Docket Nos. CP75-96, *et al.*
Exhibit EP-_____ (RAF/DLW-1)
Witnesses: R. A. Furniss
D. L. Ward

COMPARISON OF WATER AVAILABILITY FOR USE IN CONSTRUCTION OF PROPOSED GAS PIPELINES ON THE ALASKAN NORTH SLOPE

Prepared by:

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Abstract

This report assesses potential winter water sources on the North Slope in Alaska, the biological characteristics of these waters, and the impact of water withdrawal upon aquatic biota. Based upon this assessment, water availability for construction purposes along the proposed El Paso and Arctic Gas gas pipeline routes is compared.

Groundwater, spring, river, and lake sources were considered. Groundwater will generally not provide reliable sources of water; most springs are critical to overwintering fish and should not be utilized as water sources; rivers will provide substantial quantities of water until freezing restricts discharge, usually in October or November. Depending upon the specific route, lakes can be the single most reliable source of water during the winter.

In close proximity to the proposed El Paso alignment, water will be available in quantities sufficient for snow/ice work pad construction. Approximately 100 miles of the 195 miles of the proposed Arctic Gas pipeline route are deficient in suitable lake water sources within five miles either side of the route. Within ten miles either side of the route, suitable lake sources are absent from 40 of the 195 miles. Other reliable water sources do not exist in many of these areas.

Over-tundra travel restrictions imposed by state and federal regulatory agencies may delay the Arctic Gas snow/ice road construction schedule. This delay could be as much as two and one-half months during any construction year. In contrast, however, the existing gravel haul road and access roads built for the Trans-Alaska Oil Pipeline can be used by El Paso to develop water sources from the Sagavanirktok River and certain lakes, thus reducing the possibility of delay due to over-tundra travel restrictions.

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COMPARISON OF WATER AVAILABILITY FOR USE IN CONSTRUCTION OF PROPOSED GAS PIPELINES ON THE ALASKAN NORTH SLOPE

1.0 Introduction

El Paso Alaska Company (El Paso) and Alaskan Arctic Gas Pipeline Company (Arctic Gas) have independently proposed to construct natural gas pipelines on the North Slope of Alaska. El Paso proposes to construct a line, generally paralleling the Trans-Alaska Pipeline System (TAPS), from Prudhoe Bay south to a terminus at Gravina Point, Alaska. El Paso proposes to utilize the existing gravel "haul road" built by Alyeska for high speed, high volume traffic and to construct a snow/ice work pad for low speed pipeline construction equipment. Arctic Gas proposes to transport the same gas in an easterly direction across the Arctic Coastal Plain into Canada. In order to utilize that route, Arctic Gas proposes to construct a snow/ice work pad for winter construction activities. Because of the absence of roads, Arctic Gas will need to widen and strengthen the work pad or construct an additional heavy duty snow/ice haul road (Arctic Gas, 1974). Both companies propose to begin snow/ice road construction in September, completing them in December.

Snow/ice road and work pad construction requires large volumes of snow and/or water to provide the necessary strength to support heavy equipment. Arctic Gas (1974) estimates that between 250,000 and 900,000 gallons of water per mile will be required for construction of haul roads and work pads. Their route extends 195 miles from Prudhoe Bay to the Canadian border. For purposes of this report, it is assumed that El Paso's maximum water requirements for work pad construction will be no greater on a per mile basis than those of Arctic Gas for work pad and haul road construction. The El Paso North Slope work pad will extend 162.5 miles from Prudhoe Bay to the crest of the Brooks Range. An additional, but smaller quantity of water will be necessary for road and work pad maintenance throughout the construction season. For example, El Paso estimates that 84,000 gallons per day will be required for camp support. Since both projects are premised on the assumption that sufficient volumes of water will be available for work pad construction, it is necessary to assess the availability of water resources, and impacts of withdrawal along each route. The major purposes of this report are: (1) to identify potential water sources along both routes, (2) to assess biological use and importance of these potential sources, and (3) to estimate the volumes of water available along both routes during the proposed construction periods.

This report identifies and discusses all major potential water sources on the North Slope of Alaska. These include (1) groundwater,

(2) springs, (3) flowing surface water (rivers, streams and creeks), and (4) standing surface water (ponds and lakes).

Three physiographic provinces descriptive of the North Slope have been identified by Spetzman, (1959). The Coastal Plain Province extends approximately 500 miles east and west and as far as 100 miles inland. This area rises from sea level to 500 feet and occasionally as high as 1,000 feet in elevation. Shallow lakes are numerous and generally do not support resident fish populations. The Foothills Province ranges from 10 to 100 miles in width and 500 to 2,500 feet in elevation. Lakes are both deeper and less numerous than those in the Coastal Plain Province and tend to support varied fish fauna. The Brooks Mountain Province extends from the Foothills Province south to the crest of the Brooks Range. Lakes are less numerous in this area than in the other two provinces, but are larger and considerably deeper. For example, Schrader Lake, located in the eastern end of this province, is over a mile in length with water depths in excess of 180 feet; Chandler Lake is approximately 3,100 acres and has a maximum depth of 58 feet; Itkillik Lake is approximately 1,330 acres and 43 feet maximum depth; and Elusive Lake is 920 acres and 55 feet maximum depth. Lakes in the Brooks Mountain Province commonly support Arctic char, grayling, whitefish, and lake trout, as well as other minor species.

This report is restricted to those portions of the proposed El Paso and Arctic Gas routes on the North Slope of the Brooks Range, Alaska and is based almost entirely upon published literature. The proposed El Paso route traverses all three physiographic regions including the Coastal Plain, the Foothills, and the Brooks Mountain Provinces. The Arctic Gas routing is confined to the Coastal Plain Province.

2.0 Historical Overview

To the casual observer, Alaska's water resources appear to be practically unlimited. The state has hundreds of thousands of lakes and rivers including the Yukon, which is one of the largest river systems in North America. In general, there is an abundance of water, but during certain seasons, it may not be available. Several factors control the quality and quantity of Alaska's water resources, including extremes of precipitation and temperature. For example, the Alaska Water Study Committee (1975) reports:

> "In cold, desert areas of the Interior and Arctic, shallow lakes and rivers may freeze solid for six months of the year. This decline in stream flow during the the winter months and the dramatic increase in flow during the spring runoff period, makes for a wide variation in available surface water resources."

They further state,

> "Climatic factors, geology, economic constraints and lack of technology combine to limit Alaska's supply of usable water . . . for much of the state, water of suitable quality for given use may be extremely limited or not available at all. This relative availability suggests that competition for water will increase and that water availability may become a significant limit for development and use of the state's resources."

Historically, attempts to locate and develop supplies of potable water in Arctic Alaska during the winter have been difficult, and often unsuccessful (Alter, 1969; Feulner and Williams, 1967; Greenwood and Murphy, 1972; Sherman, 1973; USGS, 1969a). The limited water sources which have been developed are generally unreliable in late winter and have proven to cost as much as one dollar a gallon (Alter, undated). Most villages on the North Slope experience difficulty in obtaining sufficient potable water during winter months (Dorris, 1973). While during the summer, they are able to supply their needs from nearby lakes and streams, they depend upon water from beneath the ice in deep lakes or from melting snow and ice during the winter (Arnow and Hubbs, 1962; Selkregg, 1975). At Prudhoe Bay, the search for water has encompassed groundwater aquifers, shallow lakes, and isolated pools in the Sagavanirktok River. To date, few of these sources have proven to be dependable (Sherman, 1973). Water use at Prudhoe Bay between October 1974 and May 1975 was in the range of 16,000 to 35,000 gallons per hour (gph) which has reportedly been sufficient to dewater some areas in the mouth of the Sagavanirktok River during the winter.

Other methods of winter water supply have been explored, including increasing storage capacity. In 1953, a reservoir was constructed in Selin Creek to provide a winter water source for the D.E.W. station at Cape Lisburne; however, the attempt was unsuccessful due to leakage through the permeable alluvium underlying the reservoir, despite attempts to seal the bottom (Feulner and Williams, 1967). During the summer of 1975, the Atlantic Richfield Company (ARCO) drained, deepened, then refilled a lake at Prudhoe Bay in an attempt to increase storage capacity for winter supply. The success of this project has not been evaluated at the time of this writing.

Alyeska's Happy Valley Camp has experienced water supply problems during the winter. As early as March, 1971, when water demand was very small, sufficient volumes of water were difficult to locate (McDonald, 1971). During the 1974-1975 winter, Happy Valley Camp utilized the Sagavanirktok River thaw bulb (thawed alluvium beneath the riverbed) for water supply. A well was installed approximately 10 feet beneath the riverbed and produced in excess of 1,500 gph (Selkregg, 1975) but went dry in late winter of 1975. A well 40 feet deep at Galbraith Lake Camp has produced 1,500 gph (Selkregg, 1975). Thaw bulb water beneath the Atigun River has been utilized by Alyeska's Atigun Camp. Camp water supply during the 1974-1975 winter consisted of a 40 to 50 foot cistern and a 150 foot well. These sources produced well over 1,000 gph until late November or December, when production dropped to approximately 500 gph. Two other wells were drilled near Atigun Camp in March and April, but were dry. A new 180 foot well was drilled in late spring which produced more than 1,000 gph.

One of the potential ecological problems created by winter water withdrawal is the possibility of severely damaging aquatic resources. During past years, withdrawals in the lower reaches of the Sagavanirktok River for Prudhoe Bay camps have dewatered isolated pools of water important as habitat for overwintering fish (Alaska Water Study Committee, 1975). It has also been reported that small fish clogged the water pump at a location approximately 15 miles south of Deadhorse (Ward and Craig, 1974).

During March, April and May, 1975, reports from the Prudhoe Bay area indicated that removal of water from isolated pools in the Sagavanirktok River was having adverse impact upon large numbers of overwintering fish. As a result, state regulatory agencies initiated a water use permitting system designed to regulate industrial water removal.

Alaska Statute Title 16.05.870, The Anadromous Fish Act, delegates to the Department of Fish and Game the authority to issue and enforce water use permits. Permit stipulations include immediate cancellation if withdrawal of water threatens to damage the fishery resource.

By this authority, the regional supervisor for the Alaska Department of Fish and Game, Habitat Protection Division, recently issued a directive to all North Slope lease holders and operators (Brooks, 1975). In part, this directive states:

> "Earlier this summer you received a notice from the Water Resources Section, Alaska Division of Lands, Department of Natural Resources, stating you must apply for water appropriation on the North Slope. Concomitantly this Department will review your application and issue our authorization pursuant to AS 16.05.870 to protect the fishery resources in the area. Because of the adverse impact of water use during the winter months to fishes overwintering in the major tributaries, it is our objective to encourage use of water from the upland lake areas to the greatest extent, and to encourage you to either singly or collectively devise a system (reservoir, etc.) where dewatering a major tributary will not occur."

This historical situation was summarized by Dorris (1973), "Water supply of the Arctic slope has been and will continue to be a difficult problem."

3.0 Potential Water Sources During Winter

This section outlines the general nature of potential winter water sources on the Arctic North Slope. Availability of these sources is discussed in broad terms, then the availability of water along the proposed El Paso and Arctic Gas routes is examined. Discussions are focused on areas five and ten miles wide on either side of, and adjacent to, the proposed alignments.

3.1 Groundwater

3.1.1 General

Groundwater in permafrost regions has been defined as "suprapermafrost water (water above the permafrost), intrapermafrost water (water within the permafrost), and subpermafrost water (water beneath the permafrost)" (Muller, 1945). Other sources discussed in this section include groundwater in thawed alluvium under major rivers and large lakes.

Suprapermafrost water is highly seasonal, its sources being rain and/or snow melt (Alter, 1969). The seasonal nature and the quantity of water in this layer are dependent on the depth of the active layer. Suprapermafrost aquifers are frozen between mid-September and June and thus are unavailable as sources of water during winter.

Intrapermafrost water finds its sources in the downward percolation of surface water or in pressurized upwellings from subpermafrost reservoirs. Since the North Slope is underlain by continuous permafrost ranging from 600 to 2,000 feet in depth (Dingman, 1973; Carlson, 1974), intrapermafrost flows are probably negligible (Dingman, 1973).

Subpermafrost water reserves are generally not considered as water sources. Thick continuous permafrost reduces potential recharge from surface waters. Subpermafrost areas, both above and within bedrock, have been shown to contain limited quantities of highly saline water (Sherman, 1973). Flow rates near Umiat have been measured at ten gph (Williams, 1970a). Low flow and high chloride concentrations eliminate consideration of subpermafrost water as potential sources of water. Finally, subpermafrost reserves require pumping up through 600 to 2,000 feet of continuously frozen ground and are therefore subject to freezing. Freezing of an aquifer may also be induced by over-pumping (Clark and Alter, 1956).

Thawed alluvium beneath large arctic rivers and lakes may provide the single reliable source of groundwater on the North Slope. Black and Barksdale (1949) report that "All but the largest (arctic) rivers, such as the Colville River, freeze solidly to permafrost every winter." Kane and Carlson (1973), however, indicate that groundwater aquifers are often found along major drainages. Thawed alluvium under abandoned oxbow channels may also provide water during North Slope winters (Williams, 1970b).

Ponds and lakes which freeze to the bottom are underlain by permafrost (Brewer, 1958a; Black and Barksdale, 1949). However, deep lakes (exceeding six to seven feet in depth) that do not freeze to the bottom are commonly underlain by a zone of unfrozen alluvium due to heat loss from the lake water (Brewer, 1958a, 1958b and 1955; Hobbie, 1973; USGS, 1969a; Williams 1970b). The thickness of this zone, sometimes referred to as a "talik," varies with the area and depth of the water body and with the composition of sediments and underlying formations. The talik beneath lakes is considered to be a potential source of water (Selkregg, 1975). Williams (1970a) states that the unfrozen alluvium beneath deep lakes in the Colville River Valley "will yield abundant year-round supplies of ground water." Beneath Imikpuk Lake, Brewer (1958a) measured a talik that was 190 feet in depth. Williams (1970a) suggests that the talik of Umiat Lake is a minimum of 103 and a maximum of 345 feet in depth, and that the water stored within thawed alluvium beneath a lake may exceed the volume of aboveground water in the lake basin. Although unstudied at this time, winter recharge to the talik is probably limited to surface water in the lake. The rate at which this aquifer would be recharged would depend upon the thickness and permeability of organic material and substrate composition.

Generally, groundwater is not to be expected where the permafrost is deep and continuous (Rice and Alter, 1974). In the eastern Arctic, from the Kuparuk River drainage east to the Canadian border, Feulner (1973) states, "the average potential yield of groundwater is on the order of zero to ten gallons per minute, although in most of the subregion, groundwater production would be zero."

3.1.2 El Paso Alignment

Near El Paso's proposed route, thawed alluvium beneath the Sagavanirktok River has the greatest potential for providing groundwater. This route parallels the Sagavanirktok River for a distance of approximately 130 miles (milepost [MP] 00 to 130). One hundred twelve miles of the proposed route, between MP 18 and 130, lie within five miles of the River (Figures 1,2, and 3). North of MP 18, the Sagavanirktok River is presently accessible by existing road networks.

Within the Coastal Plain Province (MP 00 to 60), the Sagavanirktok River alluvium has not been a reliable winter source of water. Alluvial groundwater wells in the Foothills Province (MP 60 to 130) have produced in excess of 1,000 gph but may have to be relocated in late winter due to depletion or freezing of the aquifer. Alluvial gravels beneath the Atigun River in the Brooks Mountain Province have produced similar quantities in early winter, but production has dropped to approximately 500 gph or less in late winter.

Thawed alluvium underlying large lakes in the Coastal Plain Province may have some development potential. However, these areas will require site specific investigation to determine the quantities of water available.

3.1.3 Arctic Gas Alignment

Since the Arctic Gas route lies entirely within the Coastal Plain Province, which is underlain by thick continuous permafrost, generally low yields of groundwater can be expected. Exploratory drilling along coastal regions has encountered saline water at 100 to 200 feet below the active layer (McCarthy, 1952).

Within the 195 mile Alaska segment of the Arctic Gas route, several major drainages are crossed (Figures 4 through 7). These include the Sagavanirktok, crossed at MP 8 and 18; Shaviovik, at MP 35; Canning, at MP 62.5; Hulahula, at MP 117.5; Jago, near MP 130; and Kongakut, crossed at MP 173. Numerous other smaller streams are crossed by this routing. Some groundwater may be available in the thawed alluvium of the larger rivers, but experience in adjacent arctic areas indicates that it will be difficult to develop and be limited to low volumes.

Thawed alluvial gravels underlying large lakes between MP 0 and 65 may have some development potential. However, these areas will require site specific investigation to determine if water is available and if so, in what quantities. Lake alluvium offers much less potential beyond MP 65. This is due to the sparsity of lakes adjacent to the proposed pipeline route. In addition, restricted access in the Arctic National Wildlife Range may preclude groundwater investigations.

3.1.4 Summary

A summary comparison of groundwater sources near the routes proposed by El Paso and by Arctic Gas on the Alaskan North Slope is shown in Table 1.

Groundwater aquifers are generally unsatisfactory water sources during winter because of the expense and difficulty of development, continuous permafrost, low yield, and predominance of saline water. This is particularly true in the Coastal Plain Province. Thawed alluvium under major rivers and lakes, however, may provide limited quantities of water sufficient for camp use during late fall and early winter. Wells within river alluvium have produced 500 to 1,500 gph during winter. These wells have sometimes failed during late winter. Lake alluvium sources are yet unproven.

Along the proposed El Paso pipeline route, alluvial water sources have been located at various places under the Sagavanirktok River, particularly in the Foothills and Brooks Mountain Provinces. However, the experience of Alyeska Pipeline Service Company indicates that these sources are sometimes difficult to locate even in this large river. Smaller rivers are not expected to be sources of alluvial water due to freezing of the alluvium.

The Arctic Gas route lies entirely within the Arctic Coastal Plain. This route crosses four major drainages including the Sagavanirktok, Shaviovik, Canning, and Kongakut Rivers. Alluvial groundwater may exist under these rivers, but will probably be difficult to locate and be restricted to low volume production. There is some potential for alluvial groundwater beneath lakes within ten miles of the Arctic Gas route between MP 00 and 65. The absence of lakes within close proximity to the alignment from MP 65 to 195, however, precludes this possibility for most of the Arctic Gas route.

Possible groundwater supplies in the Foothills and Brooks Mountain Provinces are not in close proximity to the Arctic Gas route.

3.2 Springs

3.2.1 General

Springs are reported to be the only sources of free flowing water during winter on the North Slope (Craig and McCart, 1975a; McCart, *et al*, 1972). Although few quantitative data are available, Leffingwell (1919) first described spring sources near the proposed Arctic Gas pipeline route. Childers, *et al* (1973) has described seven springs in the Sagavanirktok River headwaters. The most current description of North Slope springs is presented by Craig and McCart (1975a). These springs are perennial in nature and are tributary to mountain streams. Most are generally less than one mile in length and only a few feet wide. Flows are reported to be relatively stable, with summer discharge ranging from 3.5 to 53 cubic feet per second (cfs).

3.2.2 El Paso Alignment

In the Coastal Plain and Foothills Provinces, no known springs have been reported near the El Paso route. Upwellings occur in the Sagavanirktok River channels in the Coastal Plain Province; in the Foothills Province, many upwellings, as evidenced by icings, occur in the Sagavanirktok.

In the Brooks Mountain Province, one spring is located near MP 140 of El Paso's proposed route. It is utilized as a supplemental water source for Alyeska's Atigun and Galbraith Camps and Pump Station 4. Quantities of water withdrawn are estimated at 8,000 to 13,000 gph.

3.2.3 Arctic Gas Alignment

Eight springs have been reported within 16 miles of the proposed alignment on seven streams crossed by the Arctic Gas route (Arctic Gas, 1974; Ward and Craig, 1974). These drainages include the Shaviovik, Katakturuk, Hulahula, Okerokovik, Ekaluakat and Kongakut Rivers, and Sadlerochit Springs (Figures 4 through 7). Flow measurements from four of the eight springs ranged from ten cfs in the Okerokovik Spring to 48 cfs in the Hulahula Spring (Table 2).

The distances from the proposed pipeline to these springs range from 1 to 16 miles. In order to utilize all eight springs, an additional 40 miles or more of access road would be required. Six of these springs, however, are reported to be major fish overwintering and spawning sites (Ward and Craig, 1974). The remaining two, namely the Okerokovik and Katakturuk, apparently do not support major fish populations and may provide a winter source of water.

Additional springs are located 25 to 100 miles south of the proposed alignment, but are not considered as potential sources due to the distance from the proposed route.

3.2.4 Summary

Few spring sources are present along the El Paso or Arctic Gas routes. One is known near MP 140 of El Paso's route. This spring is being used as a source of winter supply by Alyeska's Atigun and Galbraith Camps and Pump Station 4.

Eight springs are located on seven streams within 16 miles of the Arctic Gas route. All but two of these have been reported to support spawning and overwintering fish. The first is the Katakturuk River Spring seven to eight miles south of MP 87.5; discharge has not been measured. The second, Okerokovik River Spring, where flow has been measured at 10 cfs, is located one mile south of MP 139.4. These two springs may supply water during winter but will require site specific evaluation prior to utilization.

3.3 Flowing Surface Waters

3.3.1 General

Hobbie (1973) notes that "there is almost nothing known about the limnology of flowing water in the Arctic." He classified arctic flowing waters as large rivers, small rivers, streams and springs. These definitions are poorly developed, however. According to Hobbie, "large rivers contain water throughout the year, and have unfrozen holes where fish can overwinter. Small rivers flow all summer, while streams are intermittent and contain water only during snowmelt or after an especially big rain."

Since Hobbie's review, another classification of arctic flowing water has been published by Craig and McCart (1975a). This work classifies stream types between Prudhoe Bay and the MacKenzie River Delta into three broadly-based categories: Mountain, Spring and Tundra Streams, based primarily upon the origin of the stream and, to some extent, its temperature, chemical properties, and biological characteristics. A synoptic description of these three stream types is presented in Table 3. To a large degree, this classification correlates specifically with the delineation of the physiographic provinces, Coastal Plain, Foothills, and Brooks Mountain.

According to Alter (1969), Dorris (1973), and Feulner (1973), few rivers in the cold regions are large enough to maintain an appreciable flow throughout the winter. Most streams in Arctic Alaska freeze solid during the winter (Alaska Water Study Committee, 1975; Hopkins, *et al*, 1955; Sherman, 1973). The actual date that flow cessation occurs is variable, depending upon the stream type and climatic conditions during a particular year.

In general, tundra streams are relatively small in terms of both drainage area and total discharge. Virtually all flow derives from surface runoff, and ceases at freeze-up, usually in mid-September. In some years, however, tundra streams continue to flow until mid-October (Craig and McCart, 1975a; Watson, *et al*, 1966).

Mountain streams have been described in considerable detail by Craig and McCart (1975a). They report that flow is derived principally from surface runoff, which ceases by mid-October, and from spring sources. Large mountain streams, such as the Sagavanirktok River, sometimes continue to flow until mid-November (Yoshihara, 1972; Nauman and Kernodle, 1973).

Data available for the two largest rivers in Arctic Alaska, the Colville and Sagavanirktok Rivers, will serve to establish maximum winter discharge characteristics. Of these, the Colville River is the largest, over 400 miles in length with a drainage area of 24,000 square miles (Table 4) and recorded peak discharge of 1,578,000 cfs (Arnborg, *et al*, 1966). In 1962, discharge dropped rapidly after September 8, the date when average air temperature dropped below 32°F. By the end of September, discharge had dropped from 368,200 cfs to 26,300 cfs. Ice began to form on the river September 30 and ice cover was complete by October 15. Discharge may cease during some winters, but the exact date is unknown (Arnborg, *et al*, 1966; Williams, 1970a).

The Sagavanirktok River is the second largest in discharge (Schallock and Lotspeich, 1974) and drainage area (Table 4). Peak discharge occurs during spring runoff, normally in the last week of May or first week of June. Surface water records for 1971 indicate that peak discharge in the Sagavanirktok River reached 22,200 cfs on June 2. Discharge fluctuates greatly during the summer until the first of September when it begins to drop steadily. Measurements made at the Lupine Gaging Station show a drop in discharge from 6,050 cfs on September 1, to 900 cfs on September 30, 1971 (USGS, 1972b) and a discharge of 249 cfs was recorded on November 15, 1970 (Nauman and Kernodle, 1973).

Ice begins to form on the Sagavanirktok River during late September. Ice depth is variable from year to year on any given date, probably due to annual climatic differences, and varies by location. For example, ice depth near the river's mouth at Prudhoe Bay was measured at 1.5 feet on November 6, 1973. A measurement of 3.0 feet was recorded near the same location on November 20, 1970 (Nauman and Kernodle, 1973). Ice depths 30 to 50 miles further upstream on November 15 to 22, 1971, ranged from 1.0 to 2.2 feet (Yoshihara, 1972).

The Sagavanirktok River is a source capable of providing large quantities of water until flow ceases and pools become isolated. At that time, most of the river is frozen to the bottom. The remaining free-water under ice is limited to isolated pools in deeper holes. As a result, free-water becomes difficult to locate and undependable as a water source. Experiences at Prudhoe Bay, Franklin Bluffs, and Happy Valley Camps have verified this situation. The importance of these isolated pools to fish is discussed later.

There are few winter oxygen measurements from arctic rivers and fewer yet from isolated pools under ice. Two measurements in the Sagavanirktok River during April recorded dissolved oxygen concentrations of less than 2.0 ppm (Schallock and Lotspeich, 1974) and one at Sagwon in late May recorded 1.1 ppm (USGS, 1969b). Four additional measurements taken from sites near Franklin Bluffs and Sagwon Bluffs found dissolved oxygen values of 4.8 ppm and 1.8 ppm, respectively (Furniss, 1975). According to Schallock and Lotspeich (1974), severe dissolved oxygen depletion during winter has been found in many river systems large and small in Alaska. Their data indicate that this dissolved oxygen depression begins in October and continues into February. Oxygen concentrations measured at stations near the mouth of a river were generally more depressed than at upstream stations. They concluded that "The depressed winter dissolved oxygen concentrations and low winter discharge in many Alaskan rivers are more severe and widespread than present literature indicates." Jam.

Groundwater in the unfrozen alluvium of arctic rivers may surface in riverbeds and is identified by the presence of an "icing" or "aufeis." All known icings in the Sagavanirktok River have been mapped by Sloan, *et al* (1975). These sites are potential sources of winter water.

3.3.2 El Paso Alignment

Within the Arctic Slope drainage, the proposed El Paso pipeline will cross approximately 135 streams and parts of four drainage basins: the Putuligayuk, Colville, Sagavanirktok, and Kuparuk Rivers (El Paso Alaska, 1974). The vast majority of these conform to the definition of Tundra Streams presented by Craig and McCart (1975a); thus, flow should cease in late September or early October and will be unavailable as winter water sources.

The El Paso alignment parallels the Sagavanirktok River which is a potential source of water through the late fall and early winter until isolated pools begin to form under ice. Groundwater upwellings in the river channel are also potential sources of water.

The Atigun River, a small tributary of the Sagavanirktok, may also provide water in early fall. The proposed alignment between Galbraith Lake and Atigun Pass is in close proximity to this stream. It is known to freeze to the bottom during the winter (McDonald, 1971) although the exact date is not known and varies from year to year. Nauman and Kernodle (1973) observed water under ice downstream from Galbraith Lake on October 16, 1971.

3.3.3 Arctic Gas Alignment

Arctic Gas (1974) reports that about 120 streams are crossed by their Arctic Coastal Plain alignment between its origin at Prudhoe Bay and the Canadian Border. Nineteen of these are Mountain Streams and the remainder are Tundra Streams.

Tundra Streams usually cease flowing in mid-September and do not begin flow again until late May (Craig and McCart, 1975a). Thus, they will not be available as sources of water during the proposed construction period.

The largest Mountain Streams crossed by the proposed pipeline east of the Sagavanirktok River are the Shaviovik, Canning, and Kongakut Rivers; none of which are as large as the Sagavanirktok River (Table 4).

Ward and Craig (1974) reported that the Canning River was frozen to the bottom at the pipeline crossing on November 5, 1973 and that the Shaviovik crossing was frozen to the bottom on November 7, 1973. The Kongakut River was reported frozen to the bottom at the pipeline crossing on November 5, 1972 (Arctic Gas, 1974). These data indicate that surface flow probably ceases during the last part of October, earlier than is the case in the Sagavanirktok River. Fall surveys conducted by Arctic Gas (Ward and Craig, 1974; Arctic Gas, 1974) indicate that most streams on which they collected data (summarized in Table 5) ceased flowing by November 7 and thus are not potential surface water sources.

3.3.4 Summary

The proposed El Paso alignment parallels the Sagavanirktok River which can provide large volumes of water until discharge ceases sometime between mid-October and late November. The Atigun River will provide water for construction activities between MP 140 and 160 until freeze-up, probably in mid-October.

The proposed Arctic Gas pipeline crosses approximately 120 streams between MP 00 and 195. Most of these are Tundra Streams which freeze solid between mid-September and mid-October. Prior to early November, water may be available from the Canning, Shaviovik and Kongakut although these rivers are reported to have been frozen to the bottom at proposed pipeline crossings in early November. The Sagavanirktok River will probably be a reliable water source until later in November, due to its greater flow. Existing data indicate that other small mountain streams crossed by Arctic Gas will be frozen to the bottom in late October or early November.

3.4 Standing Surface Water

3.4.1 General

Most arctic lake basins were created by various types of glacial activity or by the effects of permafrost (Hobbie, 1973). As a result of different physical and geological processes, the characteristics of standing water in the three Arctic Slope Provinces are somewhat different.

Standing water bodies are generally most abundant in the Coastal Plain Province, uncommon in the Brooks Mountain Province and intermediate in number in the Foothills Province (Figures 1 through 3). In the western portion of the Coastal Plain, standing water in the form of shallow oriented lakes covers 50 to 75 percent of the land surface area and as much as 90 percent in some regions (Black and Barksdale, 1949). The number and total surface area of these lakes decline toward the east becoming relatively sparse on the Arctic Slope between the Canning River and the Alaska/Yukon Border (Figures 4 through 7). The distribution of lakes within ten miles either side of the proposed El Paso and Arctic Gas alignments is shown in Figures 1 through 7.

Hobbie (1973) has classed standing bodies of Arctic water into three types: ponds, shallow lakes, and deep lakes. Ponds are defined as standing water less than 6.6 feet deep, which freeze solid during the winter, thus preventing the establishment of permanent fish populations. Most shallow lakes are seldom greater than 16.4 feet in depth; fish populations may or may not be present depending on specific situations. Deep lakes exceed 16.4 feet in depth, and usually, but not necessarily, are inhabited by fish.

The most abundant water body in the Coastal Plain Province is the pond; millions have been counted (Britton, 1957). Shallow ponds are formed by water which seeps through cracks in the ground and forms ice wedges in the permafrost. These eventually create a polygonal ridge network which fills with water. This action results in rows of ponds usually less than 200 feet in diameter. These shallow ponds quite often coalesce into larger ponds (Hobbie, 1973). Other shallow lakes on the Coastal Plain form as a result of the thawing of large masses of ground ice - the so-called thermokarst process (Black and Barksdale, 1949; Hopkins, *et al*, 1949; Wallace, 1948). These large, shallow lakes become oriented as a result of wind-generated currents (Livingstone, 1963; Carson and Hussey, 1969), and their number has been estimated at tens of thousands in some North Slope areas (Black and Barksdale, 1949). These "thaw" lakes are characterized by elliptical basins with generally regular bottoms (Hobbie, 1973; Livingstone, *et al*, 1958; USGS, 1969a). According to Black and Barksdale (1949), these lakes can be classified into two groups based upon their underwater profiles. The first group has a bottom profile that is uniformly concave and is less than six feet in depth. The second group consists of those lakes which have a shelf or shallow underwater bench surrounding a deeper central portion which exceeds six feet in depth. Generally, shallow lakes with uniform concave profiles are more abundant in the northern part of the Coastal Plain, and deeper lakes with shallow shelves are more abundant in the southern part of the Coastal Plain. Sellman, *et al* (1975) state that in general, depth of thaw lakes on the Arctic Coastal Plain are "fairly uniform with water depth usually less than 6.6 feet." Bergman (1974) measured the depth of several ponds in a small area within 4.5 miles of the Beaufort Sea northwest of Prudhoe Bay. Those ponds had a maximum depth of 3.3 feet.

Another type of shallow lake, termed an "oxbow" lake, is formed by the movement of river channels. These are common along many major arctic rivers.

Shallow Coastal Plain lakes close to the Arctic Ocean may be brackish due to salt water intrusion; however, the extent of this condition is not known for the area between Prudhoe Bay and the Canadian Border. Doran (1974) reports that lakes in the Mackenzie River Delta are "often brackish."

Lakes of the Foothills Province are generally less numerous, smaller in surface area, and deeper than those on the Coastal Plain. Lakes on the low ridges originated primarily from thawing or glaciation, but in the river bottoms oxbow lakes are most numerous (Livingstone, *et al*, 1958).

In the Brooks Mountain Province, lakes are relatively uncommon (Ward and Craig, 1974). The majority of these result from glaciation and are deep, occurring where a glacial moraine blocks a narrow valley (Hobbie, 1973). Characteristics of several of those lakes are presented in Table 6.

Just as geologic processes create lakes in the Arctic, they also destroy them. Black and Barksdale (1949) report, "In certain areas adjacent to the coast, along many of the larger rivers, and wherever slopes are moderate, gullies have intersected and largely drained the oriented lakes without, however, completely destroying the lake basins themselves. The evidence shows conclusively that most of the present lakes were much larger than they are today and that many formerly oriented lakes are now completely drained." This phenomenon has also been noted by Brown, *et al* (1968) and by Sellman, *et al* (1975). Thus, some of the lakes indicated on USGS maps of the North Slope (Figures 1 through 7) no longer exist.

Ice begins to form on arctic lakes sometime during September, but as is the case with temperate lakes, the exact date of freezing depends upon the seasonal weather, including temperature, wind, and cloud cover. Other factors determining freeze-up are summer heat income, the variable lengths of time different lakes require to cool sufficiently, and lake depth (Hobbie, 1973). At Barrow, lakes 8.2 to 9.8 feet deep may freeze over anytime after September 1 (Brewer, 1958b). The average freeze date is September 15 to 20, but open water may extend until September 30 (Brewer, 1958b). Arctic Gas (1974) states that freeze-up of Coastal Plain lakes "generally . . . is complete by early October." Some very deep lakes in the Brooks Mountain Province sometimes remain open into early October (Hobbie, 1962), but this is unusual.

Ice depth normally reaches two feet sometime between November 7 and 30. It reaches a maximum of six to seven feet in the late winter (Billelo and Bates, 1975; Brewer, 1958b; Kalff, 1968). Ice depth measurements encompassing most of the ice covered period have been made by Bilello and Bates (1971, 1972, 1975) for two typical shallow lakes on the Arctic Coastal Plain. Their data for October, November and December are listed in Tables 7 and 8.

Both of the lakes for which Bilello and Bates report ice depth information are used by local residents for water supplies, and are located on the Arctic Coastal Plain near the Beaufort Sea. The first

(Table 7) is an unnamed lake located on Barter Island approximately one mile south of the D.E.W. site. The surface area is approximately 150 acres and maximum depth is approximately 8 to 9 feet. The second, Imikpuk Lake (Table 8), is located 3-1/2 miles north of Barrow village and immediately east of the Naval Arctic Research Laboratory. Brewer (1958b) considered Imikpuk Lake to be typical of lakes on the Arctic Coastal Plain. He reported that the surface area is approximately 155 acres and the lake is 6 to 10 feet deep.

Arctic lakes are generally ice free for two to three months (Boyd, 1959; Brewer, 1958b; Hobbie, 1961; Kalff, 1968). Only a few arctic lakes retain a permanent ice cover; a few in the Canadian High Arctic are open most years, but the majority are completely open every year. Deep lakes are usually clear of ice by mid to late July (Brewer, 1958b). A deep lake, however, can retain its ice cover into August depending on winter ice thickness and cold weather during June and July.

Hobbie (1973) states, "The extended duration of the ice cover in the Arctic means that ponds and lakes become ice free after the insolation peak." After that, the generally cloudy weather of July and August reduces the amount of solar radiation available throughout the summer and ensures that water temperatures of lakes seldom exceed 15°C. Smaller ponds, however, may warm to 18°C. Temperature stratification occurs infrequently in arctic standing waters during ice free periods (Hobbie, 1973; Livingstone, *et al*, 1958). Deeper lakes warm slowly and are generally subjected to frequent winds. These conditions prevent establishment of density gradients in the form of thermoclines. However, lakes sheltered from wind and with adequate exposure to sunlight may stratify for brief periods. Hobbie (1961) has observed stratification in Lake Schrader.

Another feature of some arctic lakes is the natural, continued loss of water during the winter. In most cases, flow into arctic lakes ends during September, except from some subsurface flow. The rivers draining certain of those lakes continue to flow for a period into the winter and the lake level falls. Hobbie (1973) reported that the water levels in Lake Peters and Lake Schrader dropped about 3.3 feet during winter due to this mechanism. He estimated that this overwinter loss was equivalent to 6 percent of the total runoff in the drainage basin. As a result of this water loss, ice falls onto the lake bed along the shore, scouring the upper several feet of the littoral zone. This, combined with the scouring of lake margins during break-up, may account for a poorly developed aquatic community along the shores.

Although arctic ponds and lakes exist in a region of little precipitation, low evapotranspiration and continuous permafrost ensure that 50 to 85 percent of the precipitation runs off the tundra and is available for replenishment (Hobbie, 1973). As a result, the normal overwinter loss of water is easily replaced during spring runoff.

As an example of available water quantities which might be expected under the ice in lakes, a calculation for a hypothetical lake is useful. Assume a lake with 1,000 acres surface area and a mean depth of four feet. From the data of Bilello and Bates in Tables 7 and 8, the ice thickness can be expected to reach about two feet by mid to late November. Thus, by that time, half of the water in such a hypothetical lake would be locked up as ice but some 2,000 acre-feet (over 650,000,000 gallons) of water would remain.

Since lakes in the Foothills and Brooks Mountain Provinces are characteristically much deeper than those on the Coastal Plain, the loss of water due to freeezing of the lake surface is relatively small compared to the total volume of water in storage. Thus, freezing will not significantly reduce water availability from lakes in these two provinces.

In the following section, detailing the availability of water from lakes near the routes proposed by El Paso and Arctic Gas, emphasis is placed upon lakes 2,000 feet or more in one dimension. Published literature indicates that 2,000 feet is the minimum size for lakes to be underlain by a talik (Feulner, 1973; Hopkins, *et al*, 1955; USGS, 1969a). Any lake which is underlain by a talik is deeper than the maximum thickness of winter ice (Brewer, 1955, 1958a and 1958b; Hobbie, 1973; Lachenbruch, *et al*, 1962; USGS, 1969a; Williams, 1970b). In short, lakes at least 2,000 feet long have been chosen for this analysis because research has shown that, in the Arctic, lakes that size or larger often do not freeze to the bottom and thus must be at least six feet deep. Therefore, they should be suitable sources of winter water.

Listed in Tables 9 and 10 are all lakes shown in Figures 1 through 7 within five and ten miles of the proposed routes. For those lakes 2,000 feet or more in length, cumulative surface area is also shown. Many, perhaps most, of the lakes in the Coastal Plain which do not meet the 2,000 feet minimum length criterion are too shallow to serve as water sources in later winter.

3.4.2 El Paso Alignment

Characteristics of standing water sources near the El Paso alignment are given in Table 11. The National Academy of Sciences (1975) reports, "The TAPS route is a water rich corridor . . . a large number of lakes of different geologic origins and histories are situated along or near the pipeline route." Brown (1975) has delineated this situation more exactly for the portion of the El Paso proposal discussed in this report, "Along the highway north of the Brooks Range many lakes and ponds are within 100 meters on either side of the road."

In the Coastal Plain Province, approximately 337 standing water bodies have been identified within five miles either side of the proposed pipeline (Table 9). Of these 337, about 254 are 2,000 feet or larger in one dimension. A minimum of 19 such water bodies are available within five miles of the route between any two consecutive 10-mile milepost markers from mile 00 to 60 (see Figures 1 and 2).

Using the minimum depth of six feet for lakes 2,000 feet or longer, and the ice depth data from Billelo and Bates, minimum potentially available water quantities from these lakes can be calculated. The surface area of the 254 standing water bodies totals approximately 34,800 acres, so a total of over 208,000 acre-feet of water, or nearly 68 billion gallons, are probably available before freeze-up begins. Since ice depth can be expected to reach two feet in mid- to late November, these lakes can provide approximately 45 billion gallons of freewater at that time. By the end of December, the Billelo and Bates data indicate, ice depth reaches three to four feet. At that time, 22 billion to 34 billion gallons of water remain available. Beneath those lakes which are sufficiently deep not to freeze to the bottom, additional large volumes of water are probably available in the underlying talik.

The proposed El Paso gas pipeline passes through the Foothills Province between MP 60 and 130. Along this segment, lake abundance, size and distribution are excellent for use as water sources and are within close proximity to the pipeline alignment as shown in Table 9 and in Figures 2 and 3. Depth measurements of lakes in the Foothills Province shown in Table 11, indicate that such waters are considerably deeper than standing water on the Coastal Plain. These waters are sufficiently deep that winter freeze-down will not significantly reduce the volume of water available. Therefore, large quantities of water should be available throughout the winter adjacent to the pipeline route in the Foothills Province.

The proposed El Paso pipeline alignment passes through the Brooks Mountain Province between MP 130 and 170. Data in Tables 6 and 11 indicate that lakes in this Province are sufficiently large and deep to provide large quantities of water throughout the winter. Analysis of lakes in close proximity to the alignment shows that large quantities of water are available during the entire winter, with the exception of the area between MP 160 and 170.

3.4.3 Arctic Gas Alignment

The Arctic Gas pipeline alignment lies entirely within the Coastal Plain Province (MP 00 to 195). Characteristics of three nearby lakes are given in Table 12. In terms of standing water abundance, the alignment between MP 00 and 60 is typical of the Coastal Plain. Large quantities of water are available in this area until about mid-December. However, east of MP 60, the proposed alignment passes through an area atypical of the Coastal Plain since standing water sources are very limited in number and acreage, as shown in Figures 5, 6, and 7, and Table 10. The Environmental Report of Alaskan Arctic Gas Pipeline Company (Arctic Gas, 1974) acknowledges this lack of standing water in the eastern portion of the Arctic Coastal Plain, "The vast majority of lakes in proximity to the proposed route are located in the western portion of the region, primarily between the Sagavanirktok and Canning Rivers." From MP 60 to 195 and even further into Canada, few standing water sources exist in reasonable proximity to the pipeline alignment and are poorly distributed for optimum access and use (Figures 5, 6, 7). Only two lakes in the near vicinity of the route have been found not to be frozen solid during late winter (Ward and Craig, 1974). One is eleven miles south of MP 59, and the other is one mile south of MP 67.

Lake water sources are absent along significant portions of the proposed Arctic Gas alignment. Only eight small lakes, none of them 2,000 feet or greater in one dimension occur within five miles of the pipeline between MP 70 and 130 and MP 140 and 180. In addition, only one small lake of 18 acres exists between MP 180 and 190 and its proximity to Demarcation Bay may mean it is saline. Within ten miles of the pipeline alignment, a few additional lakes are available; however, none of them occur between MP 80 and 100 and MP 150 and 170.

3.4.4 Summary

Lakes probably will be the primary source of water for El Paso's proposed winter construction requirements. Within five miles of the route, a minimum of 19 lakes, greater than 2,000 feet in length, are available between any two consecutive 10-mile milepost markers (MP 00 to 60). Lakes will also provide ample quantities of water between MP 60 and 160. Although less numerous, lakes in this region are generally larger and deeper than those in the first 60 miles.

Until frozen solid, large volumes of water exist in lakes adjacent to the Arctic Gas route between MP 00 and 60. Lake sources, however, are limited and, in some cases, absent between MP 60 and 195. Within five miles of the route, lakes greater than 2,000 feet in length are absent from approximately 100 of the total 195 miles in Alaska. Within ten miles of the route, such lakes are absent from approximately 40 of the 195 miles.

4.0 Biological Importance of Winter Water Sources

Surface water in the Arctic is significantly reduced due to freezing during winter. Consequently, most free-water during this time is critical to the survival of endemic aquatic biota. For instance, the eggs, juveniles, and adults of all freshwater fish are restricted to limited numbers of isolated pools of water under ice in rivers, limited numbers of springs, and to relatively deep lakes, for eight to nine months of each year. In this section winter utilization of water sources by aquatic biota is described and analyzed.

4.1 Groundwater

4.1.1 General

The importance of groundwater upwellings in river channels to spawning and overwintering fish has been documented for some upstream areas of major river systems (Craig and McCart, 1974; Furniss, 1974, 1975; Yoshihara, 1972, 1973). During winter, groundwater supplies a continuous flow of well oxygenated water to these sites. Some of these upwellings are, of themselves, small spring streams.

The importance of groundwater upwellings to endemic biota in the mainstem and delta areas of arctic rivers is not understood as well as in the case of upriver areas. Within the mainstem and delta areas of rivers such as the Sagavanirktok, Canning, and Kongakut, groundwater upwellings are not generally utilized by Arctic char for spawning. However, all known fish overwintering areas in the mainstem of the Sagavanirktok River are located in the vicinity of aufeis areas. Furniss and Alt (in prep.) found grayling and round whitefish overwintering in the Sagavanirktok River at Franklin Bluffs in close proximity to an icing. Craig and McCart (1974) report a similar situation in the Brooks Mountains, along the mountain front and in the nearby foothills adjacent to the Arctic Gas pipeline alignment. According to these authors, "Arctic char typically spawn and overwinter in braided, gravel-bottom stream channels in the vicinity of *aufeis*."

4.1.2 El Paso Alignment

Groundwater appears to be biologically important in the Sagavanirktok River.

4.1.3 Arctic Gas Alignment

Groundwater appears to be biologically important in the Canning, Hulahula and Kongakut Rivers and where it occurs in other smaller mountain streams, it may also be important.

4.1.4 Summary

Groundwater upwellings (as identified by icings) are correlated with fish overwintering areas.

4.2 Springs

4.2.1 General

The following description of the biological characteristics of spring streams is excerpted from Craig and McCart (1975a):

> "The Spring Stream habitat is one of relative stability and this appears to have a profound biological influence. Kalff and Hobbie (1973) have described these areas as 'green oases in the polar environment.' Streambanks are often overgrown with vegetation and the streambed is covered in most places with a heavy growth of moss or algae.
>
> Echooka Spring is primarily a spawning area for anadromous char and a rearing habitat for their young. This situation appears to be typical of those springs with easy access to Mountain Streams and the Beaufort Sea."

Approximately 36 spring areas have been located in the Coastal Plain and Foothills Provinces of the North Slope between the Sagavanirktok River and the Canadian border. Thirty-four of these are known spawning and overwintering areas for anadromous and resident Arctic char, and overwintering sites for lesser numbers of grayling and other species (Craig and McCart, 1974; Furniss, 1974; Furniss and Alt, in prep.; McCart, *et al*, 1972; Ward and Craig, 1974; Yoshihara, 1972 and 1973). As early as mid-August, Arctic char begin to gather in the vicinity of spring streams to spawn. Spawning peaks between September 15 and November 15, although some spawning continues into December (McCart, 1975b; McCart, *et al*, 1972; Yoshihara, 1972 and 1973).

Craig and McCart (1975a) report that char eggs cannot tolerate freezing. As a result, most if not all spawning takes place in springs because "these are the only stream areas in which winter flow is assured." The eggs begin to hatch in mid-April and fry emerge during mid-June (Yoshihara, 1973). Through the year, fry and juvenile char are abundant in the vicinity of spring water sources (Craig and McCart, 1975a; Furniss, 1975, Furniss and Alt, in prep.; McCart, *et al*, 1972; Yoshihara, 1972 and 1973).

In springs where conditions are favorable, fish densities are often high. According to Craig and McCart (1975a), "At Echooka Spring, densities of 5.2 and 3.4 fish/m^2 were recorded (July 20, 1971). In many other spring areas, values ranged from 0.1 to 3.1 fish/m^2."

Spring areas provide some but not all of the overwintering habitat for Arctic char. After studying the Sagavanirktok River drainage, Yoshihara (1972) concluded "Spring areas at the headwaters of most tributaries provide some overwintering capabilities but it is believed the total fish population is not contained within these restricted areas." Evidently most char spawners move out of the open water areas of springs, presumably to the shelter of ice cover up or downstream (Furniss, 1975; Furniss and Alt, in prep.; Yoshihara, 1972). The distance that spawned-out char move away from the spawning bed to an overwintering site has not been determined. However, it is likely that these fish overwinter in the area of spring influence adjacent to spawning site since spawning activity extends beyond the date when portions of the river freeze to the bottom.

Springs are also important to other forms of aquatic biota, such as insects. The density of benthic organisms in springs often far exceeds that found in other stream habitat types on the North Slope (McCart, *et al*, 1972). In most cases, biomass is also greater in springs. Density and biomass of benthic invertebrates in Spring, Foothill (Tundra) and Mountain Streams are ranked in Table 13. The highest density of benthic macroinvertebrates recorded in any of these springs was more than 84,000/m^2; by contrast, benthos densities in open water areas of Mountain Streams were reported to be as low as 22/m^2.

4.2.2 El Paso Alignment

One spring is reported approximately one to two miles west of MP 140. This spring has not been studied. Surveys will be necessary to determine whether or not others occur in the vicinity of the proposed route.

4.2.3 Arctic Gas Alignment

Eight spring areas are located within 16 miles of the Arctic Gas route. Existing information for these springs is summarized in Tables 2 and 14.

4.2.4 Summary

Springs are biological "oases" of the arctic aquatic environment. Various life stages of Arctic char utilize spring areas year-round. Diversity and density of benthos are reported to be greater in springs than in other North Slope waters. Withdrawal of water from springs constitutes a risk in terms of possible impact upon aquatic biota.

Thirty-four of the 36 surveyed springs in the Coastal Plain and Foothills Provinces on the North Slope support overwintering and spawning populations of char. Eight of the 36 springs are within 16 miles of the Arctic Gas alignment. Two of the eight may not support overwintering fish populations, but the other six are important to fish populations. None of the 36 springs are found near the El Paso route. One additional unsurveyed spring is located approximately one mile west of El Paso MP 140 in the Brooks Range.

4.3 Flowing Surface Water

4.3.1 General

Rivers and streams in the Arctic are seasonally important to fish and other endemic biota for spawning, rearing, feeding, as migratory routes, and for overwintering.

Tundra streams are primarily important to grayling for spawning in the spring, and rearing and feeding in the summer (Craig and McCart, 1975a; Craig and Poulin, 1974; Furniss and Alt, in prep.; McCart, *et al*, 1972; Yoshihara, 1972 and 1973). Low flow and freezing prohibit fish use during the late fall and winter. Use by char and other species is infrequent. For example, at "Weir Creek", Craig and Poulin (1974) report that "only one percent of the 18,000 fish enumerated at a fish weir were char, the rest were grayling." The ninespine stickleback becomes more abundant in Tundra Streams closest to the Beaufort Sea (Craig and McCart, 1975a).

The Arctic char is the characteristic species in Mountain and Spring Streams, according to Craig and McCart (1975). Char use them for migratory paths during late spring as they move from overwintering sites to summer feeding areas in the Beaufort Sea and again in August to mid-September when returning to spawning and overwintering sites (Furniss, 1974 and 1975; Yoshihara, 1972 and 1973).

In general, the dominant aquatic insects found in flowing waters of the Trans-Alaska oil pipeline corridor are immature chironomids and plecoptera, although others are sometimes locally important (Nauman and Kernodle, 1974).

Shallow areas of major North Slope rivers usually freeze to the bottom in October or November, restricting the availability of free-water to isolated pools under river ice. As winter progresses, these isolated pools continue to diminish in size.

Alaska Department of Fish and Game surveys have indicated that fish may overwinter in pools greater than six feet in depth in the Sagavanirktok River (Furniss, 1974 and 1975; Yoshihara, 1972). Investigations conducted by Furniss and Alt (in prep.) during 1974-1975 found two isolated pools of water within the Sagavanirktok River. One of these sites is near Franklin Bluffs. The pool, approximately 1,500 feet long and 60 feet wide, was covered by up to 9 feet of ice. Dissolved oxygen was measured at 4.8 ppm (April 10, 1975). Maximum water depth was about 5.5 feet. Hook and line techniques failed to capture fish, but a gill net placed under the ice caught 28 grayling and 7 round whitefish in 20 hours. Grayling stomachs contained eyed fish eggs, presumably those of whitefish, indicating that this isolated pool is a spawning area for whitefish as well as an overwintering site. A second, smaller, isolated pool was located near Sagwon. Dissolved oxygen was measured at 1.8 ppm (April 9, 1975). Maximum water depth was approximately 2 feet. Hook and line techniques failed to capture fish. A gill net could not be set.

Data collected by Arctic Gas (Table 5) indicate that most stream crossings along their proposed route are frozen in winter months. Four fish overwintering areas have been reported; the first two are in the Hulahula River approximately 20 miles south and two miles north of the proposed alignment. Both pools are known Arctic char overwintering sites and are also utilized as annual subsistence fishing grounds by Kaktovik (Barter Island) villagers. The other two sites are in the Canning river approximately 25 miles south of the proposed alignment.

Deltas of large arctic rivers are probably important to overwintering fish (Furniss, 1975), although data on these areas are sparse (Craig and McCart, 1975b). Encroachment of salt water from the Beaufort Sea sometimes creates a brackish area which is well upstream in the delta regions in the winter (Kogl, 1971; Walker, 1973). Fish species composition and distribution may be altered in these areas due to salt water invasion. Not enough is known at this time about fish utilization of delta areas to identify the importance of this habitat during the winter.

4.3.2 El Paso Alignment

Environmental studies resulting from construction of the Trans-Alaska oil pipeline provide a strong base of biological knowledge for the area surrounding the proposed El Paso alignment. A substantial part of this information, dealing specifically with aquatic resources, has been compiled and summarized by Johnson and Rockwell (1975) into a resource catalogue.

Along the proposed route, the Sagavanirktok River is the only major flowing water where fish overwinter in isolated pools. This river can be used as a water source without damaging endemic biota until isolated pools begin to form under ice. Since this date is variable, determination of water availability will require field investigation. All other streams crossed are expected to freeze to the bottom early in the proposed construction period.

4.3.3 Arctic Gas Alignment

Along this route, the Sagavanirktok, Shaviovik, Canning, Hulahula and Kongakut Rivers are known to be large enough to overwinter fish in isolated pools. Fish may overwinter in other streams as well. All rivers can be utilized as water sources without damaging endemic biota until freezing begins to isolate pools under ice. Since this date varies from year to year and from river to river, determination of water availability will require field investigation.

4.3.4 Summary

Flowing water in the Arctic is seasonally important to fish. In terms of water removal, late fall and winter are periods during which conflicts may exist. Evidence indicates that isolated pools under river ice are important to fish fauna. Six isolated pools have been reported by various study groups. Five of the six are known to contain fish during winter. Two of these, located on the Hulahula River, are also subsistence fishery sites utilized by Eskimos. Two others are known to occur on the Sagavanirktok River near the proposed El Paso route. The Franklin Bluffs site has been shown to support overwintering populations of grayling and round whitefish. Fish have not been found at the Sagwon site. The remaining two pools, both on the Canning, are known to contain fish.

Until freezing eliminates flow, creating isolated pools, substantial quantities of water can be removed from large mountain streams without conflict with endemic biota. Since pool isolation varies from year to year and stream to stream, determination of when water removal should cease will require field investigation during construction.

4.4 Standing Surface Water

4.4.1 General

Arctic freshwaters are generally low in nutrients, receive little direct sunlight, rarely exceed 10°C, and seldom stratify. Shallow lakes may be severely deoxygenated in the winter. For example, oxygen concentrations in Lake 5 (9.8 feet deep) at Cape Thompson were measured at 5 ppm of oxygen at the end of January 1961, and 0 ppm on April 10 (Tash and Armitage, 1967). Edgington (1971) measured 0 ppm oxygen in a second lake near Sagwon (Sagavanirktok River Lake No. 730) on April 23, 1971. The latter measurement was made when one foot of free-water remained under six feet of ice cover.

In response to these environmental factors, the number of floral and faunal species inhabiting standing waters is low, and the resulting food chain is relatively simple (Hobbie, 1973). Although arctic ecosystems are simplified in terms of species diversity, the interrelationships of organisms are still extremely complex and difficult to understand.

"The most striking biological characteristic of arctic Alaskan lakes is the absence of a well-developed shore community," note Livingstone, *et al* (1958). They further observe, "The lack of a shore community, combined with the scars of heavy ice-push, gives to even the most permanent arctic lake a barren, raw, and temporary aspect. The shoreline looks like that of a spring puddle or temporary ditch rather than a lake." Although lack of a shore community is characteristic of most lakes on the tundra, it cannot be said with certainty that all lakes will be without one.

According to Spetzman (1959):

> "Very few kinds of higher aquatic plants grow on the Arctic Slope, and their distribution is erratic. Almost all aquatic vegetation of the Arctic Slope occurs in lakes. Plant communities in each lake are usually arranged in concentric bands, corresponding to depth of water. Most vegetation is limited to water less than 4 feet deep, and the depth preferred by any given species decreases from the foothills northward into the more severe climatic conditions of the coastal plain. Each species forms an extensive colony, mostly by vegetative means, once it becomes established, thus excluding other species. Two ecologic life forms occur, rooted submerged and rooted emergent aquatics. The former are relatively unimportant and usually lacking; the latter play an important part in the obliteration of lakes through the accumulation of peat. In small lakes, the remains of emergent aquatics from the lake margins accumulate, with the result that the water is gradually replaced by fibrous organic debris and the bottom gradually freezes to higher levels, which eventually permits the development of a mat of vegetation over the lake bed. Thus, a wet sedge meadow is finally formed."

This filling of lakes by vegetative growth was also noted by Black and Barksdale (1949) and Brown, *et al* (1968). Because of that obliteration process, some lakes on the Arctic Coastal Plain no longer exist, although they appear on USGS maps of the area.

Spetzman goes on to list a total of only thirteen species of aquatic vascular plants on the North Slope. Livingstone, *et al* (1958), report that in the smaller lakes there is sometimes a good stand of *Arctophila fulva*, a coarse aquatic grass, and in the shallow ponds there is often a good growth of *Hippuris vulgaris* or *Ranunculus pallasii*. Hobbie (1973) has reported phytoplankton production to be low in arctic ponds and lakes.

Surprisingly, quantities of algae are greater in arctic lakes than subarctic or alpine lakes. Hobbie (1973) attributes this to the fact that deep snow does not accumulate on ice-covered lakes in the Arctic, so that light penetration through the ice during long days in the late winter and early spring results in considerable algal photosynthesis. Photosynthetic rates are mainly limited by the low nutrients of arctic lakes.

Howard and Prescott (1971) studied productivity in several tundra lakes of the Brooks Range and Coastal Plain. They reported that primary productivity was highly variable. Compared to temperate lakes, most arctic lakes are oligotrophic.

Two International Biological Program (IBP) studies - at Char Lake and Barrow ponds - have shown that primary production of aquatic plants is many times greater than production of the phytoplankton. The study of ponds at Barrow indicates that sediments derived from vascular aquatic plants dominate the energy and nutrient flow and that nutrient release from these sediments controls phytoplankton productivity (Hobbie, *et al*, 1972).

The biomass of the zooplankton in arctic waters is low but comparable to winter zooplankton quantities in temperate lakes. In spite of the low production, the biomass of zooplankton almost always far outweighs that of the phytoplankton (Hobbie, 1973).

The dominant group of benthic animals in arctic water is the chironomid larva. They dominate northern Alaskan lakes (Livingstone, *et al* 1958), and make up 75 to 95 percent of total numbers and biomass in five ponds at Barrow and five lakes at Prudhoe Bay (Bierle, 1972). Chironomids are most abundant in shallow ponds with organic sediment; in the Barrow ponds their number may reach 9,000 per m^2 (Bierle, 1972). Shallow ponds near Cape Thompson contained up to 40,000 per m^2 (Watson, *et al*, 1966). Deeper lakes support less biomass than shallow ponds. For example, Chandler Lake is reported to support approximately 1 gm per m^2 as compared to 36 gm per m^2 found in the Barrow ponds (Livingstone, *et al*, 1958).

Species diversity is not as great in the shore zone of arctic lakes as compared with more temperate lakes. For example, freshwater sponges, Notonectidae, Corixidae, Gyrinidae, Dytiscidae, and Amphibia are not reported north of the Brooks Range (Livingstone, *et al* 1958). Tundra ponds have about 10 species of chironomid larvae, while similar ponds and shallow lakes in temperate areas will have 60 to 160 different species. Hobbie (1973) states that chironomids "are also the most important food for fish and shore birds."

Fish species known to occur on the North Slope include Arctic char, lake trout, grayling, ninespine stickleback, round whitefish, sculpin, burbot and least cisco (Furniss, 1974; Ward and Craig, 1974).

Based on existing information, the standing freshwaters of the Arctic Coastal Plain are little utilized by fish and withdrawal of water from them can be considered to entail relatively little environmental risk. However, use by waterfowl during ice free months dictates that those which are important to birds should not be seriously altered.

Most standing waters of the Foothills Province are considerably deeper than those of the Coastal Plain, and are capable of supporting fish fauna. Surveys in the Sagavanirktok River drainage and in the Arctic National Wildlife Range indicate that most Foothills lakes support limited fish populations consisting primarily of lake trout and grayling with populations of Arctic char, round whitefish, and burbot occurring less frequently (Furniss and Alt, in prep.; Kogl, 1971; McCart, *et al*, 1972; Ward and Craig, 1974; Yoshihara, 1972).

Within the Brooks Mountain Province, lakes are deep and generally support resident populations of fish, including lake trout, grayling, Arctic char, and round whitefish (Furniss, 1974; Hobbie, 1960; Kogl, 1971; McCart, *et al*, 1972; Ward and Craig, 1974). Although fish in these lakes are characterized by slow growth, they may attain large size and live to ages exceeding 40 years.

4.4.2 El Paso Alignment

The proposed route passes through the entire spectrum of standing water environments: Coastal Plain ponds and shallow lakes, Foothills lakes, and Mountain lakes. Some of these lakes have been surveyed by various agencies and organizations as a result of the North Slope hydrocarbon exploration and the construction of the Trans-Alaska Pipeline System. Lakes surveyed were limited to waters potentially impacted by oil pipeline construction or to those with particularly interesting characteristics. A substantial portion of this information has been compiled and summarized by Johnson and Rockwell (1975). Some lakes in and near that corridor have been found to be biologically important, but many are relatively unimportant. An extensive limnological study of lakes and ponds in the Trans-Alaska oil pipeline corridor north of the Brooks Range has been initiated by scientists from seven universities (Brown, 1975).

4.4.3 Arctic Gas Alignment

Studies show that up to 50 percent of the Coastal Plain lakes surveyed do not support resident populations of fish (Ward and Craig, 1974).

4.4.4 Summary

Available data indicate that many lakes on the Coastal Plain and some in the Foothills are probably unimportant to fish production. The majority of Brooks Mountain lakes support lake trout, char, and grayling, which are the only sport fish species occurring in abundance on the Arctic North Slope. Where lakes are found, most will probably be suitable as water sources.

Some site specific investigations are necessary to identify the relative importance of particular lake and to identify acceptable locations for water withdrawal.

5.0 Problems of Winter Water Use Along Both Proposed Routes

5.1 Timing of Construction as Related to Availability of Water and Over-tundra Travel

Many water sources capable of meeting proposed construction requirements are not located immediately adjacent to the proposed routes. Utilization of these lake sources will require additional access roads across delicate tundra. According to Adam (1974), "The major impact upon the terrain resulting from winter roads is anticipated to result from misuse; that is, use too late in the spring or too early in the fall." Because of this, federal and state agencies regulate vehicular travel on tundra of the North Slope in order to minimize damage. Thus, if meteorological conditions are not favorable, it may not be feasible to construct access roads to or from water sources during much of the proposed snow/ice road construction period, September to December.

The State of Alaska regulates tundra travel on state land, the Park Service on National Park lands, the Bureau of Land Management on unappropriated Federal Public Domain lands, and the Wildlife Service on Wildlife Refuges and Ranges. These agencies determine when conditions are adequate to support over-tundra vehicular traffic without tundra damage. Dates of past permits issued by the Alaska State Department of Natural Resources (Table 15) provide a guideline for evaluating the feasibility of snow and ice road construction between September and December. Within the Arctic National Wildlife Range, over-tundra travel permits have never been issued for vehicles larger than single passenger snow machines.

Utilization of the ditch centerline as access across tundra areas has been proposed by Arctic Gas (Dau, 1975b) to compensate for late freeze-up or insufficient snowfall. However, Arctic Gas (1974) has reported, "Fresh water is scarce in the vicinity of the route during the winter construction period." The remote location of most water sources will require numerous and lengthy access roads, and large numbers of heavy vehicles travelling across tundra, north and south of the pipeline right-of-way. Adam (1974) reports, "Off-right-of-way winter roads are potentially a very significant source of impact . . . . This type of access even for all-terrain type vehicles, needs to be controlled if impact is to be minimized."

The El Paso proposal differs from the Arctic Gas proposal in that it is not entirely contingent upon authorization for tundra travel. El Paso can utilize the existing gravel haul road and associated access roads, constructed by Alyeska Pipeline Service Company, to obtain water from many lakes and from the Sagavanirktok River without crossing tundra.

5.2 Impact of Withdrawal Upon Aquatic Biota

One of the biological problems created by proposed gas pipeline construction in the Arctic is the conflict between large volume water removal and use of that water by endemic aquatic biota during the winter. Water withdrawals during late fall may adversely impact spawning fish; in winter and early spring, it may have deleterious effects on hatching and overwintering fish.

Large volume removal of water from the thawed alluvium beneath large arctic rivers could reduce surface flow at groundwater upwelling sites. Partial and/or total dewatering of isolated pools under ice may result.

Spring areas in arctic streams are extremely important to aquatic biota and especially to anadromous fish species. Human activity in and around spawning areas will probably disturb Arctic char and may reduce spawning success. The period of sensitivity for spawning Arctic char is late August to mid-December, with a highly critical period during the peak of spawning activity September 15 to November 15.

Another potential impact of water removal from springs is the reduction of flow below a minimum necessary for survival of overwintering fish and survival of eggs deposited in the gravel. It is suspected that adult char overwinter in spring influenced areas in the vicinity of spawning grounds. As flow decreases, marginal areas will become dewatered. Since char spawn in shallow pools and riffles which are constantly fed by spring flow, a reduction in flow may expose eggs to freezing and reduce survival.

Prior to cessation of flow, water removal from large rivers will not be harmful to endemic biota. However, flow in most rivers ceases in the late fall or early winter. At that time, isolated pools of water remain which are evidently important as overwintering areas for Arctic grayling and round whitefish and may be spawning areas for the latter. Direct removal of water from isolated pools has killed fish in the Sagavanirktok River near Prudhoe Bay. Removal short of complete dewatering may adversely affect overwintering fish by concentrating already dense populations into even smaller areas; the resultant overcrowding may create serious dissolved oxygen depletion, since dissolved oxygen is low at those locations and times. According to Schallock and Lotspeich (1974) low winter dissolved oxygen levels in arctic rivers, particularly near the mouths, may normally be a limiting factor for aquatic biota. Any activity which compounds this problem has the potential for seriously affecting aquatic biota and should not be considered. For this reason, although existing biological information is scarce, isolated pools should probably not be considered as water sources at this time.

Standing water appears to be the single most reliable source of water in the Arctic during winter. The Habitat Protection Section of the Alaska Department of Fish and Game has encouraged all North Slope lease holders to use lake sources rather than river sources whenever possible (Brooks, 1975). Although lakes are the preferred water source, they will require site specific investigation.

5.3 Mitigation of Damage to Aquatic Resources

Site specific consideration of each water source will be necessary during the final design phase of the proposed projects to ensure minimal impact. Should there be river and lake sources where some adverse biological impact is unavoidable, lakes should be chosen over rivers because they offer certain advantages in terms of assuring successful fishery rehabilitation as a mitigative measure.

Arctic lakes capable of supporting fish are generally not utilized by anadromous species. Resident fish populations offer several rehabilitative advantages over flowing water habitats with migratory populations. These advantages include: (1) pre-impact conditions are more easily assessed; (2) extent of impact is more predictable; (3) assessment of damages can be done more accurately; and, (4) more is known and published concerning lake fishery restoration (Hammarstrom, 1975; Kalb, 1974; Kramer, 1975; Peckham, 1974; Watsjold, 1973 and 1975; Williams, 1975). Results of those programs have shown that lake fishery restoration can be successful in Alaska. There are few, if any, published accounts of stream fishery rehabilitation in Arctic and subarctic Alaska.

6.0 Summary Comparison of Winter Water Availability Adjacent to Proposed Routes

This section summarizes the comparisons of available sources and quantities of water along the proposed El Paso and Arctic Gas pipeline routes on the North Slope of Alaska. For summary purposes, discussions are limited to areas within five miles either side of the proposed pipeline alignments.

Estimated quantities of water available from groundwater, springs, flowing water, and standing water sources near the El Paso and the Arctic Gas routes are shown in Tables 16 and 17, respectively.

The availability of water, for the purpose of this section, means large volumes which may potentially be utilized for snow/ice road construction and are not critical to fisheries. For example, springs known to support spawning and overwintering fish are not discussed as a possible source in this section because of their high fishery value. Isolated pools of river water are also deleted from this section due to their importance to overwintering fish. All lakes 2,000 feet or more in length, however, are included because they can support large volume water removal. Calculated volumes of water shown are based on assumed ice thickness in late November (two feet, see Tables 7 and 8), a lake depth of six feet, and lake surface areas given in Tables 9 and 10.

The data shown in Table 16 indicate that water is present in more than sufficient quantities within five miles of the El Paso route to meet winter construction requirements, with the exception of the segment between MP 150 and MP 170. Data in Table 17 indicate that available water quantities are not sufficient to meet requirements in major segments of the Arctic Gas route. A total of 100 of the 195 miles of that route is entirely lacking in lake water sources within five miles. Some river sources may be available, but these are likely to become unavailable by late October due to freezing to the bottom. Two springs, one at MP 87.5 and one at MP 139.4, apparently are available. One of these has a measured flow of 79 gps and the other has not been measured. Both of these springs are located in the segments deficient in lake sources. The proposed Arctic Gas route thus appears to be deficient in accessible water sources capable of meeting estimated water requirements for snow/ice road and work pad construction.

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Table 1. A COMPARISON OF POTENTIAL GROUNDWATER SOURCES WITHIN TEN MILES EACH SIDE OF THE EL PASO AND ARCTIC GAS PIPELINE ROUTES, NORTH SLOPE, ALASKA.

	EL PASO			ARCTIC GAS	
	Coastal Plain	Foothills	Brooks Mountain	Coastal Plain	COMMENTS
Suprapermafrost	No	No	No	No	Shallow nature and winter freezing in this aquifer eliminate consideration as water source.
Intrapermafrost	No	No	No	No	Water is generally not present in this layer. If found, it is usually saline.
Subpermafrost	No	No	No	No	Any water found in this aquifer is difficult to locate, costly to develop, usually saline, and not reliable as water source. Flows of 10 gph have been recorded.
Bedrock Water	No	No	No	No	Limited quantities have been found between 1,693 and 2,894 feet below the land surface. Water is saline.
Thawed Alluvium Under:					
Rivers	Yes Limited quantity June to December	Yes 500-1000 gph 12 months in some locations	Yes 500-1000 gph 12 months in some locations	Yes Limited quantity June to December	El Paso route parallels an excellent source, Sagavanirktok River, for 130 miles. An existing road allows tapping at many locations. Arctic Gas crosses several potential sources, all on the Arctic Coastal Plain.
Lakes	Yes Unknown quantity	Yes Unknown quantity	Yes Unknown quantity	Yes Unknown quantity, principally MP 00-65	Alluvium on the Coastal Plain Province is not generally a reliable water source; thus, shortages can be expected from river alluvium after freezing eliminates surface flow.

Table 2. POTENTIAL SPRING SOURCES AND AVAILABILITY NEAR THE PROPOSED ARCTIC GAS ROUTE, NORTH SLOPE, ALASKA.

Spring Source	Distance from Centerline (miles)	Flow (cfs)	Availability
Shaviovik	16 south MP 36.5	28.6 (11/03/73) 17.0 (04/11/73)	No. Major fish overwintering area.
Katakturuk	7-8 south MP 87.5	not measured	Yes. No fish reported in this area. Requires site specific evaluation.
Sadlerochit	1-6 south MP 113	22.0 (05/19/72) 45.0 (04/12/73) 27.0 (11/07/73)	No. Arctic char present.
Hulahula	2 north MP 117.5	48.0 (11/05/73)	No. Arctic char spawning and overwintering site. Also native subsistence fishing site.
Okerokovik	1 south MP 139.4	10.0 (11/07/73)	Yes. No fish seen in this area. Requires site specific evaluation.
Ekaluakat	5 south MP 166	not measured	No. Arctic char spawning and overwintering site.
Kongakut	5-25 south MP 173 5-10 north MP 173	not measured not measured	No. Arctic char spawning and overwintering sites.

Source: Ward and Craig, (1974) p. 91-147.

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Table 3. SYNOPTIC DESCRIPTION OF ARCTIC STREAM TYPES.

	MOUNTAIN STREAMS	TUNDRA STREAMS	SPRING STREAMS
Origin	Brooks Mountain Province	Foothills and Coastal Province	Brooks Mountain and Foothills Province
Size	Largest in area	Moderate	Small to moderate
Temperature	Usually less than 10°C	May exceed 16°C	Usually 3 to 7°C
Flow:			
Surface	5 months, late May to mid-Oct.	Normally late May to mid-September	Minimal
Groundwater	Minimal	None	Perennial
Fish Species	Arctic char, grayling, other	Mostly spawning and rearing; grayling	Spawning, over-wintering and rearing; Arctic char, grayling, other
Benthic Density	Low (100 organisms/m^2)	Intermediate	High (10,000 organisms/m^2)

Source: Craig and McCart, (1975a).

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Table 4. SELECTED DATA ON MAJOR RIVER SYSTEMS OF ARCTIC ALASKA EAST OF AND INCLUDING THE COLVILLE RIVER. (Selkregg, 1975).

Name	Tributary to	Drainage Area in Sq. Mi.	Length of Main Stream Miles
Colville	Arctic Ocean	24,000	428
Kuparuk	Arctic Ocean	3,659	183
Toolik	Kuparuk	1,181	101
Sagavanirktok	Arctic Ocean	5,546	166
Kadleroshilik	Arctic Ocean	654	75
Shaviovik	Arctic Ocean	1,602	102
Staines	Arctic Ocean	28	21
Canning	Arctic Ocean	2,256	117
Tamayariak	Arctic Ocean	337	37
Katakturuk	Arctic Ocean	281	42
Sadlerochit	Arctic Ocean	761	70
Hulahula	Arctic Ocean	781	87
Okpilak	Arctic Ocean	428	70
Jago	Arctic Ocean	999	79
Okerokovik	Jago River	293	33
Aichilik	Arctic Ocean	238	39
Kalokut	Arctic Ocean	75	20
Kongakut	Arctic Ocean	1,579	103
Turner River	Arctic Ocean	67	11
Clarence	Arctic Ocean	174	31

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Table 5. ICE THICKNESS AND FLOW OBSERVATIONS FROM STREAMS AT PROPOSED ARCTIC GAS PIPELINE CROSSINGS. All milepost designations are Arctic Gas proposed alignment. (Ward & Craig, 1974; Arctic Gas, 1974).

River	Location of Observation	Date of Observation	Ice Depth (feet)	Water Present	Flow (feet/second)
Sagavanirktok	2 mi N PLC	11/06/73	1.5	Yes	1.1
	PLC MP 8.5	04/18/73	1.0 - 1.6	No	0
Kadleroshilik	PLC MP 27.5	11/04/73	2.0	No	0
	PLC MP 27.5	04/19/73	2.0 - 2.9	No	0
Shaviovik	PLC MP 36.5	04/18/73	1.0 - 2.0	No	0
Kavik	PLC MP 49.5	11/31/73	1.4 - 1.5	No	0
Unnamed tributary to	PLC MP 48	11/05/73	0	No	0
Kavik River		05/26/73	0	No	0
	PLC MP 58.5	11/07/73	0	No	0
Canning	PLC MP 63	11/05/73	not recorded	No	0
	Approx. 3 mi N PLC	11/05/73	1.0 - 1.6	No	0
Tamayariak	PLC MP 82.5	11/07/73	0	Yes	1.5
		05/26/73	0.7 - 1.1	No	0
	1 mi S PLC	11/07/73	0	No	0
Katakturuk	PLC MP 87.5	11/07/73	0	No	0
Sadlerochit Springs	PLC MP 113	11/07/73	0	Yes	2.5
Sadlerochit River	PLC MP 114	11/07/73	0	No	0
Hulahula	PLC MP 117.5	11/07/73	0	No	0
Okpilak	PLC MP 125	11/07/73	0	No	0
Jago	PLC MP 131.5	11/07/73	0.8	No	0
Okerokovik Springs	PLC MP 139.4	11/07/73	0	Yes	0.3*
Niguanak	PLC MP 142	11/05/73	not recorded	No	0
Kogotpak	PLC MP 150	11/05/73	not recorded	No	0
Aichilik	PLC MP 151.5	11/07/73	2.2	No	0
Egaksrak	PLC MP 162.2	11/05/73	0	Yes	0.03
Ekaluakat	PLC MP 166	11/05/73	1.1 - 1.4	No	0
Kongakut	PLC MP 173	11/05/72	0	No	0
	PLC MP 173	11/05/73	0	Yes	"minimal"

Note: PLC = pipeline crossing. *AAG Sec. IIIB, Table IIIB-2.

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Table 6. WATER AND ICE DEPTH MEASUREMENTS OF LAKES IN THE BROOKS MOUNTAIN PROVINCE, NORTH SLOPE, ALASKA.

Name or I.D. No.	Location	Surface Area (acres)	Date	Depth (ft.) Water	Ice	Fish Present	Information Source
C-1	60°15'45", 145°58'	---	04/19/73	26	6	Yes	3
Porcupine Lake	68°47'15"N, 146°26'W	---	04/03/73	7*	5	Yes	3
Eagle Creek Lake - 1	69°23'45"N, 145°53'W	---	04/10/73	50	4	Yes	3
Big Lake - 1		---	---	135	4	Yes	3
CT-28	60°26'30"N, 146°00'30"W	---	04/12/73	41	3	Yes	3
Lake Peters*		---	06/08/52	164	4	Yes	2
Lake Schrader*		---	---	187	-	Yes	2
Itkillik Lake	68°25'N, 149°55'W	1,330	07/73	43	0	Yes	1
Elusive Lake	68°40'N, 148°30'W	920	07/73	55	0	Yes	1
Chandler Lake		3,100	07?73	58	0	Yes	1

* Probably not deepest point in lake.

1 - Furniss (1974)
2 - Hobbie (1973)
3 - Ward & Craig (1974)

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Table 7. ICE DEPTH MEASUREMENTS FOR A SHALLOW FRESH WATER LAKE ON THE COASTAL PLAIN PROVINCE APPROXIMATELY 1 MILE S. OF D.E.W. LINE STATION, BARTER ISLAND, ALASKA, 1966-1971.

		Ice Depth (Feet)					
	Year	1966	1967	1968	1969	1970	1971
Month	Day						
Oct.	3	---	---	---	---	0.8	---
	4	---	---	---	0.4	---	---
	10	---	---	---	---	1.0	---
	11	---	---	---	0.6	---	---
	14	---	0.8	---	---	---	---
	15	0.8	---	---	---	---	---
	17	---	---	---	---	1.1	---
	18	---	---	---	0.7	---	---
	21	---	0.9	---	---	---	---
	22	1.0	---	---	---	---	---
	24	---	---	---	---	1.3	---
	25	---	---	---	0.9	---	---
	28	---	1.0	---	---	---	1.2
	29	1.0	---	---	---	---	---
	31	---	---	---	---	1.6	---
Nov.	1	---	---	---	1.1	---	---
	2	---	---	0.5	---	---	---
	3	---	1.7	---	---	---	---
	5	1.8	---	---	---	---	1.3
	7	---	---	---	---	1.8	---
	8	---	---	---	1.4	---	---
	9	---	---	0.7	---	---	---
	11	---	2.2	---	---	---	---
	12	---	---	---	---	---	1.4
	13	2.2	---	---	---	---	---
	14	---	---	---	---	2.0	---
	15	---	---	---	1.8	---	---
	17	---	2.4	---	---	---	---
	18	2.5	---	1.0	---	---	---
	19	---	---	---	---	---	1.6
	21	---	---	---	---	2.0	---
	22	---	---	---	2.3	---	---
	23	---	---	1.4	---	---	---
	26	---	2.6	---	---	---	2.2
	27	2.8	---	---	---	---	---
	29	---	---	---	2.7	---	---
	30	---	---	2.0	---	2.3	---
Dec.	2	---	2.8	---	---	---	---
	3	3.0	---	---	---	---	2.2
	5	---	---	2.4	---	2.5	---
	6	---	---	---	3.0	---	---
	8	---	3.0	---	---	---	---
	10	3.1	---	---	---	---	2.7
	12	---	---	---	---	3.0	---
	13	---	---	---	3.3	---	---
	14	---	---	2.8	---	---	---
	16	---	3.8	---	---	---	---
	17	3.3	---	---	---	---	---
	19	---	---	3.3	---	3.5	---
	20	---	---	---	3.5	---	---
	23	---	3.9	---	---	---	---
	24	3.5	---	---	---	---	3.6
	26	---	---	---	---	3.8	---
	27	---	---	---	3.7	---	---
	28	---	---	3.7	---	---	---
	31	3.7	4.1	---	---	---	3.6

Sources: Billelo and Bates (1971, 1972, 1975).

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Table 8. ICE DEPTH MEASUREMENTS FOR IMIKPUK LAKE, A SHALLOW FRESH-WATER LAKE ON THE COASTAL PLAIN PROVINCE NEAR BARROW, ALASKA, 1966-1971.

		Ice Depth (Feet)					
	Year	1966	1967	1968	1969	1970	1971
Month	Day						
Oct.	15	0.5	---	---	---	---	---
	16	---	---	---	---	1.3	0.9
	17	---	---	0.6	---	1.2	---
	21	---	1.1	---	1.1	---	---
	22	0.8	---	---	---	---	---
	23	---	---	---	---	---	1.2
	25	---	---	---	1.2	---	---
	26	---	---	1.0	---	---	---
	28	---	1.3	---	---	---	---
	29	1.0	---	---	---	---	---
	30	---	---	---	---	---	1.5
	31	---	---	---	---	1.6	---
Nov.	1	---	---	---	1.7	---	---
	2	---	---	1.1	---	---	---
	4	---	1.4	---	---	---	---
	6	---	---	---	---	---	1.6
	7	1.4	---	---	---	1.9	---
	8	---	---	---	1.9	---	---
	9	---	---	1.4	---	---	---
	13	---	---	---	---	---	2.0
	14	1.6	---	---	---	---	---
	15	---	---	---	2.1	---	---
	16	---	---	1.5	---	---	---
	18	---	1.9	---	---	---	---
	19	1.7	---	---	---	---	---
	20	---	---	---	---	---	2.1
	21	---	---	---	---	2.2	---
	22	---	---	---	2.5	---	---
	23	---	---	1.9	---	---	---
	25	---	2.1	---	---	---	---
	27	---	---	---	---	---	2.3
	28	2.0	---	---	---	---	---
	29	---	---	---	2.7	---	---
	30	---	---	2.2	---	---	---
Dec.	2	---	2.3	---	---	---	---
	4	---	---	---	---	---	2.7
	5	---	---	---	---	2.9	---
	6	---	---	---	2.7	---	---
	7	---	---	2.4	---	---	---
	9	---	2.6	---	---	---	---
	10	2.3	---	---	---	---	---
	11	---	---	---	---	---	3.0
	12	---	---	---	---	3.0	---
	13	---	---	---	3.0	---	---
	14	---	---	2.9	---	---	---
	16	---	2.8	---	---	---	---
	17	2.6	---	---	---	---	---
	18	---	---	---	---	---	3.4
	19	---	---	---	---	3.2	---
	20	---	---	---	3.1	---	---
	21	---	---	3.1	---	---	---
	23	---	2.8	---	---	---	---
	24	2.0	---	---	---	---	---
	25	---	---	---	---	---	3.5
	26	---	---	---	---	3.3	---
	27	---	---	---	3.3	---	---
	28	---	---	3.4	---	---	---
	30	---	3.1	---	---	---	---
	31	3.1	---	---	---	---	---

Sources: Billelo and Bates (1971, 1972, 1975)

Table 9. NUMBER OF LAKES AND APPROXIMATE SURFACE AREA OF THOSE GREATER THAN 2,000 FEET LONG WITHIN 5 and 10 MILES OF THE PROPOSED EL PASO ROUTE, NORTH SLOPE, ALASKA.

	Within 5 Miles			Within 10 Miles		
Milepost	Total No. of Lakes	No.	Surface Acreage	Total No. of Lakes	No.	Surface Acreage
COASTAL PLAIN PROVINCE						
00- 10	140	104	14,326	223	150	19,984
10- 20	61	39	5,176	119	68	8,059
20- 30	26	19	1,495	61	47	4,598
30- 40	23	20	3,000	48	42	6,133
40- 50	49	42	7,327	90	71	11,397
50- 60	38	30	3,471	70	48	5,053
FOOTHILLS PROVINCE						
60- 70	4	2	425	25	11	1,157
70- 80	12	9	819	17	11	1,090
80- 90	15	10	707	20	12	840
90-100	33	15	973	45	19	1,157
100-110	23	14	753	44	22	1,111
110-120	28	7	338	52	19	1,454
120-130	36	14	988	60	30	2,166
MOUNTAIN PROVINCE						
130-140	22	11	1,654	30	14	1,900
140-150	13	4	328	13	4	328
150-160	1	1	51	2	1	51
160-170	0	0	0	1	0	0

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Witnesses: R. A. Furniss,
D. L. Ward

Table 10. NUMBER OF LAKES AND APPROXIMATE SURFACE AREA OF THOSE GREATER THAN 2,000 FEET LONG WITHIN 5 AND 10 MILES OF THE PROPOSED ARCTIC GAS ROUTE, NORTH SLOPE, ALASKA.

	Within 5 Miles			Within 10 Miles		
Milepost	Total No. of Lakes	No.	Surface Acreage	Total No. of Lakes	No.	Surface Acreage
00- 10	106	79	11,351	236	155	20,659
10- 20	65	40	4,117	121	69	6,401
20- 30	74	42	4,434	116	66	6,943
30- 40	49	30	3,333	99	54	6,077
40- 50	43	20	1,638	74	35	2,846
50- 60	46	22	1,167	59	27	1,618
60- 70	6	3	251	15	4	359
70- 80	3	0	0	18	6	292
80- 90	0	0	0	0	0	0
90-100	1	0	0	1	0	0
100-110	0	0	0	2	1	51
110-120	1	0	0	3	1	46
120-130	1	0	0	12	4	307
130-140	5	2	220	17	8	706
140-150	1	0	0	13	6	364
150-160	0	0	0	0	0	0
160-170	0	0	0	0	0	0
170-180	1	0	0	4	1	87
180-190	4	1	18	6	1	18
190-195	14	8	1,388	17	9	1,419

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Witnesses: R. A. Furniss,
D. L. Ward

Table 11. DEPTHS OF SOME POTENTIAL STANDING WATER SOURCES WITHIN TEN MILES EACH SIDE OF THE PROPOSED EL PASO ROUTE, NORTH SLOPE, ALASKA.

Name/No.	Location	Surface Acreage	Water Depth (ft.) Maximum	Water Depth (ft.) Mean	Fish Present	Information Source
COASTAL PLAIN PROVINCE						
ME-1	Prudhoe		6.6	--		1
ME-2	Prudhoe		6.6	--		1
ME-3	Prudhoe		8.2	--		1
ME-4	Prudhoe		11.5	--		1
"Oil Drum"	69°47'N, 148°55'W		5.0	--		5
FOOTHILLS PROVINCE						
Sagwon Lake	69°20'N, 148°35'W	400	14	--	Yes	5
Cache 1	69°17'N, 147°28'W	--	25	--	Yes	2
Island Lake	69°15'N, 148°58'W	470	12	6	Yes	3 & 4
Unnamed	69°02', 148°15'	200	87	36	Yes	3 & 4
Unnamed	69°01', 148°54'	300	20	8	Yes	3 & 4
Unnamed	68°50', 148°13'	300	33	19	Yes	3 & 4
Murphy (Toolik)	68°38', 149°35'	--	82	--	Yes	6
Campsite Lake	68°35', 149°13'	--	95	--	Yes	3
BROOKS MOUNTAIN PROVINCE						
Galbraith Lake	68°27'N, 149°20'W	1,540	25		Yes	3

1 - Sherman (1973).
2 - Edgington (1971).
3 - McCart, *et al*, (1972).
4 - Yoshihara (1973).
5 - Winslow and Roguski (1970).
6 - Brown (1975).

Table 12. WATER AND ICE DEPTH MEASUREMENTS OF STANDING WATER NEAR THE PROPOSED ARCTIC GAS ROUTE, NORTH SLOPE, ALASKA. (Ward & Craig, 1974).

COASTAL PLAIN PROVINCE					
I.D. Number	Location	Date	Depth (ft.) Water	Ice	Fish Present
No. 459	Approx. 2 mi. S MP 58 Between Sagavanirktok and Canning Rivers 69°54'N, 146°36'W	05/31/73	4	4	No
CT-1	11 mi. S MP 59 69°41'45"N, 146°21'W	---	15	-	Yes
CR-22-1	Approx. 1 mi. S MP 67 69°53'30", 146°20'	04/18/73	8	7-8	Yes

Table 13. RANKED DENSITIES AND BIOMASS (FROM GREATEST TO LEAST) OF BENTHIC INVERTEBRATES IN TWELVE STREAMS ON THE ARCTIC NORTH SLOPE, ALASKA.

		DENSITY	
Rank	Spring Streams	Foothills Streams	Mountain Streams
1	Echooka Spring		
2	Ribdon Spring		
3	Lupine Spring		
4		Section Cr. (upper)	
5		Kuparuk River	
6		Toolik River	
7		Happy Valley Creek	
8			Accomplishment Cr.
9			Ribdon River
10			Ribdon Tributary
11			Echooka River
12			Lupine River

		BIOMASS	
Rank	Spring Streams	Foothills Streams	Mountain Streams
1	Echooka Spring		
2		Kuparuk River	
3	Lupine Spring		
4	Ribdon Spring		
5		Toolik River	
6			Echooka River
7		Section Cr. (upper)	
8		Happy Valley Creek	
9			Accomplishment Cr.
10			Ribdon River
11			Lupine River
12			Ribdon Tributary

Source: McCart, *et al* (1972).

Table 14. SPRINGS LOCATED ALONG THE PROPOSED ARCTIC GAS ROUTE, NORTH SLOPE, ALASKA.

Spring Source	Fish Present	Comments
Shaviovik River	Grayling, Char	A single overwintering area is located approximately 15 miles south of MP 36.5.
Katakturuk River	--	No fish were seen or caught in these springs. Located 7-8 miles south of MP 87.5.
Sadlerochit Springs	Grayling, Char	Spring supports lush growth of aquatic vegetation. Benthic densities are high (3,200-10,000/m^2). Anadromous char were not caught. However, it is utilized as a juvenile char rearing ground, and possibly as spawning grounds for dwarf Arctic char.
Hulahula	Grayling, Char	Overwintering ground 2 miles south of crossing. Subsistence fishery for Barter Island natives.
Okerokovik	--	Although no fish were observed in November 1973, it is a possible overwintering site for fish.
Ekaluakat	Char	This river supports a large population of Arctic char. A spawning and overwintering area is located approximately 5 miles upstream of the crossing.
Kongakut	Char	The Kongakut River is probably one of the most important Arctic char streams in this region. Major spawning and overwintering areas are located 5-10 miles both upstream and downstream of the crossing.

Source: Ward and Craig (1974), pp. 91-148g.

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Witnesses: R. A. Furniss,
D. L. Ward

Table 15. DATES BETWEEN WHICH OVER-TUNDRA VEHICULAR TRAVEL ON STATE LANDS OF THE ARCTIC NORTH SLOPE HAS BEEN ALLOWED BY ALASKA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF LANDS. (Source: Chris Guinn, Alaska Department of Natural Resources).

Year	Date Authorizing Permit Issued	Date Authorizing Permit Terminated
1969/70		May 21
1970/71	Oct. 20	May 27
1971/72	Nov. 01	May 20
1972/73	Nov. 01	June 04
1973/74	Nov. 15	May 20
1974/75*	Nov. 18	May 30
1975/76	Nov. 01	

*Some types of vehicular travel were never authorized in 1974 due to inadequate snow cover on tundra during the entire winter.

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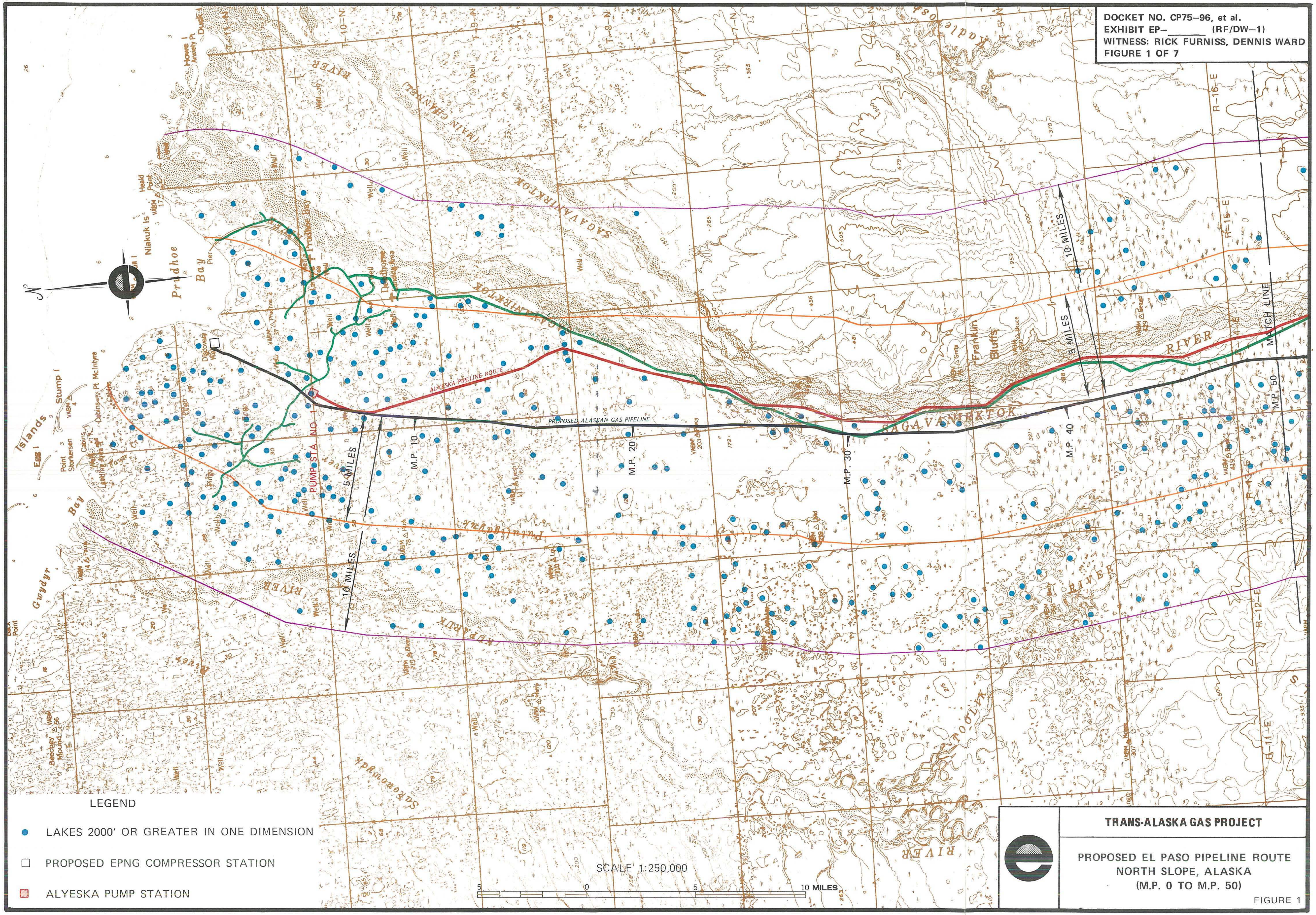
Witnesses: R. A. Furniss,
D. L. Ward

Table 16. ESTIMATED QUANTITIES OF WATER AVAILABLE FROM ALL SOURCES WITHIN FIVE MILES OF THE PROPOSED EL PASO ROUTE, NORTH SLOPE, ALASKA, LATE NOVEMBER.

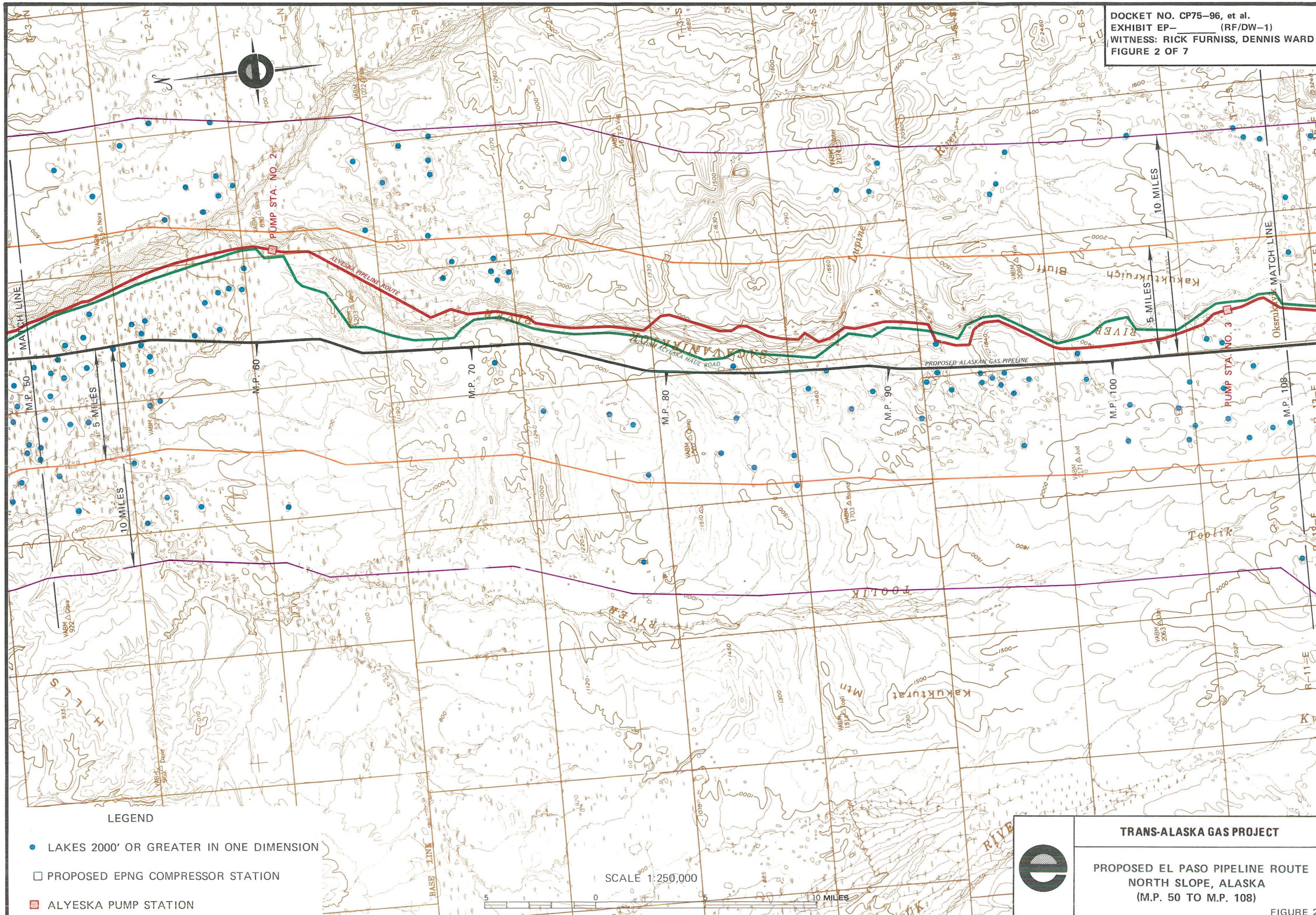
Milepost	Available Groundwater	Available Springs	Available Flowing Water	Available Standing Water (million gal.)
00 - 10	Very limited quantities; unreliable	0	Substantial quantities from Sagavanirktok until freeze-up	18,673
10 - 20	"	0	"	6,746
20 - 30	"	0	"	1,949
30 - 40	"	0	"	3,910
40 - 50	"	0	"	9,550
50 - 60	"	0	"	4,524
60 - 70	Alluvium, 24,000+ gpd	0	"	554
70 - 80	"	0	"	1,067
80 - 90	"	0	"	922
90 - 100	"	0	"	1,268
100 - 110	"	0	"	981
110 - 120	"	0	"	441
120 - 130	"	0	"	1,288
130 - 140	"	0	0	2,156
140 - 150	Alluvial gravel; 12-25,000+ gpd	1 spring 2 miles west 8-13,000+ gpd	Substantial quantities from Atigun until freeze-up	428
150 - 160	Possible 12-25,000+ gpd	0	0	66
160 - 170	0	0	0	0

Table 17. ESTIMATED QUANTITIES OF WATER AVAILABLE FROM ALL SOURCES WITHIN FIVE MILES OF THE PROPOSED ARCTIC GAS ROUTE, NORTH SLOPE, ALASKA, LATE NOVEMBER.

Milepost	Available Groundwater	Available Springs	Available Flowing Water	Available Standing Water (million gal.)
00 - 10	Very limited quantities; unreliable	0	Substantial quantities from Sagavanirktok until freeze-up	14,795
10 - 20	0	0	0	5,366
20 - 30	0	0	0	5,779
30 - 40	0	0	Shaviovik MP 31 until freeze-up	4,344
40 - 50	0	0	Kavik MP 49.5 until freeze-up	2,135
50 - 60	0	0	0	1,521
60 - 70	Very limited quantities; unreliable	0	Canning MP 62.5 substantial until freeze-up	327
70 - 80	0	0	0	0
80 - 90	0	7 to 8 miles south MP 87.5, flow not measured.	0	0
90 - 100	0	0	0	0
100 - 110	Possibly very limited quantities; unreliable	0	Hulahula MP 117.5 until freeze-up.	0
110 - 120	0	0	0	0
120 - 130	0	0	0	0
130 - 140	0	MP 139.4, spring flow approx. 79 gps.	Jago near MP 130 until freeze-up.	287
140 - 150	0	0	0	0
150 - 160	0	0	0	0
160 - 170	0	0	0	0
170 - 180	Possible very limited quantities; unreliable	0	Kongakut MP 173 until freeze-up	0
180 - 190	0	0	0	23
190 - 195	0	0	0	1,809


DOCKET NO. CP75–96, et al.
EXHIBIT EP–_______ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 1 OF 7
LEGEND
LAKES 2000' OR GREATER IN ONE DIMENSION
PROPOSED EPNG COMPRESSOR STATION
ALYESKA PUMP STATION
SCALE 1:250,000
10 MILES
TRANS-ALASKA GAS PROJECT
PROPOSED EL PASO PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 0 TO M.P. 50)
FIGURE 1
PROPOSED ALASKAN GAS PIPELINE
ALYESKA PIPELINE ROUTE
PUMP STA. NO. 1
M.P. 10
M.P. 20
M.P. 30
M.P. 40
M.P. 50
MATCH LINE
5 MILES
10 MILES
Prudhoe Bay
SAGAVANIRKTOK RIVER
KUPARUK RIVER
Franklin Bluffs
Gwydyr Bay
Stump I
Niakuk Is
Heald Point
Point Storkersen
Beechey Point
Sakonowyak
Putuligayuk
MAIN CHANNEL

DOCKET NO. CP75-96, et al.
EXHIBIT EP-________ (RF/DW-1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 2 OF 7

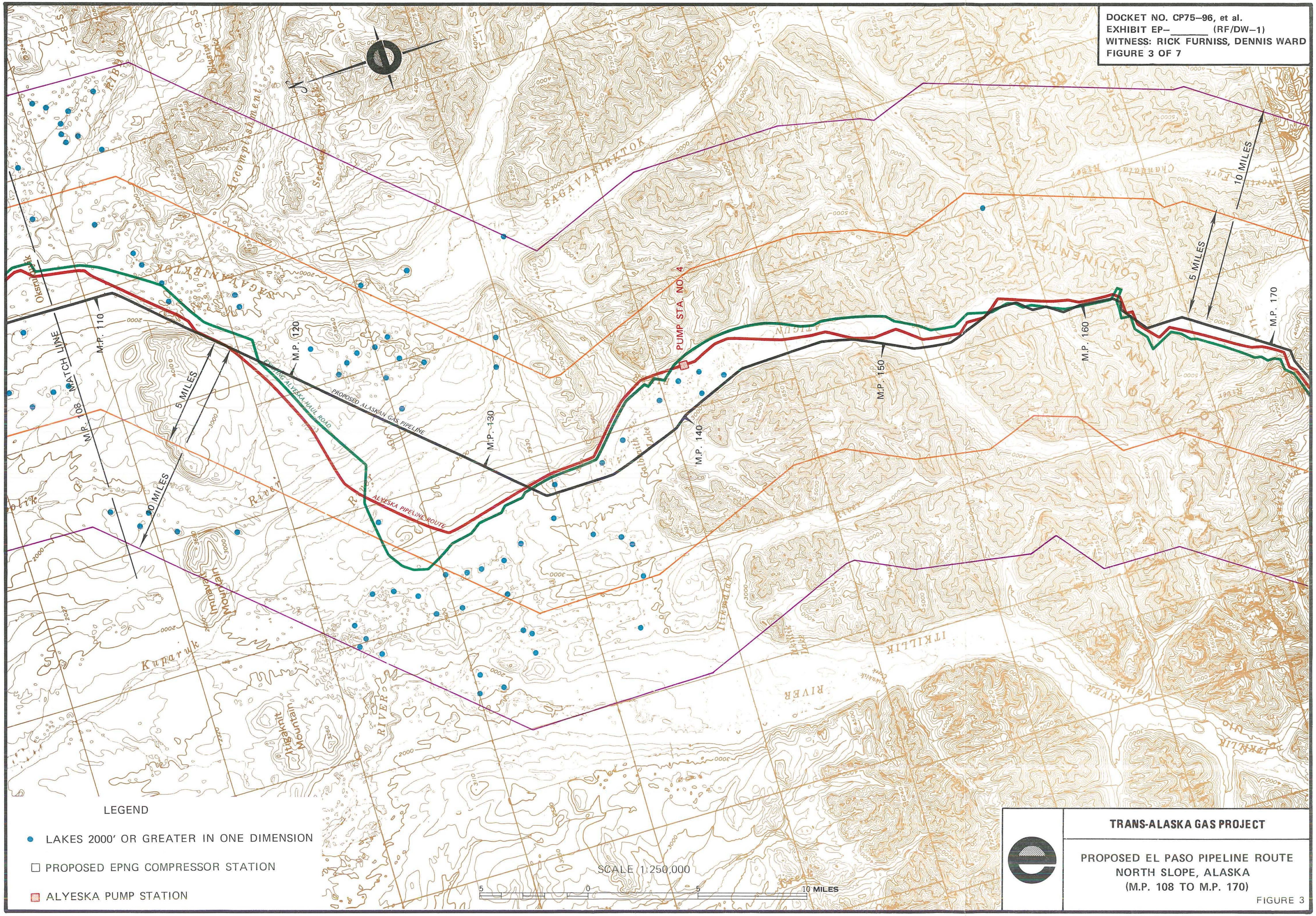


TRANS-ALASKA GAS PROJECT

PROPOSED EL PASO PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 50 TO M.P. 108)

FIGURE 2

DOCKET NO. CP75–96, et al.
EXHIBIT EP–______ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 3 OF 7



LEGEND

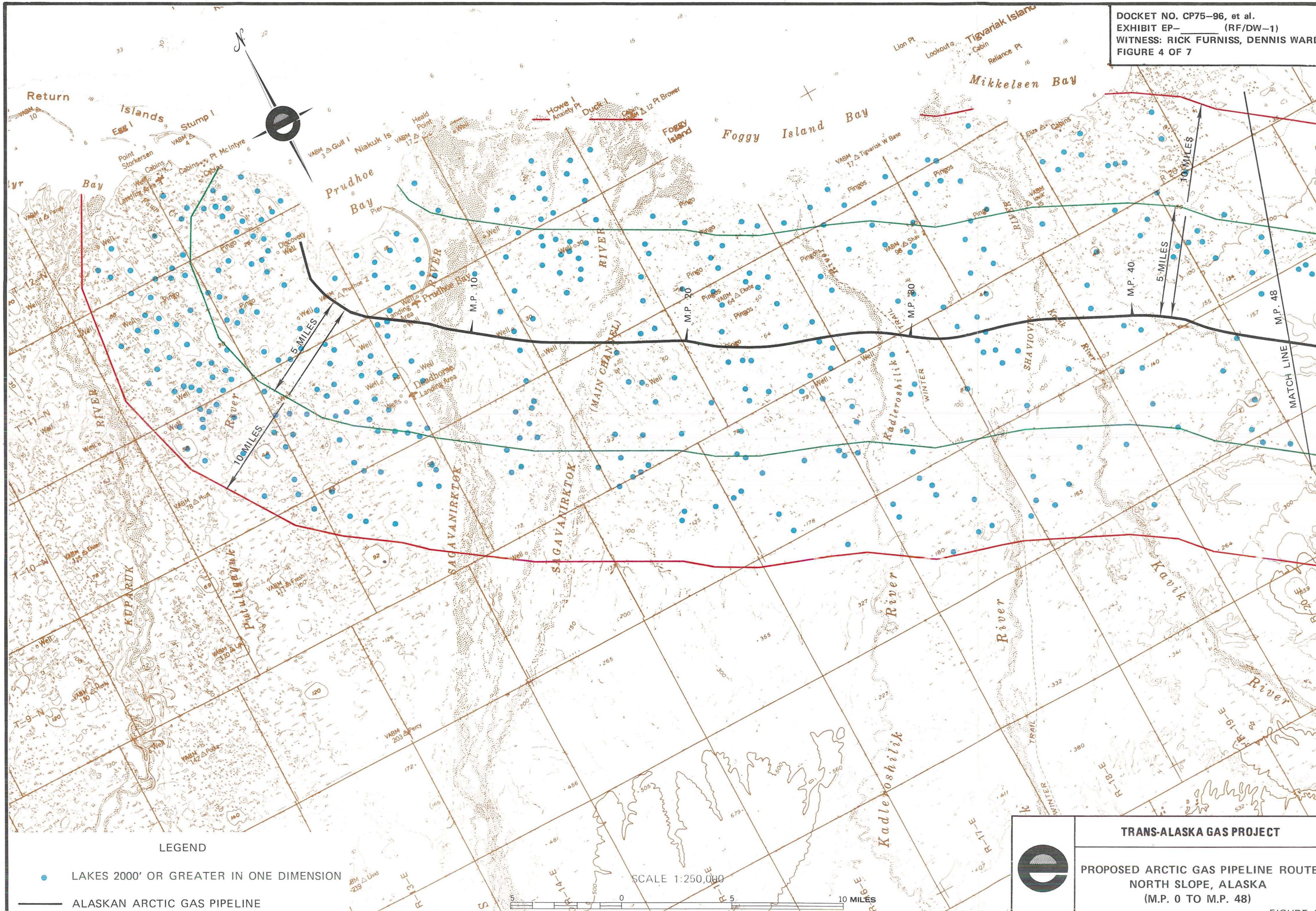
- LAKES 2000' OR GREATER IN ONE DIMENSION
- PROPOSED EPNG COMPRESSOR STATION
- ALYESKA PUMP STATION

TRANS-ALASKA GAS PROJECT

PROPOSED EL PASO PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 108 TO M.P. 170)

FIGURE 3

DOCKET NO. CP75–96, et al.
EXHIBIT EP–_______ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 4 OF 7



LEGEND

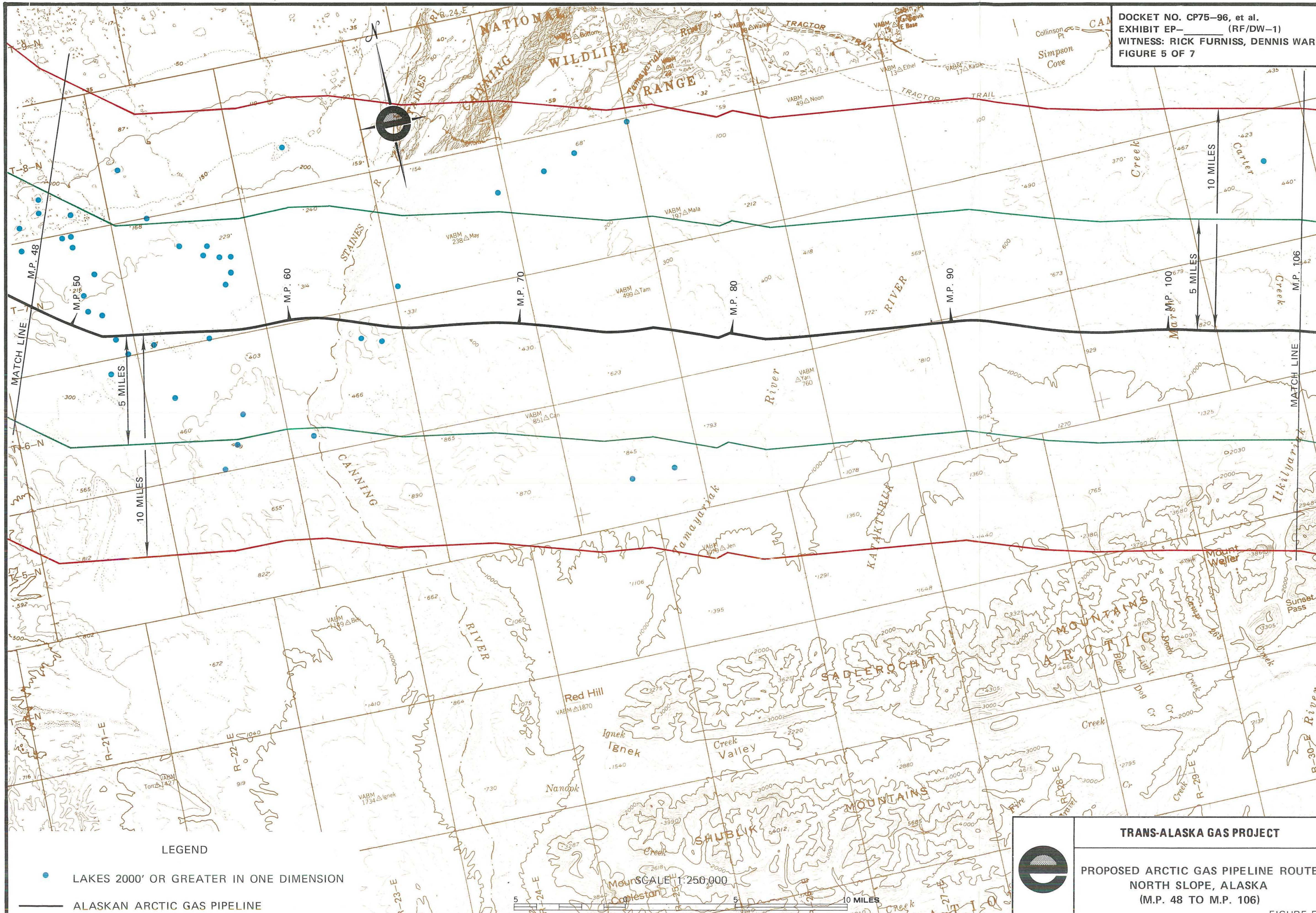
- LAKES 2000' OR GREATER IN ONE DIMENSION
- ALASKAN ARCTIC GAS PIPELINE

TRANS-ALASKA GAS PROJECT

PROPOSED ARCTIC GAS PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 0 TO M.P. 48)

FIGURE 4

DOCKET NO. CP75–96, et al.
EXHIBIT EP–_______ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 5 OF 7



TRANS-ALASKA GAS PROJECT

PROPOSED ARCTIC GAS PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 48 TO M.P. 106)

FIGURE 5


DOCKET NO. CP75–96, et al.
EXHIBIT EP–________ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 6 OF 7
TRANS-ALASKA GAS PROJECT
PROPOSED ARCTIC GAS PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 106 TO M.P. 163)
FIGURE 6
LEGEND
LAKES 2000' OR GREATER IN ONE DIMENSION
ALASKAN ARCTIC GAS PIPELINE
SCALE 1:250,000
5
0
5
10 MILES
MATCH LINE
M.P. 106
110 M.P.
120 M.P.
130 M.P.
140 M.P.
150 M.P.
160 M.P.
M.P. 163
5 MILES
10 MILES
T-7-N
T-6-N
T-3-N
T-2-N
R-31-E
R-34-E
R-35-E
R-36-E
R-37-E
R-38-E
JAGO
Okpilak River
Okerokovik River
Niguanak
Sikrelurak River
Kogotpak River
AICHILIK RIVER
EGAKSRAK
HULAHULA RIVER
SADLEROCHIT
Sadlerochit Spring
Kingak Hill
Akutoktak River
Okpirourak Creek
Angun River
Ekaluakat River
Nataroarok Cr
Old Woman Cr
Marie Mountain
Okpilak Lake
BASE LINE
ARCTIC NATIONAL WILDLIFE
VABM 495 Caribou
VABM 357 Willa
VABM 1273 Bitty
VABM 2537 Hula
N

DOCKET NO. CP75–96, et al.
EXHIBIT EP–_______ (RF/DW–1)
WITNESS: RICK FURNISS, DENNIS WARD
FIGURE 7 OF 7

TRANS-ALASKA GAS PROJECT

PROPOSED ARCTIC GAS PIPELINE ROUTE
NORTH SLOPE, ALASKA
(M.P. 163 TO M.P. 219)

FIGURE 7

Docket Nos. CP75-96, *et al.*
Exhibit EP-_____(RAF/DLW-1)
Witnesses: R. A. Furniss,
D. L. Ward

Appendix A-1. LIST OF FISH SPECIES KNOWN TO OCCUR ON THE NORTH SLOPE AND IN THE BEAUFORT SEA DRAINAGES.

Common Name	Scientific Name
Arctic char	*Salvelinus alpinus*
Grayling	*Thymallus arcticus*
Lake trout	*Salvelinus namaycush*
Round whitefish	*Prosopium cylindraceum*
Broad whitefish	*Coregonus nasus*
Humpback whitefish	*Coregonus pidschian*
Longnose sucker	*Catastomus catastomus*
Arctic cisco	*Coregonus autumnalis*
Least cisco	*Coregonus sardinella*
Four-horned sculpin	*Myoxocephalus quadricornis*
Burbot	*Lota lota*
Ninespine stickleback	*Pungitius pungitius*
Northern pike	*Esox lucius*
Arctic cod	*Boreogadus saida*
Slimy sculpin	*Cottus cognatus*
Pink salmon	*Oncorhynchus gorbuscha*
Chum salmon	*Oncorhynchus keta*
Arctic flounder	*Liopsetta glacialis*

Appendix A-2. INFORMATION AVAILABLE ON WATER SUPPLIES BY COMMUNITY, ARCTIC REGION.

Village, Location	Present Water Supply
Alaktak	Surface water during summer months
Anaktuvuk Pass	Surface water
Atkasook	River and melted snow
Atigaru Point	Lakes
Atigun	Lakes
Barrow	Lakes
Barter Island (Kaktovik)	Lakes
Bullen Point	Lakes
Camden Bay	Lake
Cape Lisburne	Gallery system (groundwater)
Cape Sabine	Lake
Deadhorse	Supplied by camp
Flaxman Island	Lake
Galbraith Lake	Two gallery wells constructed in 1974
Happy Valley	Gallery well constructed in 1974
Helmericks	Lake
Icy Cape	No data available
Icy Reef	Lake
Lonely	Stream or lake
Nuwuk	Lake
Nuiqsut	Surface water
Oliktok Point	Lakes
Point Lay	Lakes, river, rainwater
Point Hope	Dug wells in summer
Prudhoe Bay	River and lakes (gallery well silted up)
Return Islands	Lake
Sagwon	Surface water
Tangent Point	Lakes
Toolik	Surface water
Umiat	River in summer, surface water
Wainwright	Surface water and stream
Woods Camp	Surface water

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Witnesses: R. A. Furniss,
D. L. Ward

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Exhibit EP-_____(RAF/DLW-1)
Witnesses: R. A. Furniss,
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