AN EVALUATION OF THE EFFECTIVENESS OF REHABILITATION AT SELECTED STREAMS IN NORTH SLOPE OILFIELDS

by
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INTRODUCTION

The Arctic environment of the North Slope poses a harsh set of environmental conditions such as permafrost, low ambient temperatures, and low levels of precipitation. As a result of these environmental conditions, many stream systems contain relatively few species of fish and low fish densities, particularly stream systems without access to overwintering habitats. Despite this pattern of fish distribution and abundance, numerous road crossings of fish-bearing waterbodies have been required as part of infrastructure development in the Prudhoe Bay, Duck Island, Kuparuk River, and Milne Point units. Locations of the stream crossings are identified in Appendix A (Maps 1 through 7).

Two major river crossings currently exist within the oilfield complex, the west channel of the Sagavanirktok River and the Kuparuk River. Moderate-sized waterbodies within the oilfield complex include Washout Creek, Little Putuligayuk River, Putuligayuk River, Leach Creek, Pebble Creek, Sakonowyak River, East Creek, Smith Creek, Ugnuravik River, and Kalubik Creek. All of these streams, with the exception of the Sagavanirktok River, are considered to be tundra streams fed primarily by snowmelt and summer rainfall. The Sagavanirktok River is classified as a mountain stream, fed by snowmelt, rainfall, and ground water discharge from springs. Tundra streams generally freeze solid during winter, with only isolated pockets of water beneath the ice by late winter. Peak discharges occur in the spring during breakup, and other peaks are associated with rainfall (i.e., storm events). Smaller tundra streams frequently become intermittent during the summer. High flow events during breakup generally do not exceed 14 days in duration and extremely low flows are common throughout the summer months.

In 1989, a report titled "North Slope Oil and Gas Cross Drainage Report" was prepared based on field inspections conducted at fish stream crossings during August 1988 (Ott 1989). The objectives of the 1988 work were as follows: (1) gather site-specific data (e.g., culvert burial depth, slope protection, erosion, erosion control structures, fish blockages, stream discharge) on cross drainage structures; (2) photograph and document cross drainage structures and stream characteristics above and below road crossings; (3) develop recommendations for the rehabilitation of streams and replacement of cross drainage structures, where needed; and (4) provide a data base which could be used in the development of design standards (design criteria and specifications for cross drainage structures) for future fish stream crossings.

Fifty-two individual fish stream crossings were field surveyed. Ten of these fish stream crossings were identified as high priority for remedial work based on the degree of rehabilitation required and the fish resources present. The ten high priority fish stream crossings identified by Ott (1989) are listed below:

(1) Washout Creek on the Endicott Access Road;

(2) West channel of the Sagavanirktok River, Spine Road crossing;

(3) Gravel Pit Slough located within the floodplain of the west channel of the Sagavanirktok River;

(4) East Fork of Charlie Creek crossed by the Access Road to Mine Site D;

(5) Nowhere Creek in the Kuparuk Development Area;

(6) East Creek crossed by the Access Road Mobil/Phillips Pad #1;

(7) East Creek at the Spine Road crossing;

(8) Pebble Creek crossed by Access Road to Exploratory Well 22-11-12;

(9) Kuparuk River at the Spine Road crossing; and

(10) Leach Creek at the Spine Road crossing.

In 1991, the Alaska Department of Fish and Game (ADF&G) worked with the Alaska Department of Environmental Conservation (ADEC), the North Slope Borough (NSB), and the oil and gas industry to assess nonpoint source pollution associated with North Slope oil and gas development. A project to develop a consistent set of design and installation standards for cross drainage structures in fish streams was determined to be a priority. As part of the State of Alaska's Nonpoint Source Pollution Control 319(h) Workplan, a proposed scope of work was submitted to the Environmental Protection Agency (EPA). The North Slope cross drainage project requested Section 319 funds to complete two tasks:

(1) prepare a cross drainage structure design manual with standardized criteria and specifications (including guidance on number, location, and sizing) for fish stream crossings; and

(2) survey 10 stream crossings and verify success of fish habitat remedial actions undertaken by industry at five high priority stream crossings identified in the 1988 survey (Ott 1989). Industry remedial actions taken on East Fork of Charlie Creek, Nowhere Creek, East Creek, Leach Creek at Spine Road crossing, and Pebble Creek are targeted for evaluation of the effectiveness of remedial measures.

Funding for the project was received from the EPA. Task #2 was to be completed by the ADF&G. Data and recommendations were to be provided to the oil and gas industry for their use in completion of Task #1. We report here our observations with photographic documentation for all ten priority streams identified for remedial work by Ott (1989). In addition, we have included data for several other fish stream crossings where fish passage problems were documented during the summers of 1991 and 1992. Our report is submitted with the understanding that data and recommendations will be considered by the oil and gas industry in their development of a design manual for fish stream crossings.

METHODS

Stream crossings were inspected visually in August 1988, with opportunistic observations made during the summers of 1989, 1990, and 1991. In 1992, all ten high priority stream crossings originally identified by Ott (1989) were field surveyed. The following data were gathered for each stream crossing in 1988: (1) date of observation; (2) location; (3) photographs; (4) culvert structure (number, size, etc.); (5) culvert outlet and inlet characteristics (armor, water depth, velocity, erosion, fill in culvert); (6) fish passage barriers; and (7) fish species present. Fish presence/absence was assessed using visual observations, angling, fyke nets, and gill nets. Gill nets were 125 ft long consisting of 25-ft panels with mesh sizes of .5, 1.0, 1.5, 2.0, and 2.5 in. Fyke nets were 12 ft in length with two 4.0 ft square entrance frames, five hoops, and a 6 ft cod end. Net wings measuring 4 ft by 25 ft were attached to the first entrance frame.

Observations made in 1992 at rehabilitated stream crossings were compared with previous data. Success of rehabilitation was assessed based on comparisons of the stream habitat before and after restoration. Recommendations made by Ott (1989) were reviewed and modified as appropriate.

RESULTS

Background data on each of the original ten priority stream crossings and fisheries and cross drainage information collected between 1988 and 1992 are summarized. Recommendations for additional rehabilitation, if required, are included.

Washout Creek on the Endicott Access Road

The existing drainage structure was installed during winter 1984-85 with two large corrugated pipes buried below the stream thalweg for fish passage (Figure 1). Fish Habitat Permit FG84-III-0094 was issued, field inspections were made during installation, and the culvert battery was installed in accordance with the Fish Habitat Permit. Gobi-mat armor protection at the inlets and outlets of the pipes was set with the top of the armor below the pipe inverts.

On August 16, 1988 the crossing was field checked and outwash gravels were noted in the stream and gravel from road grading covered the sandbag armor protection. Ott (1989) recommended that a plan be developed to stop erosion of the road slope and to remove outwash gravels from Washout Creek upstream and downstream of the Endicott Access Road (Ott 1989). Plans for corrective action at Washout Creek were submitted to the department by BP Exploration (BPX) on September 7, 1989, and Fish Habitat Permit FG89-III-0189 was issued on September 19, 1989, for the removal of debris, repair of armor, placement of gravel to stabilize the roadway and culverts, removal of outwash gravels upstream and downstream of the road, covering the outwash area with overburden, and the reestablishment of vegetation through seeding, mulching, and fertilization. In early October 1989 the Washout Creek crossing was field checked and removal of outwash gravels from the stream was verified (Shideler 1989). As stated in the letter from Mr. Taylor (BPX) dated October 9, 1989, removal of outwash gravels from Washout Creek using a VRCA "super sucker" was successful in removing 25 to 30 cubic yards of material without damage to aquatic vegetation.

In 1992 the crossing was rechecked and outwash gravels again blocked Washout Creek downstream of the road. Materials have continued to erode along the upslope side of the road west of the creek. Although rehabilitation as conducted by BPX was successful, no work was done to stabilize and/or control the source of sediments. We recommend that a plan be developed and implemented to stop the source of sediments to the creek and for the removal of gravels from Washout Creek. The culvert battery has remained stable since construction in 1984 and provides for free movement of fish. No evidence of scour or erosion exists at the crossing. Road grading practices have dramatically improved since 1988 as there was no evidence of gravels covering the armor protection (Figure 1).

West Channel of the Sagavanirktok River, Spine Road Crossing

The Spine Road crossing of the west channel of the Sagavanirktok River consists of a single bridge, river training structures along the west side of the floodplain, culvert batteries, and soft plugs (i.e., portions of road fill material designed to fail under high flows). The natural floodplain is restricted to less than 10% of its original width. Backwater areas, outwash gravels, isolated highwater channels, and scour pools below culvert batteries characterize the altered floodplain of the west channel of the Sagavanirktok River. The original crossing was constructed prior to implementation of the department's Fish Habitat Permitting program for North Slope activities. Various modifications were made to the crossing in the last 10 years and these actions (e.g., adding culverts, maintenance on dikes, vehicle travel within the floodplain, replacement of road fill materials after washouts) have been permitted pursuant to AS 16.05.870.

The department recommended both short-term and long-term rehabilitation for the west channel of the Sagavanirktok River. Short-term recommendations focused on highwater channels located east of the main channel where surface flows become isolated from overwintering habitats in the main river and Sag Site C (a flooded deep-water gravel pit) following spring breakup. Our long-term request involved an evaluation of the entire crossing with the objective of returning the west channel to a normal flow pattern in an unrestricted floodplain.

Fyke and gill-net sampling for fish in the west channel of the Sagavanirktok River (e.g., sloughs, backwater areas, main channel, highwater channels, isolated waters), including Sag Site C, was conducted between 1988 and 1992. Fish species documented included burbot (Lota lota), broad whitefish (Coregonus nasus), Arctic grayling (Thymallus arcticus), ninespine stickleback (Pungitius pungitius), round whitefish (Prosopium cylindraceum), slimy sculpin (Cottus cognatus), and Dolly Varden (Salvelinus malma). In the highwater channels crossed by the Spine Road, ninespine stickleback, juvenile broad whitefish, and Arctic grayling were collected in the fall during low flow conditions when the highwater channels were isolated from overwintering habitats in the Sagavanirktok River. Overwinter survival is unlikely among fish trapped in areas without access to suitable overwintering habitat. Numbers of fish trapped each year is unknown.

A comprehensive rehabilitation plan for the west channel of the Sagavanirktok River has not been developed. Actions taken by ARCO Alaska, Inc. (AAI) during the last four years, with the exception of the rehabilitation of Sag Site C, were conducted due to road failures, ponding of water upstream of the road, and excessive scour adjacent to bridge piles. On August 19, 1992, we noted areas of aquatic habitat isolated from suitable overwintering areas (Figure 2). After our field work, discharge in the river rose significantly and AAI requested authorization to place more culverts in the road. Ponded water had saturated road fill materials creating an unstable driving surface. Fish Habitat Permit FG92-III-0204 was issued on September 4, 1992, covering placement of culverts at two locations. The permit was amended on September 9, 1992, authorizing the use of smooth wall pipes (corrugated pipes were not available) and the installation of two additional culverts. The permit was issued with the understanding that AAI and ADF&G would meet to discuss the status of cross drainage structures and associated facilities within the west channel of the Sagavanirktok River. A meeting occurred in late December of 1992; however, definitive plans for rehabilitation have not yet been developed.

We believe that the existing cross drainage structures in the west channel of the Sagavanirktok River do not provide for fish passage and are not consistent with the proper protection of anadromous fish habitat. If necessary, fish surveys could be conducted to quantify the numbers and species of fish trapped in isolated waters. We plan to meet with AAI representatives and conduct joint field inspections during the summer of 1993 to assess and evaluate potential options for providing fish passage and ensuring the proper protection of anadromous fish resources in the Sagavanirktok River.

Gravel Pit Slough located within the floodplain of the West Channel of the Sagavanirktok River

Gravel Pit Slough was created by gravel removal operations conducted in the early 1970s. A portion of the Sagavanirktok River floodplain was shallow-scraped leaving a oxbow slough with variable depths (0.5 to 5.0 ft), an irregular shoreline, and a water surface area of 17 ac. A portion of the site was isolated from the Sagavanirktok River when a road was constructed across the floodplain. A 48-inch diameter spiral pipe was placed in the road fill at the lower end of the site, providing fish access from overwintering habitats in the Sagavanirktok River to the site during the ice-free season. Discharge through the pipe varies with the quantity of water in the Sagavanirktok River, and under low flow conditions discharge barely exceeds zero. Physical changes (e.g., depths, sediment accumulation) in Gravel Pit Slough have been minor because the site is protected from the river by the road.

The ADF&G recommended that Gravel Pit Slough be considered as a potential gravel site with a gravel mining plan that would incorporate the development of overwintering habitat (excavate gravels to a depth of greater than 40 ft) in the slough while maintaining at least 20% of the surface area of the slough as littoral habitat (Ott 1989). We also recommended that the 48-inch spiral pipe be replaced with several large culverts properly set to provide for free fish passage under various flow conditions. AAI responded to the recommendations in a letter dated October 9, 1989, stating that field inspections had been conducted, fish passage was not obstructed, and that enhancement options would be costly with no obvious benefit (Frampton 1989).

Fyke net sampling of Gravel Pit Slough was conducted by the ADF&G in 1989 (mid-July, late August) and 1990 (late June, late August). In mid-July 1989, 129 fish, including 114 small broad whitefish (43 to 55 mm), 13 Arctic grayling, 1 ninespine stickleback, and 1 round whitefish were captured in Gravel Pit Slough (Hemming 1990c). In late August 1989, 559 fish were collected, including 327 Arctic grayling, 150 ninespine stickleback, 50 round whitefish, 4 broad whitefish, and 28 burbot (Hemming 1990c). In late August 1990, 237 small (mean length 74.8 mm, SD = 2.6 mm) broad whitefish were caught in a fyke net (Hemming 1991b). The high catch of juvenile broad whitefish in Gravel Pit Slough in two successive years is a strong indicator of the importance of shallow-backwater habitats to this species (Hemming 1991b). A high catch of young-of-the-year Arctic grayling, broad whitefish, burbot, and round whitefish also suggests the value of backwater habitat to various fish species using the Sagavanirktok River.

Contrary to previous site inspections, on August 19, 1992, under low flow conditions in the Sagavanirktok River, a partial barrier to fish passage did exist at the culvert structure (Figure 3). If water levels remained stable or decreased, all fish in the slough probably would have been forced to use suboptimal winter habitat resulting in mortality. Increased water occurred later in August providing an opportunity for fish to emigrate from the slough to overwintering habitats in the main river.

Based on results of fisheries investigations and site inspections, we have altered our recommended actions for Gravel Pit Slough. The high use by rearing fish, particularly Arctic grayling and broad whitefish, indicate that the shallow-backwater type habitat should be maintained and that gravel mining (e.g., deep excavation to create overwintering habitat) in this area need not occur. However, we recommend that a larger culvert be placed in Gravel Pit Slough so that fish passage is ensured under various river discharges.

East Fork of Charlie Creek crossed by the Access Road to Mine Site D

The East Fork of Charlie Creek was diverted around Mine Site D during gravel removal operations. The stream was placed in an excavated diversion channel and a culvert battery was installed in the access road crossing. Gravel removal operations were completed in 1983. In August 1988, the ADF&G conducted a site inspection at Mine Site D and recommended remedial work at the culvert battery crossing and culvert structure replacement in the East Fork of Charlie Creek be a part of an overall rehabilitation plan for Mine Site D.

AAI prepared and submitted for review and approval a comprehensive rehabilitation plan for Mine Site D and the East Fork of Charlie Creek culvert crossing on March 19, 1990. The rehabilitation plan included replacement of the East Fork of Charlie Creek culvert battery (three 60-in diameter culverts, one placed 18 inches below the stream thalweg, two placed 18 inches above the stream thalweg, estimated water velocity at breakup was six feet per second), excavation of eight channels connecting the creek to Mine Site D, overburden removal and placement on the ice in Mine Site D along the south and west sides, and the creation of perched wetlands on the overburden pile along the east side of the site. Fish Habitat Permit FG90-III-0088 was issued to AAI on April 13, 1990, authorizing rehabilitation. Construction was scheduled for completion under winter conditions and rehabilitation was finished by mid-May 1990 (Hemming 1990a).

Field inspections of Mine Site D and the East Fork of Charlie Creek culvert were conducted during the summers of 1990, 1991, and 1992. Rehabilitation was completed in accordance with approved plans and specifications; however, the water elevation in the Mine Site D lake was approximately three ft lower than in 1989 leaving portions of the channel connections dry (Hemming 1990b). Field inspections by ADF&G and AAI revealed lower lake elevation was caused by two of the excavated channels which were located downstream from a natural hydraulic control in the East Fork of Charlie Creek. Remedial work to correct the water elevation was identified and AAI developed a plan to install two channel plugs. Fish Habitat Permit FG90-III-0088 was amended on January 24, 1991, authorizing the installation of two channel plugs. The plugs were installed by AAI during winter 1990-91. Observations during the summers of 1991 and 1992 indicated that the water elevation in Mine Site D was still three ft lower than desired. One of the channel plugs has failed each spring even though repair work has been done by AAI. We plan to continue to work with AAI to determine the best approach to reestablish natural water levels in Mine Site D.

During summer 1992, 708 Arctic grayling were transferred from the Kuparuk River drainage to Mine Site D. Arctic grayling ranged in size from 40 to 407 mm. On August 19, 1992, during our field inspection, Arctic grayling were observed feeding along the edges of the flooded mine site. Hemming (1992) documented adult Arctic grayling actively pursuing and taking ninespine stickleback along the edges of the pit. Loons were observed on the Mine Site D lake and waterfowl were present in the perched wetland created by AAI as part of the Mine Site D rehabilitation (Figure 4). We believe that rehabilitation conducted by AAI at Mine Site D represents one of the most successful rehabilitation projects conducted to date on the North Slope. We hope water levels can be returned to the natural level. We also speculate that the Arctic grayling transplant will be successful. Monitoring to determine the fate of Arctic grayling in Mine Site D will be conducted.

<u>Nowhere Creek in the Kuparuk Development Area</u>

Nowhere Creek, a tributary to Kalubik Creek, was crossed by an access road from Drill Site 3F to 3G. The original culvert battery consisted of five pipes (one 72 inch, two 60 inch, and two 54 inch) with the 72-inch pipe to be installed 15 inches below the stream thalweg. Fish Habitat Permit FG86-III-0115 was issued to AAI on April 28, 1986, authorizing installation of the culvert battery. The culvert battery was constructed during the summer of 1986.

The Nowhere Creek culvert battery survived spring breakup in 1987; however, on June 12, 1988, the crossing failed. Extension erosion of road fill material occurred with outwash gravels carried 500 ft downstream. Possible reasons, according to AAI, for culvert failure are summarized below (Thompson 1988):

> "First, the culverts are located at a deep point in the stream, and are set low to permit fish migration. As a result, the culverts will probably be about three-fourths, or more, full of water at freezeup time, severely restricting their flow capabilities. Second, just prior to break-up we clean out any accumulated snow and ice from all of the culverts at Kuparuk. This year, however, just after completing this clean-out activity, we experienced a late storm, which included blowing snow. The culverts on the 3G access road were not rechecked after that last blow in early May, and were probably filled in with drifted snow."

Recommended remedial work at Nowhere Creek as identified by the ADF&G (Ott 1989) included the complete reinstallation of the culvert battery and removal of outwash gravels from the stream channel. At the time of Ott's inspection (August 1988) rehabilitation had not commenced. On August 25, 1988, AAI submitted a proposed redesign for the Nowhere Creek culvert battery, including plans for removal of outwash gravels. Fish Habitat Permit FG86-III-0115 (Amendment #1) was issued on August 31, 1988, for rehabilitation work. The proposed remedial work included retaining the 72-inch pipe at its current elevation (35 ft), removal and replacement of the remaining pipes at an invert elevation of 40 ft, armoring of the road slopes with sandbags, and removal of outwash gravels using a Supersucker Industrial Vacuum Loader.

On August 19, 1992, a field inspection was made at the Nowhere Creek crossing and photographs were taken (Figure 5). Four of the five culverts had been reset in accordance with AAI's proposed redesign. One culvert remained as originally set for fish passage. Outwash gravels had been removed from the streambanks and streambed. Removal of gravels washed downstream had been completed with minimal impact to the streambed and associated riparian habitat. Continuous flow providing for free passage of fish existed and there was no evidence of additional erosion at the crossing. No further remedial work is needed at the Nowhere Creek crossing. Snow clearing prior to breakup and road maintenance procedures should continue to be closely monitored.

East Creek, Access Road to Mobil/Phillips Pad

The original access road was constructed by Mobil/Phillips to an exploratory well prior to establishment of a state policy prohibiting construction of gravel roads to access exploration well sites. The crossing failed in the early 1980s. Fishery use of East Creek was assumed to be minimal with only a few ninespine stickleback present and a Fish Habitat Permit was not required for the initial construction.

Fyke-net sampling of East Creek by the ADF&G in 1986 and 1987 documented the presence of both ninespine stickleback and broad whitefish. A Fish Habitat Permit was issued to AAI to remove culverts and outwash gravels in East Creek. AAI was requested to complete the rehabilitation prior to implementation of an Arctic grayling transplant to Mine Site B (a flooded gravel pit connected to East Creek) located about 1.3 mi downstream of the road crossing. We speculated that adult Arctic grayling would use Mine Site B as overwintering habitat and would move into and up East Creek for spawning after spring breakup. AAI removed the culvert battery and most of the outwash gravels from East Creek at the Mobil/Phillips crossing (Figure 6). Subsequent fyke-net sampling within East Creek both upstream and downstream from the old road crossing revealed that adult Arctic grayling, as well as other fish species (e.g., broad whitefish, ninespine stickleback), had migrated through the rehabilitation area. Mature Arctic grayling in spawning condition were collected upstream from the crossing following their introduction to Mine Site B.

On August 19, 1992 a field inspection was made during a time when surface flows were not present in East Creek. A fish barrier existed downstream of the road crossing. We recommend that consideration be given to some additional work in East Creek (i.e., removal of outwash gravels below the road crossing). However, it should be noted that a fish barrier does not normally exist when surface flows are present in East Creek.

East Creek at the Spine Road Crossing

The East Creek Spine Road crossing was initially constructed in the mid 1970s with no requirement for a Fish Habitat Permit. In 1984 we reported the presence of significant quantities of outwash gravels in East Creek downstream of the road. We requested that rehabilitation of East Creek be conducted and that cross-sectional surveys of the creek be performed above and below the road. At this time, only ninespine stickleback had been observed in East Creek. AAI completed the surveys, submitted a rehabilitation plan, and implemented a gravel removal operation in accordance with Fish Habitat Permit FG84-III-0071 to reestablish fish passage at low flows. On August 18, 1988, the East Creek Spine Road crossing was field checked and continuous surface flow was present with an estimated three cubic feet per second in East Creek. Fish barriers did not exist under these flow conditions. We recommended that serious consideration be given to culvert removal and bridge installation due to stream size and the presence of anadromous fish. Besides ninespine stickleback, broad whitefish had been collected in East Creek upstream of the road. East Creek was nominated to and was incorporated into the ADF&G Anadromous Fish Stream Catalog. Additional fish surveys conducted from 1988 to 1992 indicated Arctic grayling (transplanted from the Sagavanirktok River), least cisco, round whitefish, and Dolly Varden also use the East Creek drainage upstream of the Spine Road crossing.

In August 1992, a follow-up survey was conducted at the Spine Road crossing. Surface flows were estimated at near zero, outwash gravels appeared to have increased, and a fish barrier was present downstream of the road (Figure 7). Erosion of material in the vicinity of the crossing from surface grading operations and high water velocities continue to add gravel to the stream (Figure 8).

We recommend the design and installation of a bridge across East Creek be considered as a long-term solution to minimize erosion and to ensure fish passage and the proper protection of anadromous fish habitat. Although fish use of East Creek was assumed minimal in the late 1970s and early 1980s, connection of a gravel mine site (Mine Site B) with East Creek which provides overwintering habitat significantly changed fish use of the creek. The Arctic grayling transplant conducted by the ADF&G was successful, and use of the creek and associated flooded gravel pit by other fish species has been documented. We note, however, that substantial changes (e.g., erosion of road fill materials) have not occurred at the crossing since 1988 and with exception of the August 19, 1992 survey, fish barriers have not been observed.

<u>Pebble Creek crossed by Access Road to Exploratory Well 22-11-12</u>

An access road across Pebble Creek to Exploratory Well 22-11-12 probably was constructed in the early 1970s. Several culvert batteries were in place along the road, failures had occurred, and gravel probably had been added to the road following washouts. Culverts had not been placed in the stream channel, road fill material had created ponded areas upstream of the road, and natural stream flows had been diverted. Visual stream surveys were conducted but only one fish (slimy sculpin) was observed. Habitat values (e.g., contiguous wetlands, deep pools with a fine gravel substrate, shallow riffles) were described as excellent for Arctic grayling for summer use (e.g., spawning, rearing) with access to the Kuparuk River for overwintering (Ott 1989). The ADF&G recommended (Ott 1989) that Pebble Creek and associated habitats affected by outwash gravels and road fill materials be rehabilitated. Rehabilitation recommendations included complete removal of gravel from the stream channel and adjacent wetlands, including reestablishment of the natural channel, and removal of culverts.

BPX developed and submitted a rehabilitation plan for the Pebble Creek crossing in September 1989. Fish Habitat Permit FG89-III-0188 was issued for instream work on September 19, 1989. Field staking of outwash gravels was completed during fall 1989 and gravel removal was initiated during winter 1989-90. A joint ADF&G/BPX survey of the stream was conducted in June 1990. Most gravel including culverts had been removed from the stream channel and associated wetlands located downstream of the road. The stream channel had been restored to ADF&Gs satisfaction. Agreement was reached to remove a small berm located along the upstream side of road. All work was completed by July 1990 with an estimated 18,000 cubic yards of material removed. All gravel from the Pebble Creek channel was excavated during the winter using a backhoe, whereas outwash gravels in wetlands were removed primarily by ripping and front-end loader. Close on-site quality control by BPX personnel was conducted and little, if any, damage occurred to tundra areas. Removal of the upstream berm was accomplished primarily with a VRCA "super sucker" during the summer assisted by hand removal efforts as well. Rehabilitation at the Pebble Creek crossing is complete (Figure 9). Fish passage is assured and monitoring from the viewpoint of vegetation recovery is recommended.

Fish use in Pebble Creek subsequent to rehabilitation was documented. Sampling using fyke-nets in Pebble Creek immediately downstream of the rehabilitation project was conducted during June, July, and September 1992. Arctic grayling, slimy sculpin, ninespine stickleback, burbot were collected in Pebble Creek. Arctic grayling juveniles and adults were present in June, mainly juveniles were collected in July, and juveniles and young-of-the-year were captured in September. Highest catch rates of Arctic grayling occurred in early September and probably represented movement of fish downstream to overwintering habitats in the Kuparuk River. Data collected clearly indicate Arctic grayling use of Pebble Creek for both spawning and rearing. Use of Pebble Creek by fish upstream of the rehabilitation project also was documented on several occasions by ADF&G field personnel.

Kuparuk River at the Spine Road Crossing

The Kuparuk River floodplain at the Spine Road crossing is approximately 1.7 mi wide, with the main channel in the middle of the floodplain and major side channels along the east and west sides of the floodplain. In the late 1970s the first crossing of the Kuparuk River floodplain was installed. The structure consisted of flatbed railroad cars and culverts (Townsend, 1993) in the main channel and failed during highwater. Access across the Kuparuk River during the ice-free season did not exist for several years until a new culvert battery (nine elliptical pipes about 16 ft in diameter and three elliptical pipes 20+ ft in diameter) was installed in the main channel during the winter of 1979-80; however, the road and culverts were washed away during the following breakup. AAI attributed the failure to inadequate compaction of fill material during winter installation of the culverts as required by the ADF&G (Grundy 1993). In 1980 a bridge with concrete armored low water approaches was built across the main channel and culvert batteries were installed in the east and west branches of the river. The bridge and culvert batteries remained essentially the same after 1980. Vehicle access was not available during the breakup period when road fill materials failed at the east and west channel crossings and the low water crossings were inundated. Between 1980 and 1988, washed out materials from the east and west channel were retrieved with heavy equipment and the road rebuilt each spring after breakup flows had subsided.

In meetings with AAI during 1986 we requested that an evaluation be conducted to determine the feasibility of replacing the existing culvert/bridge crossing with bridges. We were informed by letter dated May 12, 1988, that a bridge crossing of the Kuparuk River floodplain was uneconomical. On August 18, 1988, a field inspection was conducted at the Kuparuk River crossing and we recommended the following actions be taken (Ott 1989):

> "redesign this crossing in such a manner that gravel washouts will not occur and that fish passage will be provided under most flow events, the intent of the design should be to provide year round access across the river with minimal need for maintenance of crossing structure(s)"

Starting in about 1989 road fill material was removed mechanically from the east and west channels prior to breakup thus minimizing instream activities following breakup. The existing culvert battery in the east channel was damaged during movement of heavy equipment and a new culvert battery was installed in the east channel of the Kuparuk River during summer 1991. Fish Habitat Permit FG91-III-0110 was issued to AAI on May 20, 1991, for the placement of the culvert battery as a temporary short-term solution to correct cross drainage problems.

On August 19, 1992, the Kuparuk River Spine Road crossing was field checked. The existing culvert battery in the east channel had been installed in accordance with FG91-III-0110; however, failure of sandbag armor protection was noted and sandbags had been placed in the culverts. Partial failure of sandbag protection and road fill material also was apparent at the crossing of the west channel (Figure 10).

Recent actions by AAI to remove material prior to breakup has significantly decreased the amount of gravel washed downstream during breakup and has minimized instream activities associated with gravel recovery. AAI also has provided a copy of the 1991 spring breakup study assessing an alternative crossing structure. The capital outlay for a permanent structure (i.e., armored roadway/modified culvert) was seven million dollars. The armored roadway/modified culvert concept would involve modification of existing culvert batteries to strengthen and stabilize the structures and paving and armoring of the road surface to allow high water events to pass over the road without incurring erosional damage (Peratrovich, Nottingham and Drage 1991). AAI's current gravel crossing annual maintenance and replacement costs range from 40 to 50 thousand dollars. AAI believes that the armored roadway/modified culvert structure is not economically justified.

The ADF&G will continue to monitor the Kuparuk River crossing. Our long-term objectives are to eliminate gravel washouts, minimize instream activities, provide for fish passage, and ensure the proper protection of anadromous fish and their habitat.

Leach Creek at the Spine Road Crossing

The Leach Creek culvert crossing probably was installed in the mid-1970s. A Fish Habitat Permit was not required at this time. The structure consisted of three 30-inch and one 48-inch diameter pipes in August 1988. All culverts were perched above the stream thalweg, upstream ponding was evident, and outwash gravels were present downstream (Ott 1989). We recommended that a rehabilitation plan be developed for Leach Creek which included removal of outwash gravels, reestablishment of a stream channel below the road, and replacement of the culvert battery with a single large pipe.

BPX field staked outwash gravels in fall 1989 and received a Fish Habitat Permit (FG90-III-0175) in June 1990 for removal of materials from the floodplain. BPX submitted a design package for Leach Creek which included removal of the existing pipes and the installation of three 60-inch diameter steel pipes with one set with the invert one ft below the stream thalweg. No armor protection was proposed for the structure. Fish Habitat Permit FG90-III-0205 was issued in August 1990 for the replacement of the culvert battery. In September 1990 culvert replacement was completed at the main crossing of Leach Creek. In addition, BPX removed and replaced another culvert in a small undefined tributary to Leach Creek.

In 1991, outwash gravels were removed from Leach Creek and adjacent wetland habitats with labor crews using rakes, shovels, and portable conveyors. A field inspection conducted by Mr. Hemming on September 10, 1991, resulted in the issuance of a field permit requesting that BPX establish a defined channel for Leach Creek approximately one ft below existing gravels within the natural streambed. In requesting that a defined stream channel be established, the ADF&G directed BPX to leave most of the remaining gravel in the creek. We believed that removal of all the gravel could result in the establishment of a wide floodplain with a shallow water blockage to fish movement under normal summer flows.

On August 19, 1992, the Leach Creek crossing was field checked. The new culvert battery had been installed in accordance with the design package submitted by BPX, outwash gravels had been removed, upstream ponding no longer existed, and a well-defined stream channel had been constructed. Substantial changes were observed in the aquatic habitat upstream and downstream of the road crossing following completion of rehabilitation (Figures 11 and 12). One fish (a ninespine stickleback) was observed moving downstream through the reconstructed stream channel. No further work is needed on Leach Creek at the Spine Road crossing, although continued monitoring is recommended with a focus on stability of the reconstructed stream channel.

In addition to the ten priority stream crossings, field data were gathered at several other fish stream crossings. Streams were selected based on the existence of fish barriers and/or erosion of road fill materials. Fisheries and cross drainage information for the selected waterbodies are summarized.

Little Putuligayuk River at the Spine Road Crossing

The original culvert battery probably was placed in the Little Putuligayuk River during the early 1970s and a Fish Habitat Permit was not required at this time. The existing culvert structure consists of several culvert batteries and two single pipes. With the exception of a single culvert, all pipes are perched above the stream thalweg and evidence of erosion (e.g., outwash gravels in stream downstream of crossing) exists (Figures 13 and 14). Installation of the various culvert batteries probably occurred during different years following failure of the road. Potential barriers to free movement of fish occur during both high (e.g., excessive water velocities) and low flow (e.g., surface flows french-draining through outwash gravels) periods. Near failure of the road was observed during spring breakup in 1991.

Fish sampling was conducted in the Little Putuligayuk River during the summers of 1991 and 1992. In 1991 fyke-nets were fished above and below the Spine Road.

On July 20, 1991, two adult broad whitefish and six ninespine sticklebacks were collected in the scour pool immediately downstream of the road (Hemming 1991c). The Little Putuligayuk River was nominated to the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes (Anadromous Catalog) in the fall of 1991 and is now included in the Anadromous Catalog. In September 1992, fyke-nets were again fished in the Little Putuligayuk River below the Spine Road and one juvenile Dolly Varden was captured (Hemming 1992).

The Little Putuligayuk River flows through a lake system immediately upstream of the Spine Road Crossing. Fish, particularly broad whitefish, probably are using the stream and lake for summer rearing. There does not appear to be deep-water habitat suitable for overwintering fish in the Little Putuligayuk River; fish use of the system probably is limited to the ice-free season.

We recommend that remedial work be conducted at the Little Putuligayuk River crossing. The existing culvert batteries constitute a blockage to fish movement under certain flows and contribute to the introduction of fill material to the stream. We recommend that a rehabilitation plan be developed that addresses the following factors: (a) design specifications for a new drainage structure that will provide for fish passage and ensure the proper protection of anadromous fish habitat; (b) removal of outwash gravels from the Little Putuligayuk River; (c) reestablishment of a natural stream channel below the Spine Road; and (d) potential development of fish overwintering habitat by excavation downstream of the road crossing. A Fish Habitat Permit pursuant to A.S. 16.05.870(b) will be required for construction work in the river.

Pebble Creek (Upper Crossing)

An access road to Exploratory Well 33-11-12 probably was constructed in the early 1970s. A Fish Habitat Permit was not issued for the initial road construction. A portion of the road (i.e., 1000 ft) covers a low-lying area (wetland complex). Several culverts still exist in the road and fill material has been washed into wetlands. One fairly extensive washout exists near the south end but is not associated with the Pebble Creek channel which is located over 500 ft north of the washout. It appears that breakup flows traverse the road through the washout area and not through the culverts located near the actual crossing of the Pebble Creek channel. The culverts at the Pebble Creek crossing are not aligned with the stream channel (Figure 15). Ponding exists in the natural channel upstream of the road; however, the channel immediately downstream of the road has not filled with outwash gravels (Figure 16). Fish were not observed during our site inspection on August 19, 1992, but use by Arctic grayling for rearing and spawning probably occurs. Large numbers (over 20) of juvenile Arctic grayling have been observed in the flooded wetlands just above the road (Shideler 1993). Pebble Creek is deeply incised, the substrate consists of small gravels, the stream gradient is low, and flooded wetlands are present. We view the aquatic habitat for fish, particularly Arctic grayling, to be excellent.

We recommend that a rehabilitation plan be developed and implemented for Access Road 33-11-12 at the Pebble Creek crossing. Rehabilitation efforts should focus on the reestablishment of natural flow in Pebble Creek. Consideration should be given to the following items: (a) summer construction schedule using the road as a working surface; (b) removal of all gravel from the road and from areas impacted by outwash gravels immediately below the road in the vicinity of the natural Pebble Creek channel; (c) road fill material should be removed for a minimum distance of 75 ft on each side of the Pebble Creek crossing; and (d) reestablish a stream channel connecting the existing natural channel. A Fish Habitat Permit is required for work in Pebble Creek. A field inspection should be conducted prior to actual construction. We believe that with a minimum amount of effort the Pebble Creek channel could be reconstructed and fish passage ensured. We recommend that rehabilitation of the remainder of Access Road 33-11-12 be addressed as a potential off-site mitigation project for new oil and gas developments on the North Slope.

Washout Creek at Drill Site 16 Access Roads

Washout Creek is crossed by two roads separated by approximately 300 ft. The workpad road crossing is a low-water ford, whereas the main access road crossing contains a culvert battery. The culvert battery consists of eight multiplates with metal bin walls for slope protection. An access road connects the workpad to the main road. Ninespine stickleback and Arctic grayling have been documented in Washout Creek. The priority rating for rehabilitation work at Washout Creek was judged to be moderate (Ott 1989). Recommendations made by Ott (1989) included surveys to determine the extent of outwash gravels and development of a plan to remove gravels from the stream and associated wetlands. In 1988 fish barriers were not observed.

Agreement on rehabilitation to be conducted at Washout Creek was never achieved. A reinspection was conducted on August 19, 1992. A barrier to fish movement existed at the workpad low-water crossing and evidence of vehicle travel across the creek was apparent (Figure 17). Extensive outwash gravels were noted downstream of the workpad (Figure 17). Evidence of erosion of gravels and inundation of wetlands also was noted at the interconnecting access road between the workpad and main road (Figure 18). Based on our field observations, the area covered by outwash gravels appears to have increased substantially since 1988. We estimate that nearly five acres of aquatic and wetland habitats are covered with outwash gravels. We rate the need for rehabilitation of Washout Creek as high priority. A plan addressing the following should be developed, submitted for agency review and approval, and implemented: (a) survey to determine aerial extent and quantity of outwash gravels above and below the main road crossing; (b) removal of outwash gravels from the Washout Creek and adjacent wetlands; (c) removal of the access road connecting the workpad and the main road; (d) removal of the workpad for a distance of at least 150 ft on each side of the creek; and (e) reestablishment of the Washout Creek stream channel.

Putuligayuk River at Spine Road Crossing

The culvert battery at the Spine Road crossing of the Putuligayuk River consists of six large pipes with metal bin walls at the inlets, and gobi-mat, energy dissipators, and gabions at the outlets. During a site inspection in August 1988 a fish barrier did not exist with about 20 cfs per second of water in the creek; however, on August 19, 1992, a barrier to fish movement existed at a discharge of about five cfs. At five cfs the water depth (i.e., less than 1/2 inch) over instream armor was inadequate for fish movement. Fish were not observed at the crossing on August 18, 1988 or August 19, 1992. Fyke and gill net sampling in the Putuligayuk River approximately 1.2 mi below the Spine Road has produced Arctic grayling, round whitefish, fourhorn sculpin, slimy sculpin, broad whitefish, least cisco, rainbow smelt, and Arctic cisco. Fish Habitat Permits have been issued over the past several years covering maintenance activities at the Putuligayuk River crossing. Our 1989 recommendation (Ott 1989) follows and remains unchanged:

"design and construct a bridged crossing of the Putuligayuk River at this location and remove all the erosion control structures currently in the stream channel and along the stream banks or redesign a culverted structure such that instream maintenance activities are minimized and further channelization of the Putuligayuk River is not required"

For example, consideration should be given to the design and installation of a culverted structure similar to one currently in place on the same river immediately downstream of the Spine Road at the Drill Site 15 access road crossing (Figure 19). The culvert battery contains seven large elliptical pipes with metal bin wall slope protection. Except for the ice-breaking bars at the culvert inlets, no instream erosion control devices have been built and virtually no maintenance has been required.

RECOMMENDATIONS

Task (2) to be completed by the ADF&G involved a survey of ten stream crossings to verify success of fish habitat remedial actions undertaken by industry. Between 1988 and 1992 the industry developed and implemented rehabilitation plans at Washout Creek on the Endicott Access Road, East Fork of Charlie Creek crossed by the Access Road to Mine Site D, Nowhere Creek in the Kuparuk Development Area, East Creek crossed by the Access Road to Mobil/Phillips Pad #1, Pebble Creek crossed by the Access Road to Exploratory Well 22-11-12, and Leach Creek at the Spine Road crossing. Some remedial work was done at the west channel of the Sagavanirktok River and at the Kuparuk River crossings. No rehabilitation was conducted at East Creek at the Spine Road crossing or at Gravel Pit Slough located within the floodplain of the west channel of the Sagavanirktok River.

Generally, rehabilitation was very successful in significantly reducing non-point source pollution, removing substantial quantities of outwash gravels, reestablishing stream channels and adjacent habitats, reducing upstream ponding, and ensuring free and uninterrupted fish movement. Methods for effective gravel removal from streams and wetlands were demonstrated at several sites under both winter (e.g., front-end loaders, backhoes) and summer (e.g., Supersucker Industrial Vacuum Loader) conditions. Surveying of outwash gravels in summer prior to removal was effective and essential for winter operations. Improved road grading practices were evident at the Washout Creek (CV#1) crossing as no gravels were observed on the sandbag armor protection at the crossing. Removal of outwash gravels from wetlands immediately adjacent to streams using the Supersucker Industrial Vacuum Loader was effective during the ice-free season and caused virtually no damage to vegetation. Several sites involved culvert replacement and in all cases the replaced structures were installed in accordance with the approved designs. The practice of placing one oversized culvert in the natural stream channel with the invert buried below the stream thalweg to provide for fish passage during most flow conditions was implemented effectively at three rehabilitated crossings. Finally, at those sites where no remedial work or minimal effort was expended, increased erosion and/or road failures occurred (e.g., Sagavanirktok River, East Creek at the Spine Road).

Based on field inspections conducted over the past four years on cross drainage structures in the North Slope oilfields, our experiences with culvert and bridge structures on other projects in Interior and Arctic Alaska, and the results of fishery sampling conducted on North Slope streams, we make the following recommendations regarding the design, construction, and installation of cross drainage structures specific to North Slope streams currently affected by oil and gas development. It is critical to note that some of our recommendations are, in part, related to the specific stream types involved (e.g., tundra streams with relatively flat gradients, minimal bed load movement, minor scour associated with breakup due to frozen soils and substrate, high flows at breakup of short duration):

(1) <u>Fish Surveys</u> - Fish stream surveys should be conducted prior to the construction of roads. Surveys should include sampling with various gear types at different times during the ice-free season. Sampling gear found most effective to date for North Slope streams within the existing oilfield development has been fyke nets. Many of the existing cross drainage problems were simply the result of the lack of knowledge regarding fishery use of streams and the absence of an Fish Habitat Permit process prior to construction. To date every major stream sampled has been documented to support both anadromous and resident fish species. In some cases (e.g., East Creek and flooded gravel Mine Site B), rehabilitation of abandoned gravel pits by connecting the pit to an adjacent stream has changed the

distribution and abundance of fish by providing overwintering habitat where none existed.

If fish surveys have not been conducted at a specific stream crossing, data from similar systems can be used to qualitatively predict fish species use. We would recommend that the cross drainage structure be designed to pass fish when there is a reasonable basis for assuming fish use of the waterbody.

(2) <u>Field Compliance Inspections</u> - ADF&G personnel should field check all new cross drainage installations immediately before, during, and after construction. Minor modifications to construction plans and/or methods of installation can be field reviewed and approved, thereby decreasing the number of after-the-fact requests for remedial work. Equally important is onsite quality control by the permittee. We believe one of the major reasons for success of the stream rehabilitation at Pebble and Nowhere creeks was the active field involvement of oil industry personnel responsible for environmental compliance.

(3) <u>Criteria for Selection of the Drainage Structure and Siting</u> - Criteria for selection of the type of drainage structure (e.g., culvert, bridge) need to be established. It is quite evident from field surveys that properly designed and installed bridges provide for spring breakup flows, ensure fish passage, provide for the proper protection of fisheries habitats, minimize instream disturbance and wetland fills, and require minimal maintenance (Figure 20). Even bridge maintenance is affected by the design, as can be seen when comparing the bridges across Central and Smith creeks (Figure 20). Sandbag armor protection had to be replaced at the Smith Creek crossing. Bridge

types with sheet pile abutments similar to the one installed by Conoco at Central Creek were used effectively for eleven major stream crossings along the Red Dog Haul Road. The bridge at Central Creek was constructed after a large culvert battery failed at the same location. Bridges should be used for crossing large streams. Criteria should be developed to address what constitutes a large stream (e.g., drainage area, fisheries resources, etc.). The decision process should consider the life-cycle maintenance costs associated with a bridge as well as culvert batteries in determining whether to install a bridge or a culvert battery.

Criteria also should be developed for siting. Roads should be sited so crossings are perpendicular to stream flow and occur in slack water (i.e., pool) for beaded tundra streams. In contrast, if mountainous streams are crossed it is critical to maintain bed load movement and flood capacity. Braided areas of rivers should be avoided; however, it is recognized that avoiding braided reaches of a stream is not always possible. Design criteria for crossing braided stream reaches need to be developed so floodplain characteristics are maintained, fish passage is ensured, and fish habitat is protected. Perpendicular crossings will affect the least amount of aquatic and adjacent wetland habitats and will ensure fish passage under more diverse flow conditions.

(4) <u>Slope Protection Selection and Maintenance</u> - In general, sandbag protection requires constant maintenance, including replacement of bags. However, there are some examples of existing culvert batteries where sandbag failure from natural forces within the stream has been minor (Figure 21). Possible reasons for stable sandbag armor protection at specific crossings include the following: (a) original design incorporated culverts with capacity to

adequately convey waters during peak flow event; (b) maintenance practices; (c) alignment of crossing and location in stream; (d) relatively small stream; and (e) larger pipes set in and buried below the stream thalweg. We believe that the placement of oversized culvert(s) in the stream channel, preferably a single oversized pipe that completely spans the natural channel, is preferred. Design should be based on the underlying assumption that it is desirable to provide the maximum cross sectional area for natural flow. Metal bin walls and grouting have been used at stream crossings and in most cases these have been effective. Appropriately sized riprap also would be effective but is currently not used due to a lack of rock on the North Slope. Biologically, we would recommend the use of riprap followed by metal bin walls. It also should be recognized that these recommendations are not intended to preclude the trail and application of technological advances in slope protection material.

(5) <u>Pipe Specifications and Instream Armoring</u> - In addition to selecting culverts based on the intended road use and weight bearing load, corrugated (i.e., preferably one and one/half inch or deeper, Mannings n=>0.035) metal pipes should be used for all crossings of fish-bearing waterbodies. Steel-walled smooth pipes should not be used in fish streams. It has been demonstrated that fish use zones of lower water velocity when moving through culverts and zones of reduced velocity are created by the corrugations in the pipe (Behlke et al. 1991).

If steel-walled smooth pipes are used they should be fitted with properly designed baffles. Steel-walled smooth pipes with baffles should only be used on the North Slope in low gradient streams (<0.5 percent) with mid-summer fish use. If Arctic grayling spawning occurs in the stream a corrugated pipe is needed to facilitate fish passage. Several streams (e.g., Pebble and Kalubik creeks) are now known to support spawning runs of Arctic grayling. Arctic grayling spawn in the spring and generally move upstream to spawning areas during or immediately following breakup when velocities though culverts would be high. In these streams smooth-walled culverts would not provide the zones of reduced velocity found in corrugated culverts, and would therefore restrict the upstream movement of fish.

Projecting, mitered end-section skirts are altered physically by maintenance activities or become perched from hydraulic pressures created by ice and water. Modified inlets and outlets reduce the carrying capacity of the culverts and lead to increased erosion of armor protection and fill materials. We believe that these structures (i.e., skirts) are unnecessary and should be avoided.

Instream armor protection (e.g., sandbags and gobi-mat) has been used at a number of crossings. It is our understanding that gobi-mat is being used to prevent and/or minimize scour in the stream. Significant scour below culvert batteries is apparent at several streams (e.g., East Creek, Ugnuravik River, Smith Creek, Putuligayuk River) crossed by the Spine Road. In most if not all of these crossings, the entire road has failed at least once. We believe that the scour observed may be linked to inadequate sized pipes and/or road failure (i.e., substantial hydraulic head when the road overtops).

In crossings built since 1984, gobi-mat has been installed for scour protection with the elevation of the top of the armor set below the invert of the pipe(s) depressed for fish passage. At several crossings (e.g., Washout

Creek on the Endicott Access Road and Kalubik Creek) there have been no environmental problems associated with the use of gobi-mat. Minimal scour has occurred below the culvert crossings; however, these crossings have never failed. The question is whether gobi-mat is necessary. There are several stream crossings (e.g., Charlie Creek and upper Ugnuravik River) without instream armor and/or armor at the culvert outlets where little if any scour of the streambed and/or tundra has been observed (Figure 22). Perhaps, erosion of the streambed and/or adjacent wetland during breakup is not an issue when breakup precedes thaw in surface and subsurface materials.

(6) Construction Timing - Construction timing should not be restricted by permit conditions unless the environmental benefits are significant (e.g., instream work in overwintering habitat could have significant negative effects on fish). For example, the requirement for winter only construction to avoid the time period of fish use probably will adversely impact compaction of bedding and padding needed for culvert stability. Summer construction during the open water season also allows for more efficient onsite field inspections.

(7) Culvert Maintenance - Installation of protective covers over culvert ends for the winter months has been used effectively to prevent snow compaction within culverts. Snow removal in the spring before breakup can and has caused significant damage to culvert inlets and outlets. Fish barriers have not been created by culvert inlet and outlet damage; however, increased sloughing of road fill materials (e.g., gravel) into streambeds has occurred and water movement through the structures has been changed. Road grading frequently causes damage to sandbags and displaces gravel fill over

armor protection and into the stream channel. The accumulation of gravels in small streams over time leads to creation of fish barriers under low flow conditions and results in a loss of adjacent wetlands that are covered with gravel. Maintenance practices need to be developed and implemented to minimize or eliminate nonpoint sediment introductions to aquatic habitats.

SUMMARY

Design criteria and standards and procedures should be developed to address the following seven topics: (a) fish surveys; (b) field compliance; (c) drainage structure type and siting; (d) slope protection and maintenance; (e) structure specifications; (f) construction timing; and (g) and maintenance. If these items are properly evaluated, and solutions developed and implemented, we believe that most cross-drainage problems will be reduced substantially.

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GLOSSARY

channel-plug - combination of insulation, fill material, and armor used to stop water movement in a natural or artificial channel

french-draining - when surface water flow encounters porous gravels and moves through the gravels, surface flow absent

gabion - wire basket of various dimensions filled will gravel and rock to provide slope protection

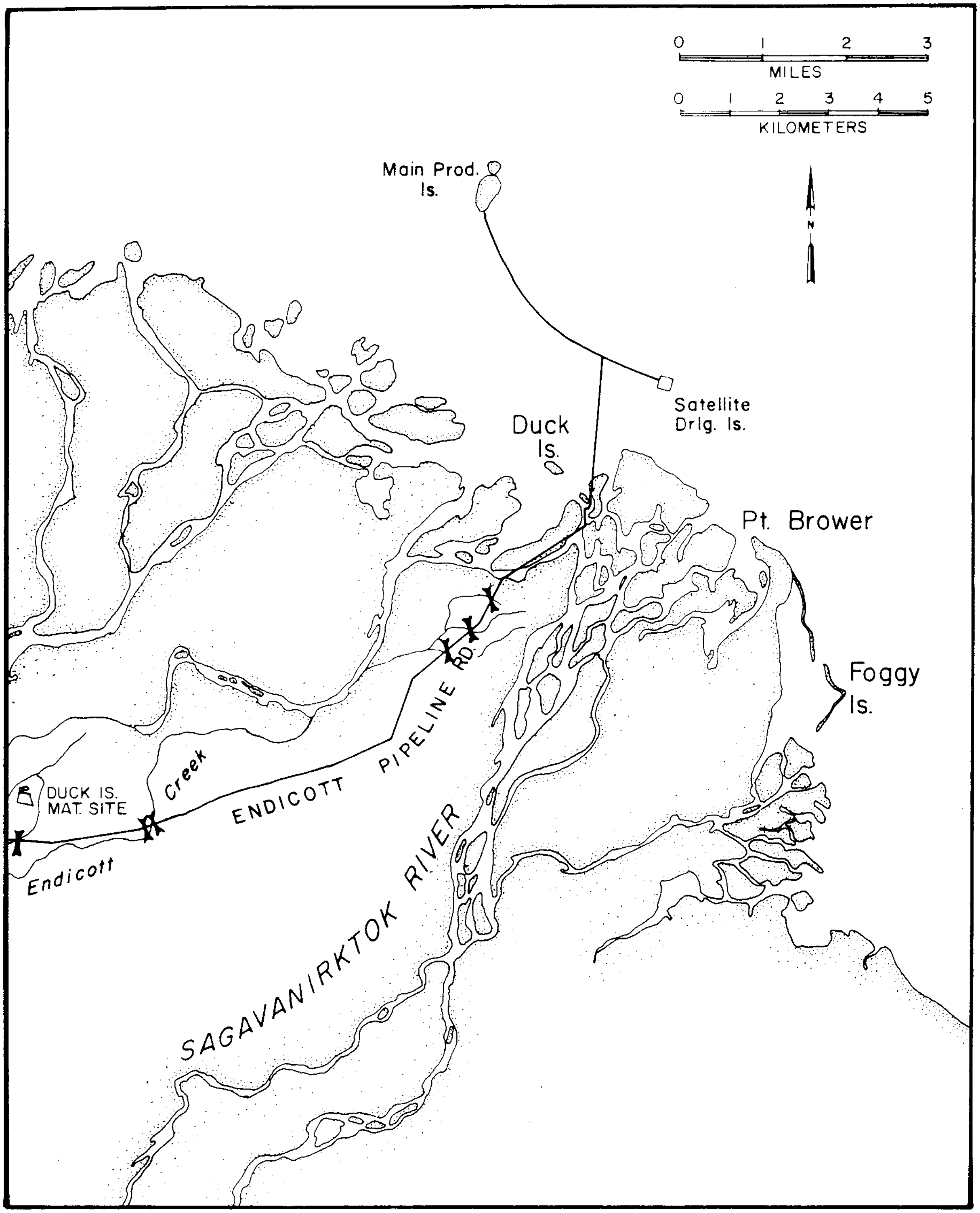
gobi-mat - concrete blocks interlocked with cable or wire, used for slope protection

outwash gravels - material (primarily silts and gravels) that have been eroded from the road by water and deposited in areas outside of the footprint of the road

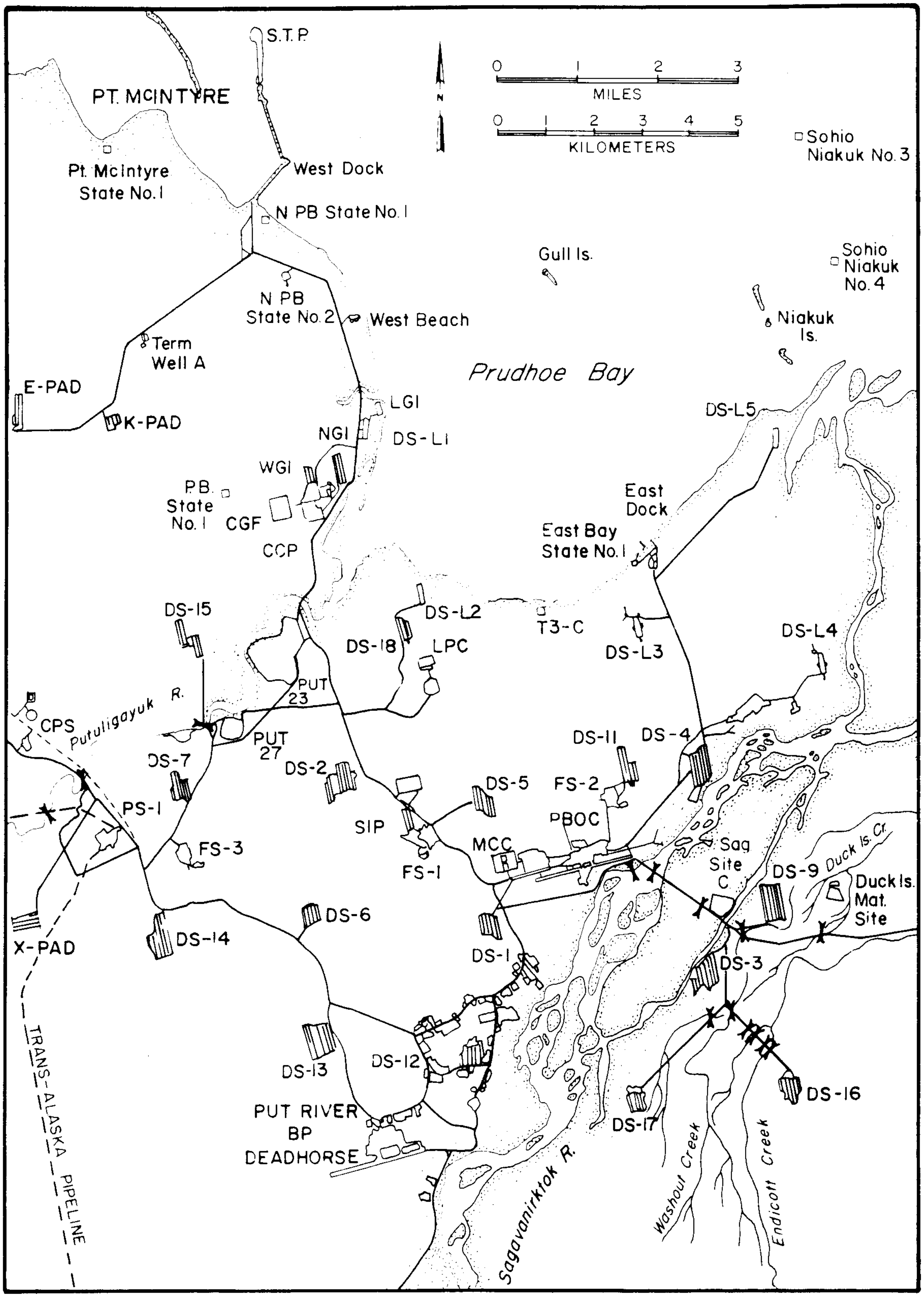
soft plug - road section designed to fail under high water events, location of soft plug set to protect existing drainage structures and oil and gas facilities

thalweg - lowest point in the stream channel, i.e., bottom elevation of pool and riffles

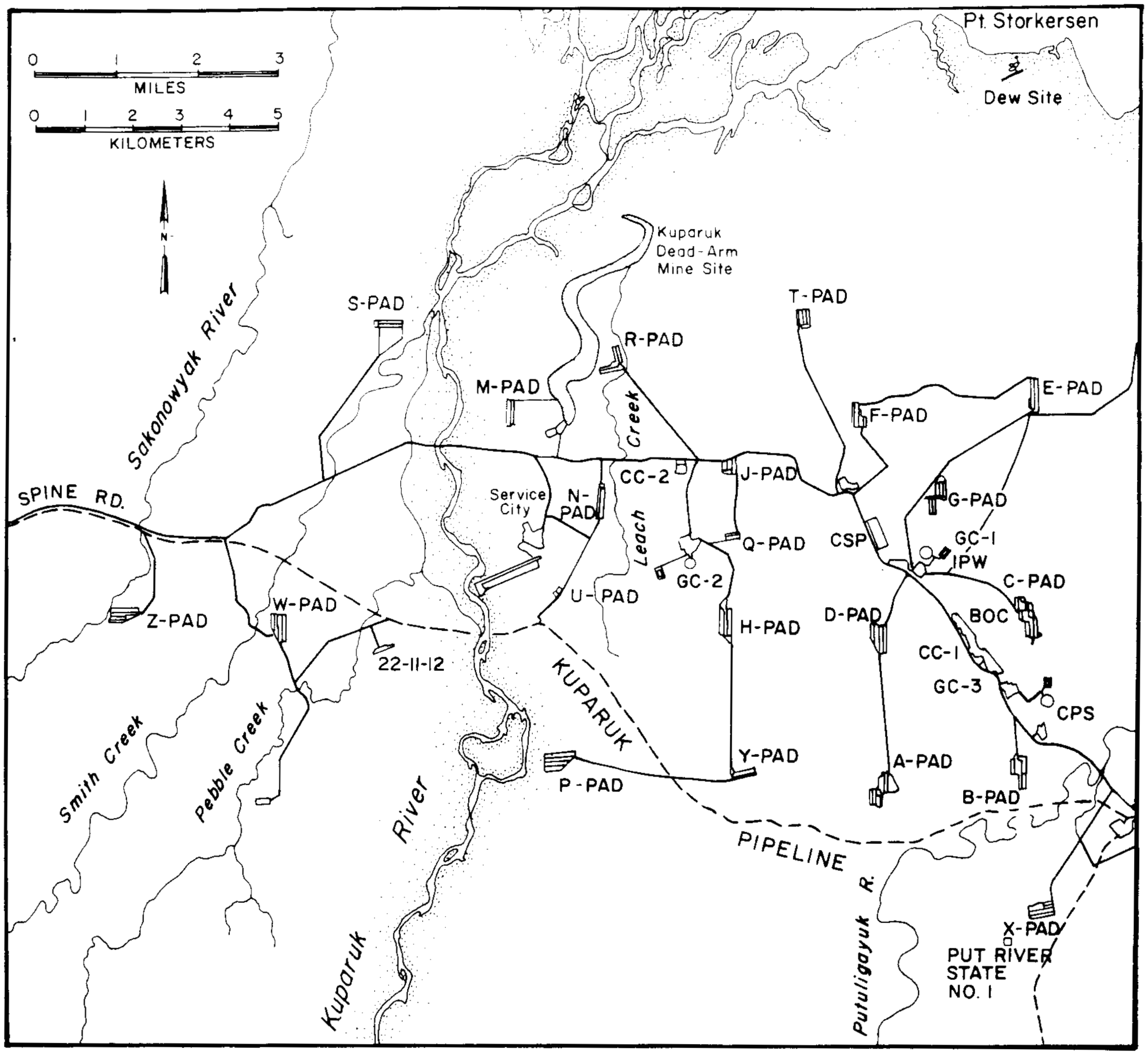
APPENDIX A - MAP 1 - ENDICOTT PIPELINE



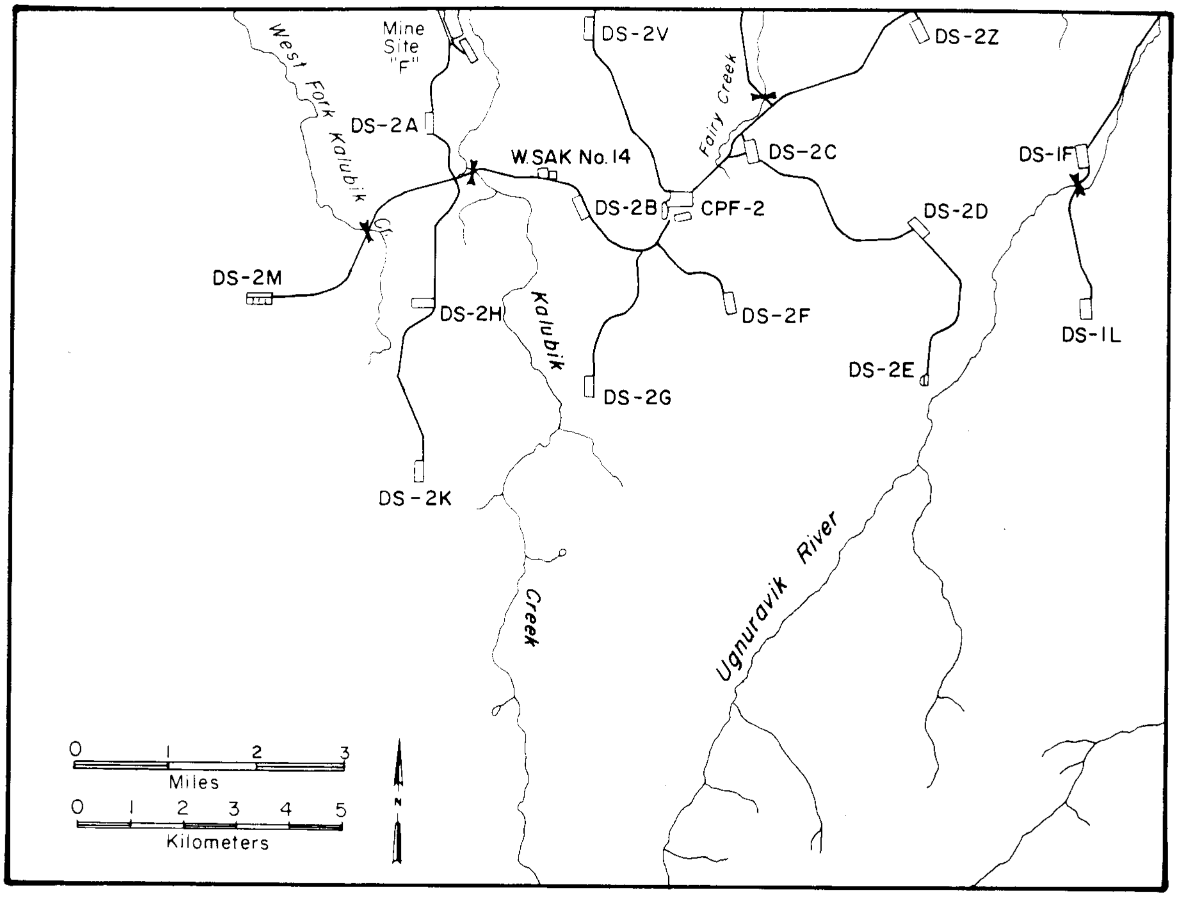
APPENDIX A - MAP 2 - EASTERN PART OF PRUDHOE BAY UNIT



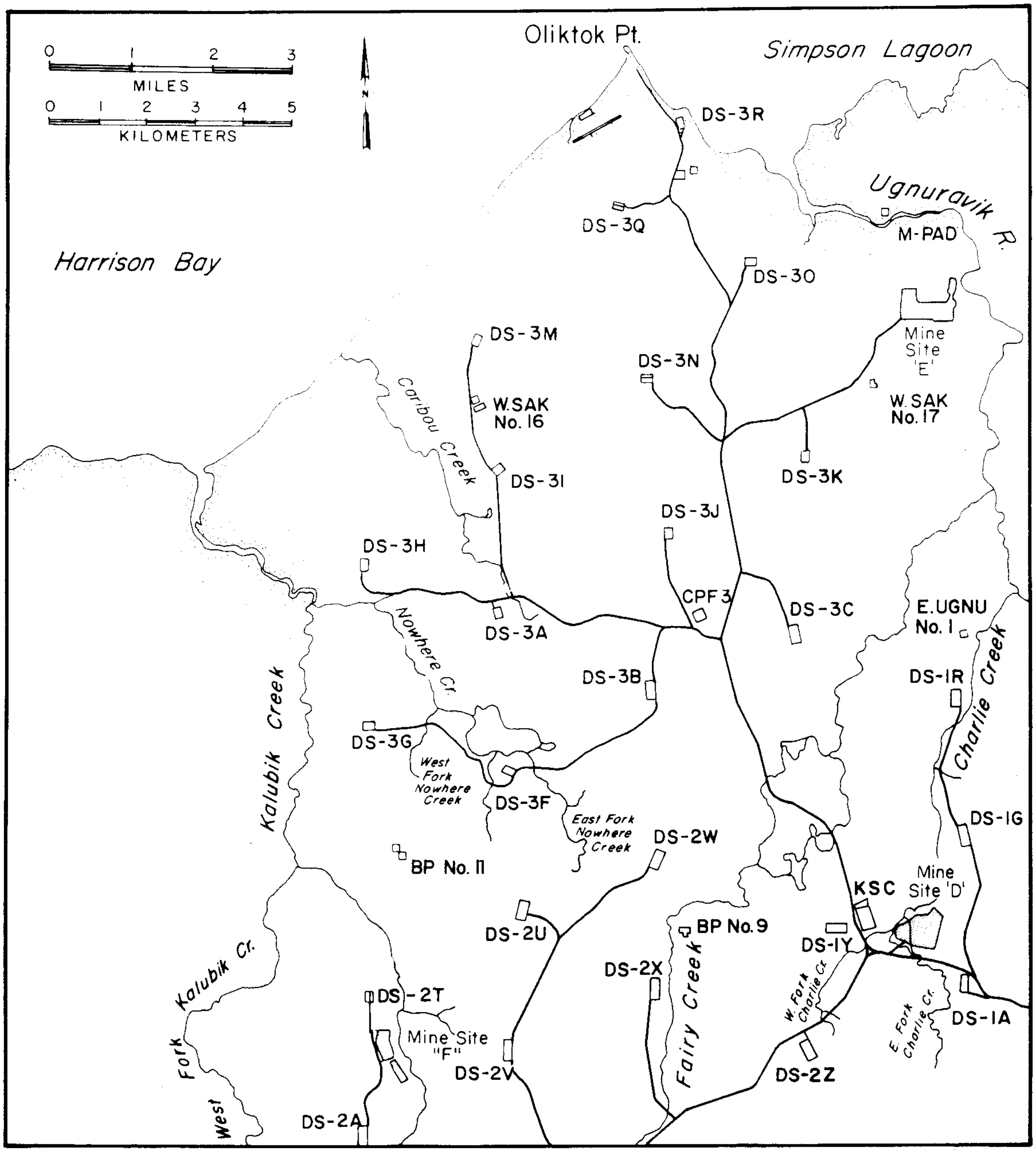
APPENDIX A - MAP 3 - WESTERN PART OF PRUDHOE BAY UNIT



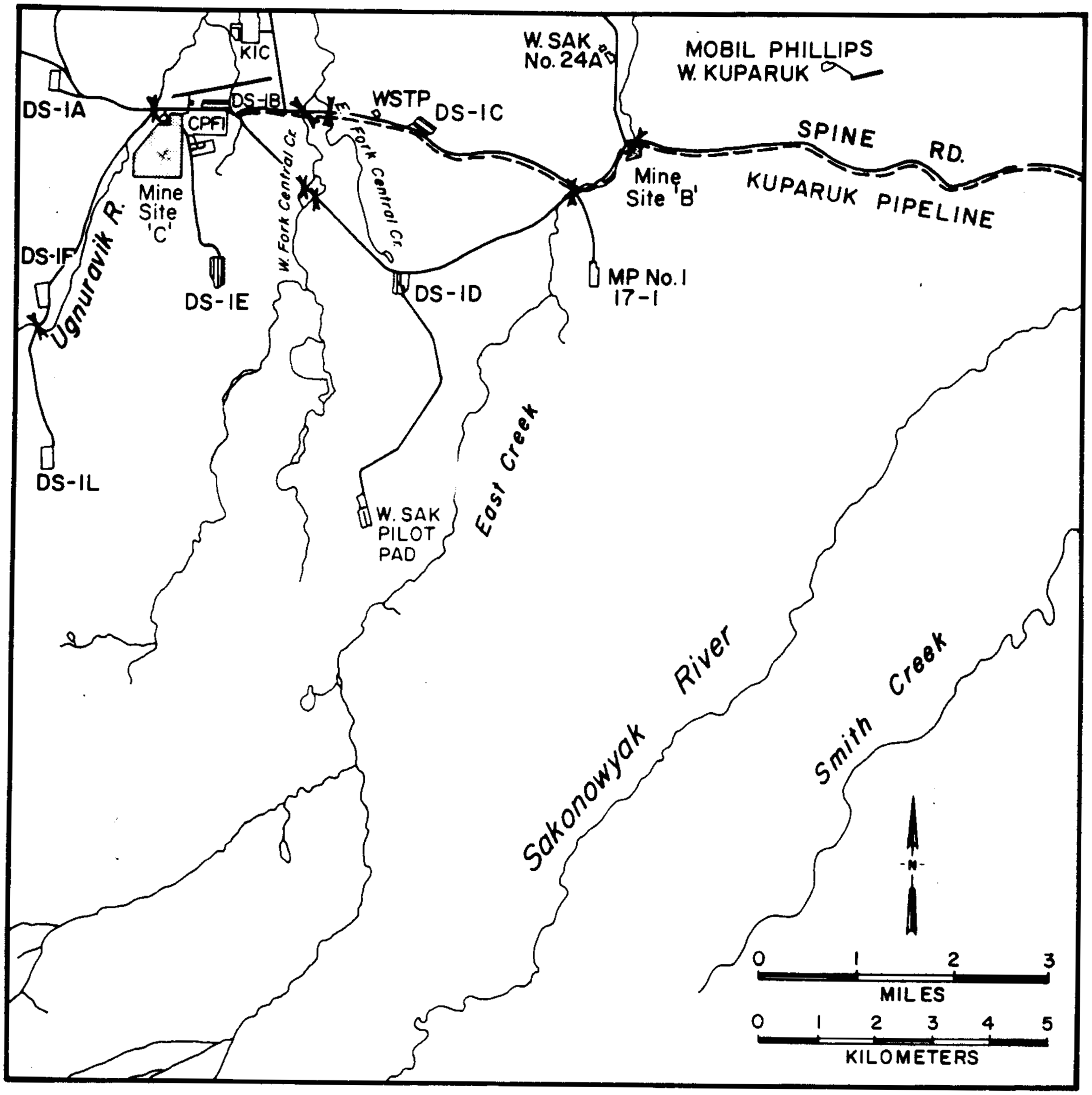
APPENDIX A - MAP 4 - CPF #2 AREA OF KUPARUK RIVER UNIT



APPENDIX A - MAP 5 - CPF #3 AREA OF KUPARUK RIVER UNIT



APPENDIX A - MAP 6 - CPF #1 AREA OF KUPARUK RIVER UNIT



APPENDIX A - MAP 7 - MILNE POINT UNIT