck.
12/9/93	1/2	Sulfuric battery acid	20 feet in front of Well 1-63	A new automotive type, 6 volt, battery was found in its box on the ground. It appears it fell off a vehicle hitting on the end of the case. The end of the case cracked, allowing the acid from one cell to leak out.
12/14/93	1	Crude oil	South side of Module 401	During a plant upset, crude in wastewater tank carried over to atmosphere via vent line.

TABLE A-12
BPXA ENDICOTT SPILL SUMMARY: 1994

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
1/10/94	5	Antifreeze	On causeway 1/2 mile south of Little Skookum Bridge	Radiator cap on side boom cat failed allowing antifreeze to discharge on to the ground.
1/11/94	2	MEG glycol	MPI 244 Pipe rack between Section E & F	A leak occurred in the glycol heat tracing for the firewater line.
1/11/94	25* (revised total)	MEG glycol	MPI 244 pipe rack. between Section E & F	When insulation removed glycol flow rate increased for a short period of time.
1/20/94	1/4	Diesel	In front of firehouse	BJ Services truck was delivering some nitrogen to purge a vessel; cold caused a drive line to slowly turn and pump fuel into the igniter box that heats the nitrogen. The box overflowed onto the ground.
3/6/94 (rig spill)	30	Brine water containing 0.7 lbs. of Xanvis	Doyon Rig 15	A valve was inadvertently opened allowing abut 30 gallons of fluid to spill onto the ground.
4/12/94	2	Hydraulic fluid	MPI Well Row 1	Hydraulic hose ruptured on the end while refueling vehicle.
4/13/94	1/4	Glycol (ethylene) antifreeze	SDI	Radiator hose broke on tractor.
4/14/94	1 pt.	Diesel fuel	Row 2 wellhouses	Hose reel leak on the refueling truck.
4/16/94	7	Diesel fuel	Row 2 wellhouses	Diesel was drained into a holding tank. Bleed valve was left open to the holding tank. Block valve on coil was opened and diesel drained from coil to tank, overfilled causing spill.
5/10/94 (rig spill)	110	Drilling mud composition 85% water, 14% bentonite and 1% sodium-hydroxide	SDI	An equalizer line temporarily plugged between mud tanks allowing one tank to overflow.
5/29/94	Undeter-mined at this time	Misc. drips and spots of fuels and lube oils.	Endicott Causeway construction sites - new breach area / SDI	Equipment used during the new breach construction during the 1993-1994 winter.
5/29/94 Updated 6/17/94	Quantity unknown	Diesel mixed with crude	Endicott Causeway construction sites - new breach area / SDI	Update: The original spill, thought to be minor drips from construction equip., has resulted in continued cleanup and removal of contaminated gravel and ice. A sample of the unreported spilled product has been sent to a lab for analysis. Product is suspected to be a mixture of primarily diesel w/small percent of crude. ACS has been contracted to clean up spill and to date has recovered approx. 32 CY of contaminated gravel. As soon as lab results are available, the gravel will be remediated.

TABLE A-12 (Cont'd)
BPXA ENDICOTT SPILL SUMMARY: 1994 (CONT'D)

DATE	AMOUNT (GAL)	PRODUCT	LOCATION	CAUSE
5/29/94 FINAL 8/16/94	55	Diesel mixed with crude	See above	Final determination: Residual material used during breach construction left in pipeline bypass.
6/2/94	Less than 1/2	Hydraulic fluid	SW Clarifier (MPI)	45-Ton Crane hydraulic cylinder leaked onto frozen gravel.
6/5/94	1/2	Antifreeze, propylene glycol	BOC bull rail parking area	Vehicle #091 developed a radiator leak.
7/9/94	Est. 2	Hydraulic or transmission fluid	Endicott breach	Contaminated gravel found at Endicott Causeway
8/7/94	Est. 5	Visco 4989 scale inhibitor	Skid 405, south side	Scale inhibitor supply line developed a flange leak.
8/13/94	100	"Dead" crude oil	In front of Well 2-26	While breaking down and sucking lines dry from a corrosion inhibitor. treatment on Well 2-26 a valve was inadvertently left open. Crude oil was then sucked from one tank through the open valve into 2nd tank, overflowing the second tank.
9/6/94	1/2 pt.	50/50 gluteraldehyde & water (biocide)	Module 305 (Outside)	Leaking bonnet flange on the fill line gate valve.
9/16/94 (rig spill)	30	60% bentonite 40% water	Well 2-41	While drilling a well on Row One the mud found its way up around Well 2-41 outer casing.
Same as above	Same as above	same as above	Well 1-41	While drilling a well on Row One the mud found its way up around Well 1-41 outer casing.
9/29/94	1	KW 0121 corrosion Inhibitor	Skid 305 north side	Ops had attempted to pump out a chemical tank. Several hours later discharge hose began leaking at a "crow's foot" connection.
9/22/94 (rig spill)	See spill report attach.	See spill report attachment.	Well 1-53 incident	Well 1-53 control incident. See spill report and attachment for details.
12/9/94	1/2	Sulfuric battery acid	20 feet in front of Well 1-63	A new automotive type, 6 volt, battery was found in its box on the ground. It appears it fell off a vehicle hitting on the end of the case. The end of the case cracked, allowing the acid from one cell to leak out.
12/14/94	1	Crude oil	South Side of Module 401	During a plant upset, crude in waste water tank carried over to atmosphere via vent line.

APPENDIX B
ATTENDEE LISTS FROM BADAMI PROJECT MEETINGS

This appendix contains the attendee lists from the following Badami project meetings:

- Public Meeting, December 12, 1994
- Pre-Application Conference, December 12, 1994
- Beaufort Sea Causeways Meeting, June 21, 1994
- Pre-Application Meeting, June 14, 1994

TABLE B-1

BADAMI DEVELOPMENT PROJECT
PUBLIC MEETING

December 12, 1994

Name and Organization	Address	Phone	Fax
GEORGE HAUGEN CTI ALASKA, INC.	4871 OLD SWD HWY ANCH 99503	562-4442	562-5093
Keith Burke The Alliance	4220 'B' St. Anchorage, AK 99508	563-2226	561-8870
GERI SAKEAGAK ASRC	301 Arctic Slope Ave Anchorage, AK 99518	349-2369	349-5476
Jim Stotts - ASRC	"	"	"
Nancy Moses - CIRI	PO Box 93330 Anch 99509	263-5160	279-8836
Karen Wuestenfeld	BPX	564-5490	564-5020
Peter Hanley	"	564-5202	"
Gary Campbell	BPX	564-4275	564-4680
Adeline Hopson	BPX - Barrow	852 5025	852 2601
MARY WEGER CORPS OF ENG.	P.O. BOX 898 ANCH. AK 99506	753-2716	753-5567

TABLE B-1 (Cont'd)

BADAMI DEVELOPMENT PROJECT
PUBLIC MEETING

December 12, 1994

Name and Organization	Address	Phone	Fax
Bruce McKenzie, ACS	12350 Industry Way Anchorage, AK 99515	345-3142	345-2435
Jeff Logan (Staff for Green)			
Debbie Reinwand	Arctic Power		
Terry Martin	St. Legislator	258-8169 333-6990	
Con Bunde	State House District 18	258-8168	
Dee Olin Hoffman	North Slope Borough Planning Dept	Please send me 852-7189	handouts from AM presentation 852-0322
Richard L Ranger -ACS	12350 INDUSTRY WAY STE 200 ANCHORAGE AK 99515	345 3142	345 2435
Chuck Sullivan - Parker Drilling Co.	P.O. Box 112070 Anch AK 99511	349-1591	344-6914
Warren Matumeak	P.O. Box 69 Barrow AK 99723	852-0350	852-6948
Robert Watkins	Suite 2-C 411 W 4th Anch 99501	271-3693	272-0690

TABLE B-1 (Cont'd)

BADAMI DEVELOPMENT PROJECT
PUBLIC MEETING

December 12, 1994

Name and Organization	Address	Phone	Fax
Judy Brady/AOGA		272-1481	272-1181
Tony Braden/JPO ADNR		271-4400	272-0690
George Dozier (Rep. Kott's Office)		~~694~~ 694-8944	694-8945
Steven Schmitz		762-2597	562-3852
Mary Cocklan-Vendl	BPX	564-4766	564-5020
KEVIN BROWN / CIRI		274-8638	279-8836
Chris Herlugson, BPX		564-4245	564-5020
Jeanne Hanson NMFS	222 W 7th Ave #43 Anch AK 99513	271-5006	271-3030
Vic Manikian/JPO-ADNR			
Pamela M. Gustavus	ADEC	271-4474	271-0690
Jack O. Hakkila	ABT P.O. Box 190083 Anchorage, 99519-0083	~~562-5468~~ 452-5149	452-5203

TABLE B-1 (Cont'd)

BADAMI DEVELOPMENT PROJECT
PUBLIC MEETING

December 12, 1994

Name and Organization	Address	Phone	Fax
Portia Babcock, Office of Senator Loren Leman	716 W. 4th Ave, suite 540	258-8189	258-3768

TABLE B-2

BADAMI DEVELOPMENT PROJECT
PRE-APPLICATION CONFERENCE

December 12, 1994

Name and Organization	Address	Phone	Fax
Lori Quakenbush USFWS	101 12th Ave Box 19 FBKS 99701	456-0442	456-0208
Karen Wuestenfeld, BPX	900E Benson	564-5490	564-5020
Leon Lynch DNR	3700 Airport Way	451-2724	451-2751
John Wolfe JPO/ADNR	411 W 4th Avenue Anchorage Ak 99501	271-4344	
Vic Manikian	JPO	272-2747	272-3551
[illegible] M. Gastfreud	ADEC/PCRO -	271-4476	272-0690
Robert Watkins	ADEC/PCRO	271-3693	272-0690
Judy Samsal	JPO	271-4393	272-0690
Bill Schroder	APUC	276-6222	
Ralph Kiehl	ADEC/PCRO	271-3649	

TABLE B-2 (Cont'd)

BADAMI DEVELOPMENT PROJECT
PRE-APPLICATION CONFERENCE

December 12, 1994

Name and Organization	Address	Phone	Fax
Tony Braden ADNR	411 W 4th Ave Anch AK	271-4400	272-0690
John Wolfe ADNR	"	271-4741	272-0690
Carl Lautenberger EPA/JPO	"	271-4306	272-0690
Rob McWhorter	JPO	271-3664	271-3071
Timothy Law ADEC	PCRO 411 W 4th Ave Anch AK 99501	271-4051	
Gary Campbell BP	900 E Benson Blvd	564 4275	564-4680
John Greenslade Colt	Calgary	403-259-1857	252-2291
Derick Nixon	Calgary	403-226-0481	Same
Wim Veldman / Colt Hydroconsult	CALGARY	403-265-6958	263-9888
AL OTT	1300 COLLEGE ROAD FAX, AK 99703	907-451-6192	456-3091

TABLE B-2 (Cont'd)

BADAMI DEVELOPMENT PROJECT
PRE-APPLICATION CONFERENCE

December 12, 1994

Name and Organization	Address	Phone	Fax
Tom Chapple	411 W 4th Ave Anc	271-4746	272-0690
Molly Birnbaum	411 W 4th Ave Ste 2C	271 4317	272-0690
Steven Schmitz	P.O. Box 107034	762-2597	561-3850
Mary Neger	P.O. Box 898 Anch. Ak 99506	753-2716	753-5567
Mary Cocklan-Vendl	BPX	564-4766	564-5020
Ted Rockwell	EPA 222 W 7th Rm 537 Anch. 99513	271-5083	271-3424
Jeanne Hanson	NMFS 222 W 7th #43 Anch 99513	271-5006	271-3030
Tom Barnes	BPX - Environment	564-5154	564-5020
Dave Matson	BPX - Civil Eng.	564-4456	564-4888

TABLE B-3

Endicott and West Dock Monitoring
The Status of Our Knowledge and Application to New Developments

June 21, 1994

Suite 1210
Frontier Building
3601 C Street
Anchorage

Name	Affiliation	Phone	Fax
Pamela M. Gretsrud	ADEC - JPO	278-8594	272-0690
Jeanne L. Hanson	NMFS	271-5006	271-3030
Ted Rockwell	EPA	271-5083	271-3424
Al Ott	ADF + G	451-6192	456-3091
Julie Murrell	DNR - JPO	271-4344	272-0690
Robert Meyer	MMS	271-6625	271-6507
Jack Colonell	Woodward-Clyde Consultants	561-1020	563-3198

TABLE B-3 (Cont'd)

Name	Affiliation	Phone	Fax
Mike Millard	Fisheries Resource Office USFWS	456-0219	456-0454
Philip Martin	Ecological Services Office USFWS	456-0325	456-0208
Thomas Newbury	MMS, Alaska OCS Region	271-6604	-6507
Mary Weger	Corps of Engineers	753-2716	753-[illegible] 5567
Leon Lynch	DNR/OL	451-2724	
Bruce Webb	DNR / D.O&G	762-2554	
Steve Schmitz	DNR / D. O&G	762-2597	
Linda Perry Dwight	BPX Consultant	564-5495	564 50[illegible]
Chris Herlugson	BPX	564-4245	564-5020
William Griffiths	LGL Ltd.	406-656-0127	
Bill Wilson	LGL	5623339	5627223

TABLE B-3 (Cont'd)

Name	Affiliation	Phone	Fax
ERIK FREDEEN	NORTH SLOPE BOROUGH	561-8820	562-1940
Peter Hanley	BP Exploration	564-5202	564-5020
Frank Wendling	MMS	271-6510	271-6504
Molly Birnbaum	JPO / DEC	271-4317	[illegible]

TABLE B-4

BADAMI DEVELOPMENT PROJECT
Pre-Application Meeting Sign-In Sheet
June 14, 1993

Name and Organization	Address	Phone	Fax
Lori Quakenbush USFWS	101 12th Ave, Box 19, Rm 232 Fairbanks, AK 99701	456-0442	456-0208
Peter Hanby	BPX	564-5202	564-5020
Gary Campbell	BPX(A)	564-4275	564-4680
Rick Smith	DNR. DOC	451-2706	451-2751
Karen Wuestenfeld	BPX	564-5490	564-5020
Jerry Jeschke	MMS	271-6188	271-6504
Bob Crandall	A.O.G.C.C.	279-1433	
Tom Murrell	MMS	271-6188	271-6504
THOMAS NEWBURY	MMS	271-6604	-6507
Douglas CHOROMANSKI	MMS	271-6066	
MARY WEGER ARMY CORPS of ENGINEERS	P.O. BOX 898 ANCHORAGE, AK. 99506	753-2716	753-5567
Ted Rockwell	EPA - Anchorage	271-5083	271-3424
Julie Murrell	DNR/SPCO	271-4344	272-0690
Cindy Bailey	BPX Gov't/Public Aff	564-5537	564-4124
Jeanne Hanson	NMFS	271-5006	271-3030

1

TABLE B-4 (Cont'd)

BADAMI DEVELOPMENT PROJECT
Pre-Application Meeting Sign-In Sheet
June 14, 1993

Name and Organization	Address	Phone	Fax
Robert Watkins	JPO 411 W 4th	258-5400	272-0260
Pamela Grossfeld	JPO/ADEC 411 W. 4th	"	"
Mary Cocklan-Vendl	BPX	564-4766	564-5020
Matt Werner	BPX: Project Engineer	564-4554	564-5200
Dan Kelleher	North Slope Borough	561-8820	562-1940
Dave Heier	NSB	563-5800	
Jim Helfinstine	Mun Coastal Board District/ JPO	463-2248	
Mac McLean	ADF&G	451-6192	
Steven Schmitz	DNR/DOG&G	762-2597	
Leon Lynch	DNR/DL	451-2724	
Judy Samsal	DNR/DGC/SPCO	278-8594	272-0690

2