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COMPARISON OF ACTUAL AND PREDICTED IMPACTS OF THE TRANS-ALASKA PIPELINE SYSTEM AND PRUDHOE BAY OILFIELDS ON THE NORTH SLOPE OF ALASKA

ARLIS
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Prepared by

U.S. Fish and Wildlife Service
Fairbanks Fish and Wildlife Enhancement Office
101 12th Avenue, Box 20
Fairbanks, Alaska 99701-6267

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ARLIS
Alaska Resources
Library & Information Services
Anchorage Alaska

DRAFT

Acronyms

We have largely eliminated the use of acronyms in the text, but several appear in citations and in the tables. Therefore, we are providing a list of commonly used acronyms and their meanings.

ADEC - Alaska Department of Environmental Conservation

ADF&G - Alaska Department of Fish and Game

ADNR - Alaska Department of Natural Resources

ADOT&PF - Alaska Department of Transportation and Public Facilities

AOGCC - Alaska Oil and Gas Conservation Commission

APO - Alaska Pipeline Office

ARCO - ARCO Alaska, Inc.

BLM - Bureau of Land Management

EIS - Environmental Impact Statement

EPA - United States Environmental Protection Agency

GAO - General Accounting Office

JFWAT - Joint State/Federal Fish and Wildlife Advisory Team

NPDES - National Pollutant Discharge Elimination System

SAPC - Standard Alaska Production Company

TAPS - Trans-Alaska Pipeline System

USACE - United States Army Corps of Engineers

USDI - United States Department of the Interior

USFWS - United States Fish and Wildlife Service

I. PURPOSE AND OBJECTIVES

This report is submitted in response to a request from Congressman George Miller, on behalf of the House Subcommittee on Water and Power Resources, to provide "an analysis which compares predictions about the development of the Prudhoe Bay Fields and the Trans-Alaska Pipeline System and what has transpired in terms of environmental effects and impacts on wildlife." We have addressed this question by summarizing some of the thousands of pages of unpublished data, published reports, and scientific papers on the impacts of these projects, and comparing this information with the predictions presented in the Final Environmental Impact Statement (EIS) on the Trans-Alaska Pipeline (Pipeline System) prepared by the U.S. Department of the Interior (USDI 1972). The EIS covers the pipeline, Haul Road, and Prudhoe Bay oilfields, and is the best comprehensive source of information on impact predictions for these projects. It is also a good representation of the level of understanding of the affected environment at that time. This comparison provides a qualitative, if not quantitative, indication of the predictive capabilities of the documents. The results should be relevant to the ongoing consideration of questions raised by the proposed exploration and development in the 1002 area of the Arctic National Wildlife Refuge.

II. SCOPE OF ANALYSIS

The predictions analyzed in this document are based on those portions of the EIS which address development on the North Slope of Alaska (i.e., that section of the pipeline extending north of the Brooks Range, and the oilfields of the Prudhoe Bay area). The pipeline south of the Brooks Range and the marine terminal at Valdez are not covered, since activities and analyses conducted in the Arctic region are most applicable to future development in the Arctic National Wildlife Refuge. Also not addressed are the extensive socioeconomic changes, related alterations in land use patterns and expansion of human access to areas outside of the Arctic, and numerous other indirect impacts generated in other regions by this massive construction project.

There has been considerable expansion of exploration and development in the Alaskan Arctic, both onshore and offshore, since construction of the Pipeline System and initial development of the Prudhoe Bay field. Some of the developments, such as the Kuparuk and Lisburne fields, were anticipated in the EIS, while others were not. Specifically, development of the Milne Point, and Endicott fields was not predicted by the EIS, but these are directly appurtenant to developments which were predicted. In addition, expected facilities within the Prudhoe Bay, Kuparuk, and Lisburne fields have been or are proposed to be significantly expanded by construction of secondary and tertiary recovery facilities, marine causeways, and the infrastructural development necessary to support such expansion. All of the above activities have been included in this analysis.

Physiographically, the scope of this review covers development on the "North Slope", or that part of the Alaskan Arctic north of the Brooks Range (Fig. 1). More specifically, it concentrates on the Arctic Coastal Plain to the north of the Brooks Range foothills. However, this region is neither physically nor biologically uniform, and the observed effects of development along the pipeline corridor and in the Prudhoe Bay area are not always readily extrapolated to other areas of the Arctic. This natural variation must be kept in mind when considering the physical and biological response of systems to human impacts.

The physical environment of the Arctic Coastal Plain varies considerably from east to west and north to south, and the kinds of facilities already in place within one physiographic subunit of the region will not necessarily be placed on identical terrain in the future. For example, the existing oilfields are confined almost exclusively to the flat, thaw-lake dotted portion of the coastal plain underlain by deep permafrost over marine and fluvial deposits In contrast, the eastern Arctic Coastal Plain lies in close proximity to the Brooks Range, and is characterized by stream-dissected rolling hills, a few deltaic features near the coast, and a relatively thin permafrost layer overlying bedrock. Meteorological conditions, such as summer rainfall, the amount and accumulation of winter snow, and wind speed and direction, also vary across this region, creating differing environments within which development impacts are or will be manifested.

This varying physical environment influences the biological features of the two areas; habitats, as reflected by vegetative cover, vary considerably from east to west. For example, the wet, seasonally flooded coastal plain and dominance of emergent vegetation around Prudhoe Bay contrasts sharply with the relatively well-drained wetlands and associated plant cover to the east. On the other hand, riparian woody vegetation, more abundant along rivers to the east, is relatively scarce in the west. These vegetation/habitat differences in turn affect the distribution and abundance of wildlife. As with physical environmental factors, biological differences have implications for development: facilities design, timing of activities, and the relative vulnerability of habitats and populations must all be considered when one attempts to assess or predict impacts.

III. BACKGROUND

To enable a better understanding of the basis for environmental oversight, the methods by which information has been gathered and reported, and how these have improved since preparation of the EIS, it is necessary to review the evolutionary history of environmental regulation and monitoring as it pertains to development of the Pipeline System and oilfields in the Prudhoe Bay area. It is important to recognize how regulatory involvement and information gathering have changed over the last 15 years, allowing us to "catch up" to some degree with the pace of development.

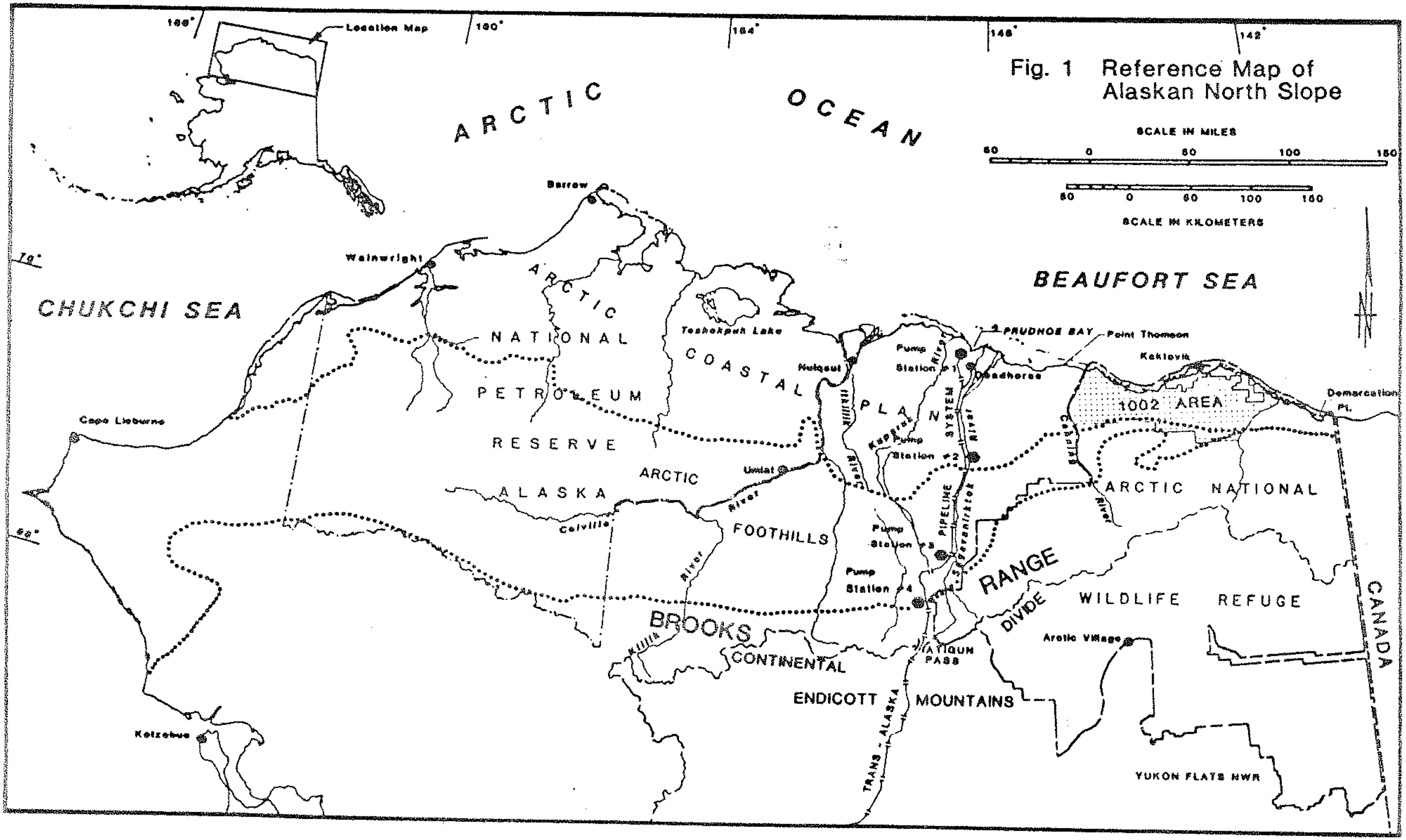

Fig. 1 Reference Map of Alaskan North Slope

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A. Pipeline Construction

Discovery of a world class oil reservoir at Prudhoe Bay in June of 1968 culminated two decades of oil exploration on Alaska's North Slope. In June of 1969, Atlantic Richfield, Exxon, and British Petroleum, principals in a newly created pipeline consortium, filed a formal application with the Bureau of Land Management of the Department of the Interior (Department) for a trans-Alaska pipeline right-of-way between Prudhoe Bay and Valdez, Alaska.

The pace of development associated with the Prudhoe Bay oil discovery and increasing concern for potential environmental impacts led environmental groups to obtain an injunction in April of 1970, against issuance of permits to proceed without full compliance with the Environmental Impact Statement (EIS) requirements of the recently enacted National Environmental Policy Act of 1969 (Act). Ultimately, the Department was required to prepare an EIS addressing the impacts associated with construction of the Pipeline System and Prudhoe Bay oilfields. In April of 1971, the Department issued a Draft EIS, and the Final EIS was released in March of 1972. In addition, Congressional legislation under the Minerals Leasing Act was necessary before Congress could declare the Final EIS adequate under the Act, issue the right-of-way permit, and authorize construction. This was accomplished in November of 1973 with passage of the Trans-Alaska Pipeline Authorization Act, which obviated the need for further review under the Act. Construction of the Haul Road was completed in 1974, and the pipeline in 1976, with oil flow commencing in 1977.

Construction delays due to both legal and engineering considerations provided an opportunity for State and Federal agencies to begin environmental studies and develop some guidelines for agency oversight. Ad hoc Federal/State environmental coordination began with creation of an informal Interagency Fish and Wildlife Team which shared information and initiated limited biological studies along the proposed route. Eventually, it was determined that a centralized entity was needed to assure pipeline integrity, review design changes, and monitor construction and its impact on fish and wildlife. In May of 1974, a cooperative agreement between State and Federal governments resulted in formation of the Joint Fish and Wildlife Advisory Team (Team). The Team consisted of biologists from the Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and the Bureau of Land Management. The Team was charged with design review, field monitoring, and advising the two pipeline surveillance agencies: the Federal Alaska Pipeline Office and the State Pipeline Coordinator's Office. Although it did not have a full range of environmental and engineering expertise, or any authority beyond that provided under State regulations, the Team was largely successful in minimizing site-specific impacts to fish and wildlife. The inadequacy of industry self-monitoring programs, and the frequency with which construction stipulations were not adhered to, forced the Team to concentrate on intensive field surveillance of existing problems, and precluded adequate follow-up monitoring (Morehouse et al. 1978).

Aside from the direct involvement of Team personnel in day-to-day pipeline construction activities, Federal regulatory oversight of environmental concerns was limited to occasional Corps of Engineers (Corps) permits related to activities in navigable waters. Under the Clean Water Act, the Corps' Section 404 program was being phased in nationally between 1974 and 1976. However, most activities in Alaska prior to 1976 were grandfathered, so it was determined that Section 404 would not apply to pipeline construction activities.

B. Oilfield Development

Although most of the Prudhoe Bay area has been developed in recent years, many facilities were in place long before pipeline construction. Between 1968 and 1971, 38 wells were drilled to explore and delineate the Sadlerochit Reservoir, and 66 miles of gravel roads, numerous pads, and three airstrips were constructed. Additional construction took place between 1971 and 1974.

Oversight by Federal and State resource agencies between 1971 and 1979 was limited by the regulatory and administrative processes available for agency involvement. Although there was some opportunity for the State to exercise its regulatory authority, this rarely occurred. Federal involvement was limited to review of occasional activities in navigable waters. Without agency involvement, initial development of the Prudhoe Bay oilfield was controlled by engineering decisions intended to maximize production and minimize cost. This resulted in significant impacts which were often avoided later when there was routine agency review of such activities (USFWS unpbl.).

In 1979, legal action by environmental groups and pressure by Federal agencies compelled the Corps to exert Section 404 jurisdiction over North Slope wetlands. In March of that year, the Corps issued two general permits covering two types of oilfield construction activities. The general permits had standardized stipulations and required applicants to obtain written authorization prior to commencement of work. These original Corps general permits were further modified into permitting processes based on the scope of proposed work: the Abbreviated Processing Procedure and individual, full-review Section 404 permits.

C. Monitoring of Operations

With the startup of the pipeline, the Joint Fish and Wildlife Advisory Team was disbanded, and Federal responsibility passed from the Alaska Pipeline Office to the Bureau of Land Management. During the early 1980's, Federal agencies began routine monitoring of activities conducted in North Slope wetlands, including virtually all oilfield activities. A process evolved which provided for formal review of development proposals. Using a wetland classification system that identified priority wetland types based on their value to migratory birds (Bergman et al. 1977), the Fish and Wildlife Service (Service) provided recommendations that mitigated some wetland and wildlife impacts through siting, timing, and other considerations. State resource agency involvement in the regulatory process existed at the outset, although conflicting positions on some issues often developed (P. Bateman, ADEC, pers. comm.). The Alaska Division of Governmental Coordination established consolidated State review of Corps permits and consistency determinations under the Alaska Coastal Zone Management Plan. Using Federal coastal zone management funds, the State has been able to develop a more intensive and well-coordinated program of oilfield monitoring.

At present, seven Federal and State resource agencies routinely participate in the regulatory process, there is a more thorough review of proposals, and project designs are more likely to include state-of-the-art mitigation measures. As monitoring of permitted activities has become more effective, greater compliance has been achieved. However, in spite of this highly structured process, there are still many projects each year which, due to a lack of planning or advance notice, receive hurried and often inadequate review.

Numerous self-monitoring programs, often required by the Corps and subject to agency review, have addressed resource concerns in the oilfields. These have included studies on the effects of road construction and traffic on wetland habitats and bird use patterns, the impacts of various oilfield activities on breeding waterfowl, development of revegetation techniques applicable to North Slope wetlands, and assessment of the effects of gravel causeways on the marine environment. In addition, the Environmental Protection Agency and the Alaska Department of Environmental Conservation have required National Ambient Air Quality monitoring programs, wastewater discharge monitoring, and related studies.

In addition to industry-funded studies required by permits, several major studies have been sponsored by the Department of Energy and National Science Foundation (Walker 1986a,b; 1987a,b) to evaluate surface alterations and their impacts on biological systems. The Service has also undertaken a series of contaminant studies related to reserve pit fluid discharges into wetlands and resulting impacts on water quality, sediments, and the biota (West and Snyder-Conn 1987; Woodward, in press; USFWS unpbl.). Other agencies have conducted more limited water quality studies. Many of these studies have suffered from a lack of adequate baseline data; in its place, control sites have been selected or models used to approximate pre-development conditions. This approach is limited by the degree of comparability of control sites within a study area and the adequacy of model assumptions. Furthermore, it has been difficult to identify causal relationships after the fact in areas affected by multiple disturbances. These uncertainties have often preserved deniability by the responsible parties.

IV. COMPARATIVE ANALYSIS

The following sections provide comparisons of facilities (predicted vs. actual) and impacts (predicted vs. actual). The analyses of facilities development and resource impacts have been separated since, in many instances, differences between predicted and actual effects are directly related to changes in the scale or design of facilities made after preparation of the EIS. The information is presented largely in tabular form to allow a more comprehensive presentation of detail and to facilitate quick reference.

A. Facilities Development

Pipeline System

In terms of the numbers of facilities and their land requirements, the Pipeline System was constructed largely as outlined in the Impact Statement. However, few predictions were specific to the North Slope section. It should also be mentioned that some design modifications were made later, when more specific engineering information was available (Morehouse et al. 1978).

The Pipeline System extends approximately 800 miles from Pump Station 1 to the Valdez Marine Terminal. The average corridor width of 2.5 miles includes the Haul Road. The North Slope segment is 145 miles, or 18% of the total Pipeline System length. The pipeline consists of 12 pump stations, 422 miles of above-ground pipeline, 345 miles of buried pipe, and 32 miles of above- and below-ground river and stream crossings (Morehouse et al. 1978). The Haul Road includes 20 permanent bridges, 1000 culverts and 135 material sites (Walker et al. 1987a). The Pipeline System was predicted to cover 39,215 acres, although the actual coverage was 33,500 acres (Pamplin 1979). However, since the estimates in the Impact Statement were based on total rights-of-way requirements, rather than actual land requirements, the actual losses exceeded the predicted losses by 935 acres (Pamplin 1979). Furthermore, while the 135 material sites needed for the section north of the Yukon were fewer than the 167 predicted, the overall acreage required was significantly higher (Table 1). For the entire development, including the section on the North Slope, material sites required the most land.

As mentioned above, certain design features were modified significantly after preparation of the Impact Statement. Permafrost limited the proportion of the North Slope section which could be buried, while requirements for free movement of large mammals necessitated a change from gravel berm-supported to pile-supported above-ground sections. Other deviations from the anticipated design resulted in both consolidation of the pipeline and Haul Road rights-of-way in some areas (e.g., Toolik and Galbraith Lake), and greater separation of the two in others (e.g., along the Sagavanirktok River).

Table 1. Summary of predicted and actual land use and facility requirements for Trans-Alaska Pipeline System (shown in acres).

Type of Use	Predicted[a] Entire project[c]	Actual[b] Entire project	Actual[b] North Slope only[d]
Haul road	8780[e]	4000[f]	1478
Pipeline (work pad and cleared area)	14065	10800	1949
Access roads	2770	1250	344
Camps	1190	800	148
Pump stations	703	610	121
Material sites	5760	12200	6528
Disposal sites	NP	715	49
Spur dikes	NP	400	16
Miscellaneous[g]	5037	825	267
Valdez marine terminal	910	1900	—
Total	39215	33500	10900

[a]From Trans-Alaska Pipeline System EIS. NP means facilities not predicted.
[b]From Pamplin (1979). Does not include construction since 1979.
[c]North Slope area not broken out separately in EIS.
[d]Construction section 6 (Pump Station #1 to Pump Station #4).
[e]Based on 200-ft permanent rights-of-way; not estimates of direct surface use.
[f]Direct surface impacts within 200-ft rights-of-way.
[g]Predicted includes communications sites, airfields and material storage sites. Actual includes airfields, staging areas, guidebanks, unidentified impacted areas and the Valdez marine terminal facilities located on uplands.

Oilfields

Oilfield development in the Prudhoe Bay area extends over approximately 800 square miles, a larger geographic area than the 550 square miles predicted in the Impact Statement (Fig. 2). The five reservoirs in production include three that were predicted (Prudhoe Bay, Kuparuk, and Lisburne), plus the more recent Milne Point and Endicott fields. Much of the Kuparuk and Endicott oilfield areas extend beyond the predicted limits of oilfield development.

The number of oilfield facilities and the land they covered exceeded predictions (Fig. 3, Table 2). The total area of gravel fill and extraction was 60% greater than expected, while gravel requirements surpassed predictions by 400%, necessitating expansion of gravel mining from the planned floodplain sites on the Sagavanirktok, Putuligayuk, and Kuparuk Rivers to several large gravel pits on tundra sites. The major reason for this discrepancy was that the acreage required for pads was more than three times what was expected, since individual pads averaged twice the predicted size. Nearly twice as many exploratory, delineation, and production wells were drilled and, while gathering centers were consolidated, they required larger pads. Larger pads were also required for storage pads, camps, and airfields. Finally, total road miles exceeded expectations by approximately 30%.

The most significant unpredicted facility type was the contractor service area. Many such facilities were constructed in Deadhorse, as well as at Frontier Camp and Service City (Table 2). In the Kuparuk field, a second concentrated support area was constructed (the Kuparuk Industrial Center). Other facilities not addressed in the Impact Statement included sewage and solid waste disposal sites, reserve pits, oily waste pits, docks, causeways, and seawater treatment plants.

With the development of these existing facilities, future expansion and development of new fields is assured. Development of the shallow West Sak field, which overlies much of the Kuparuk and Milne Point fields, will require closer well spacing, and therefore more pads, roads, and pipelines. Expansion into adjacent Gwydyr Bay, the Colville Delta, Seal Island (offshore), and Pt. Thomson is anticipated, since the State has unitized these fields. Thus far, nearly 4 million acres of the North Slope have been leased by the State, and this area will be doubled when proposed lease sales are added (ADNR 1987). Offshore, in the Beaufort Sea, the State has leased nearly 1 million acres, while nearly 2 million acres have been leased on the Federal Outer Continental Shelf. Exploration of these areas is continuing.

B. Resource Impacts

This section compares predicted and actual impacts of the Pipeline System and Prudhoe Bay oilfields, using the Final EIS for the overall development as a basis for comparison. However, there are limitations on

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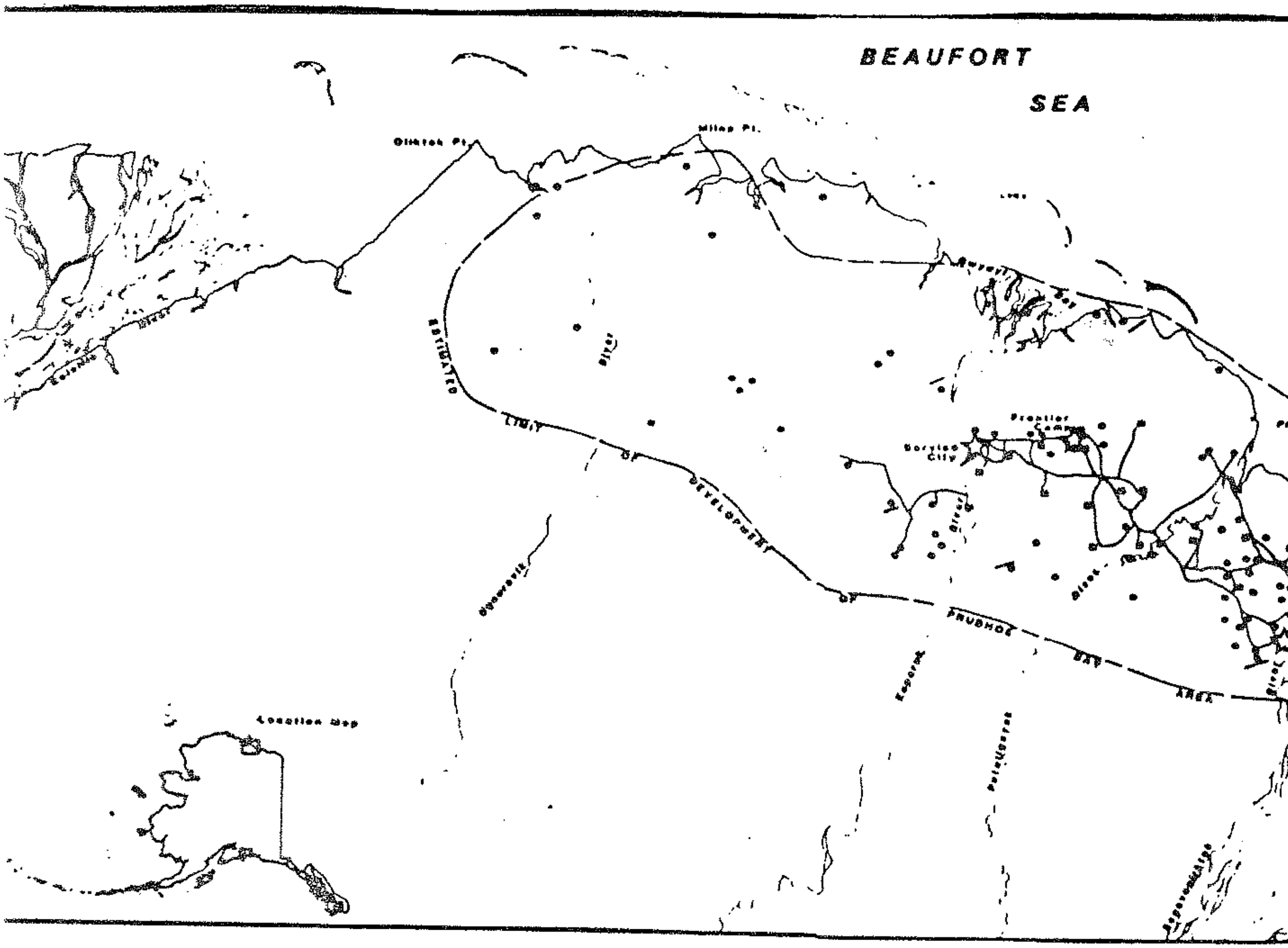

Fig. 2. Existing and predicted extent of Prudhoe Bay area oil field development at time of EIS (1972)

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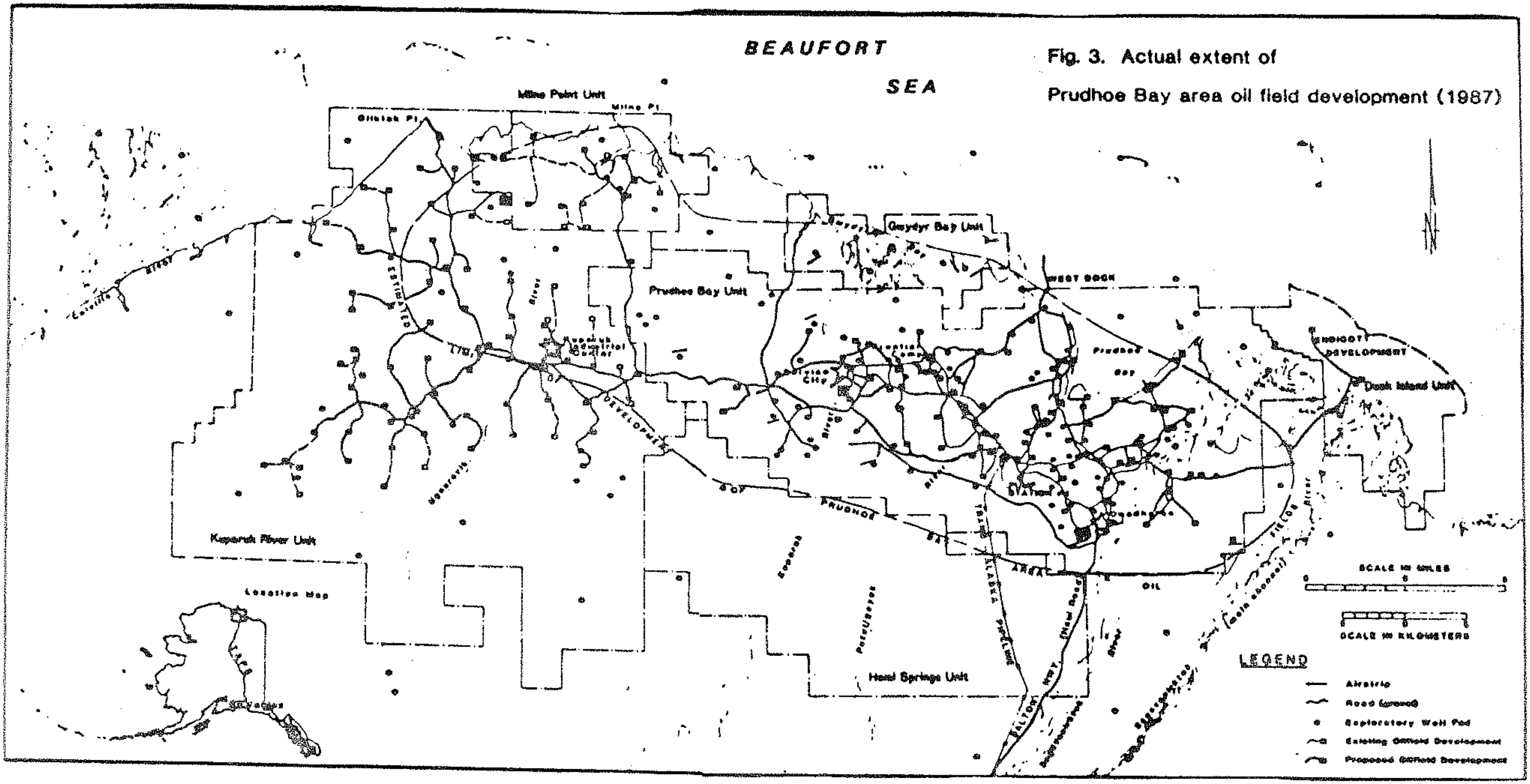

Fig. 3. Actual extent of Prudhoe Bay area oil field development (1987)

Table 2. Summary of predicted and actual land use and facility requirements for Prudhoe Bay oilfield. (NP indicates facilities not predicted in Trans-Alaska Pipeline System EIS; NQ means not quantified.)

Type of use	Predicted: Prudhoe Bay[a]	Actual: All Oil fields[b]	Actual: Prudhoe Bay Unit	Actual: Lisburne	Actual: Kuparuk[c]	Actual: Milne Point[c]	Actual: Endicott[c]
All pads[d] (acres)	2155	6815	4333	230	2090(429)	147 (7)	15
Roads[e] (miles)	250	630	225	15	145 (25)	35(15)	10
(acres)	2121	2500	1267	70	850(146)	203(83)	110
Production drill pads (no.)	99	112	36	5	58 (17)	13 (5)	—[f]
(acres)	1535	3009	1900	175	1605(429)	117 (7)	—[f]
Exploratory drill pads[g] (no.)	38	61	42[h]	—	18	1	—[f]
(acres)	190	305	210[h]	—	90	5	—[f]
Wells (no.)	700	1319	828	37	305	29	120(100)
Gathering centers[i] (no.)	31	16	10	2	3	1	1
(acres)	150	805	500	55	220	30	—[f]
Camps (no.)	3	11[j]	7[k]	—	2[k]	1	1
(acres)	180	225[j]	225[k]	—	—[m]	—[m]	—[f]
Storage pads (no.)	10	16[j]	8	—	7	—	1
(acres)	100	285[j]	200[j]	—	70	—[m]	15
Airfields (no.)	8	12	10[p]	—	2	—	—
(acres)	185	725	685	—	40	—	—
Contractor service areas (no, leases)	NP	170	169[p]	—	1	—	—
(acres)	NP	1800	1735[p]	—	65	—	—
Seawater treatment plants (no.)	NP	3	1	—	1	—	1
Marine causeways/docks (no.)	NP	4	2	—	1	—	1
(acres)	NP	512	182	—	2	—	328
Pipelines[e] (miles)	377	520	63	—[q]	418	15	28
(acres)	2284	NQ	NQ	NQ	NQ	NQ	NQ
Material sites[r] (no.)	NQ	12	5	—	5	1	1
(acres)	NQ	1720	805	—	650	35	220
(million cu. yd. gravel)	15.5	60	NQ	NQ	NQ	NQ	NQ
Sewage disposal sites (no.)	NP	12	9	—	2	1	—
Solid waste disposal sites (no.)	NP	5	4	—	1	—	—
Oily waste pits (no.)	NP	7	6	—	1	—	—
Total (acres only)	6745	11473	5782	300	3592(575)	385(90)	673

[a]From Trans-Alaska Pipeline System EIS. Production of Prudhoe Bay, Kuparuk and Lisburne Reservoirs were included.
[b]Includes existing and proposed construction (permitted but not yet built and projects presently under review) in 5 oilfields. From Walker et al. (1986) for most of Prudhoe Bay (measured); Other areas estimated from USACE permits, ADNR (1987) and USFWS (unpbl.).
[c]Parentheses show the portion that is proposed additions.
[d]Includes drill pads, gathering centers, camps, storage pads, airfields, and contractor service areas located onshore.
[e]Pipeline construction pads considered as roads; peat roads not included.
[f]Located on artificial offshore production islands, included under marine causeways/docks.
[g]Includes test/delineation wells; does not include offshore wells.
[h]Includes pads in Lisburne and Endicott areas.
[i]Includes power stations, gas injection and crude oil topping plants.
[j]Does not include Deadhorse facilities which are listed under contractor service areas.
[k]Includes Frontier Camp and Service City (Prudhoe Bay) and Kuparuk Industrial Center; acreage listed in contractor service areas.
[m]Facilities consolidated with gathering centers; acreages listed with gathering centers.
[n]Includes 7 exploratory airstrips averaging 5 acres each.
[p]98 ADNR leases, average 15 acres each (ADNR, pers. comm.); 71 ADOT&PF leases, average 3.7 acres each (ADOT&PF, pers. comm.).
[q]Lisburne included with Prudhoe Bay.
[r]Includes excavation and overburden placement. Some removal areas in river floodplains not included.

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such a comparison, particularly for the Pipeline System, which must be taken into account when analyzing this information:

- Prior to construction, pre-project baseline information on fish, wildlife, air, and water resources of the affected area, particularly on the North Slope, was limited and qualitative in nature.

- Predictions made by the EIS were also very general and largely qualitative, reflecting the lack of specific information on the resources and environment of the region and technical uncertainties associated with such a massive construction project (Morehouse et al. 1978).

- Comparison is further limited by the lack of followup information gathered during and after construction (GAO 1981), since biological monitoring was reactive and tended to focus on site-specific correction of recurring environmental problems. There were too few personnel, too little time, and not much emphasis placed on quantification of observed impacts or gathering of detailed ecological data.

- Generalizations of actual impacts for purposes of comparison tend to mask the tremendous variability of site-specific effects related to regional topographic and biological variability, the variety of engineering practices applied, and the duration of impacts.

- There were extreme differences in training or points of view of the numerous observers and practitioners, with a concomitant lack of coordination in reporting and responding to problems, so there is no single standardized data base which can be readily summarized.

- Due largely to a lack of funding, much of the intensive monitoring conducted during and immediately after construction has been curtailed, preventing a comprehensive assessment of long-term impacts. Since many effects may only be assessed over the long term (e.g., contaminants, revegetation, wildlife population responses), this is a serious shortcoming in our knowledge of actual impacts.

Nearly all of the limitations described above also extend to development of the Prudhoe Bay Oilfield. Little baseline information was available for this area, and the U.S. Army Corps of Engineers did not extend their jurisdiction under the Clean Water Act to the North Slope until 1980, so there was little monitoring of development at Prudhoe Bay by regulatory agencies prior to this time. Thus, more than a decade of development activity had occurred in the area prior to initiation of environmental monitoring, and the severity of impacts could and continues to be estimated only through extrapolation. Furthermore, oilfield monitoring studies have been largely project-specific, and have tended to describe impacts in isolation from one another. Such methods may significantly underestimate actual losses. As for the Pipeline System, monitoring conducted in the Prudhoe Bay area has concentrated on compliance with environmental regulations, rather than on documenting environmental effects.

One important topic that was not addressed in the EIS, and continues to elude scrutiny, is the issue of long-term, cumulative impacts. The sheer size and scope of the developments, and the complexity of ecological systems, both justify and hinder such an analysis. Assessment of cumulative impacts is required under the National Environmental Policy Act of 1969 (40 CFR, Part 1508.25(b)(7)), which states that impacts which may be individually insignificant, but significant when considered together, must be addressed. Implicit in this requirement is an understanding that the ultimate effect of many actions may exceed the sum of individual impacts, and that the effects may also be synergistic. Construction of several causeways in the marine environment is a good example of this kind of impact. In addition, when considering cumulative impacts it is necessary to anticipate the extent of development which may be stimulated by the proposed action. Development of the Pipeline System and Prudhoe Bay field made it possible to expand production to the Kuparuk and Lisburne fields, which was anticipated in the EIS, but they in turn allowed expansion to adjacent reservoirs, such as Milne Point and Endicott, which would not have been feasible without the Prudhoe Bay infrastructure. These are now making it possible to develop finds further offshore, and so on. Ultimately, development of the Arctic National Wildlife Refuge will be made possible by the presence of Prudhoe Bay and the Pipeline System.

Finally, when comparing the predicted and actual impacts of existing developments, it is necessary to consider the effect of mitigative measures applied during or after construction which may have served to reduce the net observed impacts of these projects. Most of the predictions stated in the EIS did not quantify potential reduction of impacts through avoidance, minimization, or replacement of resource values through design modifications or site rehabilitation. While many of these actions had little or no effect on the outcome, there was some net reduction of losses achieved, and it is therefore useful to indicate in this tabulation where mitigative measures have been applied and assess their degree of success. It is also important to note that the mitigative measures (e.g., stipulations or corrective actions) developed for the projects were not uniformly applied or enforced, that these measures were based on the same limited information relied upon in the EIS, and that compliance enforcement tended to focus on those problems which were most visible. Unfortunately, follow-up studies on the effectiveness of the various mitigative strategies employed has also been limited. Therefore, in assessing the relative success of mitigation measures, we have relied heavily upon the combined experience and observations of technical personnel both within the Fish and Wildlife Service and other resource agencies.

Using the various EIS predictions for each category of resources as a basis for comparison, the following table summarizes information gathered on the actual impacts to these resources and provides an assessment of the degree to which mitigative efforts have affected the outcome.

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
emissions at pump stations	-emissions of 115 lbs/hr hydrocarbons at pump stations with topping units and 15 lbs/hr at other stations -air quality standards for SO_2 not exceeded north of the Brooks Range	-no monitoring of hydrocarbons emission at North Slope pump stations; possible emission excesses due to recent unplanned use of pipeline to deliver 50,000 barrel/day natural gas liquids (ADEC unpbl.) -NO_2 emission levels at Pump Station 2 within performance standards (EPA unpbl.) -Alyeska modeling studies show probable compliance with NO_x, CO, or SO_2 standards at pump stations (EPA unpbl.)	-use of natural gas for fuel for all North Slope pump stations reduced gaseous emissions -installation of full-capacity vapor recovery system at Pump Station 1 (J. Coulte, ADEC, pers. comm.)
particulate emissions	-low probability of measurable particulates	-no monitoring of total suspended particulates at pump stations or elsewhere along TAPS	-none
dust	-unquantified dust conditions predicted	-serious impairment to visibility (M. Tinker, ADOT&PF, pers. comm.) -dust shadow to 1000 m on Haul Road (Everett 1980) -early snow melt 30-100 m -higher pH, conductivity, alkalinity in soil and water (Werbe 1980)	-road watering, road oiling ineffective, insufficient frequ[illegible] -about 1/3 of Haul Road surface replaced with crushed gravel, reducing dust (M. Tinker, ADOT&[illegible] pers. comm.) -dust pallitives effective when used recently
noise	-74 dB predicted at 600ft from pump stations, effects unknown	-no noise measurements available for pump stations or elsewhere along TAPS; no violations reported from 1985-1987 (Nathan Tibbs, Industrial Hygenist, Alaska Dept. of Labor, pers. comm.)	-none
blasting	-blasting impact on biota if conducted underwater	-temporary high dB impacts -increased sediment load in streams by blasting/moving dust, coarse material, boulders, ice -no documented impacts on aquatic biota (A. Ott, ADF&G, pers. comm.)	-timing restrictions on blasting (usually late winter) in streams/rivers effective in minimizing impacts to biota and in reducing water loss during use periods
aircraft	-helicopters and fixed-wing aircraft result in temporary noise/disturbance impacts	-as predicted, most impacts a function of aircraft altitude	-sensitive wildlife area advisories along TAPS, including timing restrictions incorporated into some construction plans -moderately effective in avoiding sensitive areas
ice fog	-some ice fog from return of wastewater to streams	-as predicted, impacts local, but sometimes hindered air operations (G.M. Zemansky, pers. comm.) -idling vehicles as additional source of ice fog (G.M. Zemansky, pers. comm.)	-none
pesticides	-not predicted	-unknown, but intensive spraying occurred at some camps (ADEC unpbl.)	-ADEC permits required for pesticide use -malathion use restricted at some camps -effectiveness unknown

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
emissions at oilfields	-measurable, but unknown emission rates at oilfield facilities	-compliance with all source performance and National Ambient Air Quality Standards for NO_x, SO_2, and CO at Prudhoe Bay and Kuparuk oilfields (Ives 1986) -one-hour O_3 standard violated during one quarter at Central Production Facility -State 6-9 hour non-methane hydrocarbon standard exceeded in 1979-80; standard now repealed (Ives 1986)	-monitoring requirements imposed by EPA and ADEC -numerous verbal warnings, notices of violation, and compliance orders issued to oil and service companies by the State (ADEC 1987a) -for large facilities, a Best Available Control Technology Analysis required, with State review and recommendations
particulate emissions	-none predicted for the onshore oilfields	-compliance with source performance and National ambient air quality standards on an annual basis (Ives 1986) -in 1979-80, violations of 24-hr standard noted at one of two pads (Ives 1986) -no recent data available for 24-hr standard compliance	-monitoring of flue gas combustion efficiency required by State to ensure adequate ash combustion -Best Available Control Technology analysis required for equipment selection
dust	-not predicted	-dust shadow to 3-4 km (Waterflood) in Prudhoe Bay from West Road (Troy 1986) -early snow melt 30-100 m on either side of some roads and pads (greater on west side) -delayed snow melt in some cases (Everett 1982, Klinger et al. 1983)	-road watering, road oiling moderately effective, but caused oil slicks on adjacent tundra ponds in some cases (Smith 1982)
ice fog	-unquantified ice fog predicted from wastewater return and ground water interception	-localized ice fog around most facilities	-none

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
oil spills	-small spills or releases into streams and groundwater with local and very small effects on fish food organisms and primary productivity -massive spills would cover and affect large areas -maximum potential (worst case) TAPS spill limited to approximately 64,000 barrels (50,000 from pipeline rupture plus 14,000 barrels during valve closure); major spills from other sources unpredicted -general predicted impacts: *interference with respiration of aquatic organisms *coating and destruction of algae and other plankton *coating of lake beds and streams *destruction of benthic organisms *interference with spawning runs *tainting fish flavor *deoxygenation of waters -magnitude of impacts contingent on location and size of spill, weather, season, oil load, sediment load, effectiveness of containment and cleanup -unquantified adverse impacts on freshwater fishery resources	-minor spills frequent during construction, major spills less frequent (JFWAT unpbl., Kavanagh & Townsend 1977, Zemansky 1983) -accurate quantification not available on number of spills or quantities spilled (missing records and unreported spills, spill report discrepancies and unknown volumes spilled) -major spills at many construction camps, frequently from faulty fuel lines, continued undetected for long periods with unknown spill volume and unknown magnitude of contamination of aquatic resources (JFWAT unpbl., Zemansky 1983) -two oil spills in excess of 100,000 gallons due to ruptures/leaks from fuel oil pipelines at camps (ADEC unpbl.) -pipeline leaks for long periods before detection (e.g., Atigun Pass spill, 1979) -many spills involved fuel truck accidents (ADEC unpbl.) -biological and water quality impacts resulting from major spills not studied	-prohibition of oil discharge -requirements for reporting accidental discharge (immediate notification of authorities) -oil spill contingency plans required -oil spill cleanup materials required on hand -mitigation effectiveness limited by enforcement and compliance problems (Kavanagh & Townsend 1977, Zemansky 1983) -numerous requirements for oil pipeline integrity including welder qualification tests, lightning protection, remote shut-off valves and maintenance block valves, radiographic inspection, pressure testing, cathodic and other corrosion protection, internal pitting surveys to monitor crustal deformation, and installation slip meters -insufficient requirements for construction-related spills
icing	-increase natural icing activity and/or induce new icing sites -numerous icings created in stream valleys	-predictions qualitatively accurate -observed but not quantified (JFWAT unpbl.) -natural icing phenomena difficult to separate from induced icing	-insulated pipe -burial depth requirements -effectiveness variable
erosion/ sedimentation	-structures located in streams increase turbulence and erosion, but impact negligible if mitigation applied -accelerated erosion from construction activities would increase sedimentation in streams with temporary sedimentation problem until construction area stabilized -interruption of shallow ground water by road cuts, resulting in erosion and new drainage patterns -erosion of stream banks from temporary access, but impact negligible if mitigated -some siltation at road crossings -icing areas created in rivers would induce numerous temporary diversions of surface flow and cause erosion	-erosion/sedimentation problems extensive and often serious during and immediately after construction (Morehouse et al. 1978) -most widespread and common problem during Haul Road and TAPS construction (GAO 1981, Zemansky 1983) -most erosion problems along TAPS alleviated after construction, but chronic erosion and stream sedimentation induced by inadequate stream crossing structures along Haul Road and gravel mining in floodplains persist in a few locations (JFWAT unpbl., USFWS unpbl., Elliott 1982, Woodward-Clyde 1980) -impacts were not quantified and vary substantially	-minimum 300' buffer required from streams unless otherwise approved -avoidance/minimization of disturbance, revegetation required -erosion control facilities to avoid or minimize erosion -stabilization of all disturbed areas required -minimize disturbance to thermal regime -water quality standards -adequate drainage structures required -temporary access over stream banks made by use of fill ramps rather than cutting banks -fill ramps removed and disposed of as approved -effectiveness limited by enforcement and compliance effort (Morehouse et al. 1978, GAO 1981, Zemansky 1983, JFWAT unpbl.)
water quality degradation	-natural quality of stream or lake habitat impaired where construction activities add or place particulate matter (silt, organic detritus, bacteria and plankton) in suspension -construction in active riparian habitats would degrade downstream water quality through increases in suspended solids and reduction in dissolved oxygen -increased siltation and turbidity would occur during construction -generally no water quality impacts from operation of TAPS	-increased sedimentation and turbidity widespread and significant problems during and immediately after construction (GAO 1981, Burger & Swenson 1977, Zemansky 1983, Morehouse et al. 1978) -high levels of sedimentation and turbidity during and sometimes after instream construction and gravel mining (Zemansky 1983) -degree and duration of impacts highly variable, contingent on site-specific characteristics, extent of mining, mode of mining and mitigation implemented (Woodward-Clyde 1980) -long-term water impacts highly variable, but usually minor and associated with physical changes in stream (DenBeste & McCart 1984)	-same as above

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
reduction in natural water flows	-loss of surface and ground water through consumptive use at camps and facilities at 60,000-80,000 gal/day per construction camp -"very small" impacts from withdrawal or return of surface water during low flow periods in immediate vicinity of some camps or stations in the Arctic, where total stream flow diverted for use -use of water for ice roads not predicted	-not quantified -very large volumes of surface and ground water used for consumption uses and construction of ice pads on North Slope (Zemansky 1983, ADEC unpbl.)	-diversion of natural drainages, alteration of stream hydraulics or disturbance of stream beds required specific authorization -protection of fish spawning beds and fish passage required -pump intakes (for surface water) screened to prevent fish impact -abandoned water diversion structures plugged and stabilized to prevent fish entrapment -mitigation effectiveness highly variable
alteration of ground water flows	-interception of shallow ground water flows in some locations by road cuts or excavations, inducing greater than normal flow of ground water to surface	-not quantified, but impacts common during and after construction -impacts more serious and widespread than predicted causing major erosion/siltation problems (Zemansky 1983, JFWAT unpbl.)	-requirements for erosion control measures and rehabilitation -alteration of natural drainage patterns prohibited unless approved -effectiveness limited by lack of construction experience in Arcti[c] and varied with level of enforcement (Morehouse et al. 19[78])
alteration of surface flows	-not quantified -impoundment of water along Haul Road from icing of culverts -excavation and fill activities for roads and pipeline alter natural drainage channels and change flow regime of streams -impacts minor if mitigation applied	-not quantified, but problems common during and immediately after construction along Haul Road and TAPS (Burger & Swenson 1977) -problems persist along Haul Road, and lesser problems along pipeline -predicted impacts frequently caused impediments or obstacles to fish movements and spawning activities, fish mortalities, erosion, and sedimentation (GAO 1981, Zemansky 1983) -over 5,200 acres in Sagavanirktok River floodplain excavated (Pamplin 1979) -some surface flows seasonally lost or reduced due to instream gravel removal (DeuBeste & McCart 1984, Elliott 1982)	-drainage facilities to pass fish and avoid siltation -site specific mitigation for activities that alter natural drainage and stream hydraulics -effectiveness limited by inadequ[ate] enforcement and compliance (Morehouse et al. 1978)
thermal effects of heated pipeline	-evaporation of soil moisture, ground water and snowmelt in vicinity of pipeline -melt water infiltration, thaw bulb around pipe, and springs forming at lower elevations -alter groundwater flow systems from thaw in permafrost and seasonal frost, induce ground water flow in pipeline trench, enlarge thaw bulb -heated pipeline will slightly increase ground water temperatures locally	-early snowmelt observed in vicinity of buried pipeline, but biological impacts not documented -not quantified, but predicted meltwater infiltration impacts occurred in some areas (JFWAT unpbl.) -at Pump Station #3, melt water flows along thaw bulb into pump station, must be pumped into Sagavanirktok River (JFWAT unpbl.) -predicted groundwater infiltration and flow changes continue to occur in some areas (Elliott 1982) -increased temperature confirmed as common occurrence, but at varying degrees along TAPS (Zemansky 1983, Elliott 1982, DeuBeste & McCart 1984) -surface flows maintained during winter in some Arctic and subarctic streams where streams froze to bottom prior to construction offering potential enhancement of overwintering habitat in thawed stream segments (ADF&G unpbl.)	-pipeline elevated in permafrost areas -burial depth requirements (often inadequate) -pipe insulation -effectiveness variable
wastewater contamination	-water locally enriched by fertilized soil leachate or sewage effluent entering ground or surface waters, possible eutrophication of small lakes -organic pollutants from human and animal wastes could enter surface and local ground water, but impacts negligible if mitigated	-many problems with wastewater effluent discharges reaching surface waters, surface discharge at nearly all camps north of Yukon River from inadequate, overloaded waste treatment facilities, which leaked overflowed, or were pumped (Zemansky 1983, ADEC unpbl.) -chronic contamination of streams, rivers and wetlands with organic pollutants from wastewater discharges (Zemansky 1983, ADEC unpbl.), extent not quantified -localized depression of dissolved oxygen and elevated conductivity documented at several construction camps and pump stations (Zemansky 1983, ADEC unpbl.) -increased temperature, alkalinity and suspended solids documented in receiving waters (Zemansky 1983, ADEC unpbl.) -impacts varied considerably among locations and over time (ADEC unpbl.)	-prior approval of waste disposal systems required -waste treatment facilities sited away from streams -State water quality standards -wastewater treatment facilities poorly designed and inadequate capacity, required frequent pumping (Zemansky 1983) -personnel often untrained -mitigation effectiveness limited by inadequate enforcement (Zemansky 1983)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
loss of natural aquatic habitat	-draining of one lake at Prudhoe Bay 0.5 mile south of Putuligayuk River	-drainage and fill of 160-acre lake for Pump Station 1 (Pamplin 1979) -approximately 12% of ponds and lakes in 3,909-acre study area filled by gravel from 1949 to 1983 in Prudhoe Bay oilfields (Walker et al. 1986a) -additional 2% of ponds/lakes subjected to indirect disturbance such as debris (Walker et al. 1986a)	-little mitigation before 1980 -avoidance, minimization recommendations moderately effective in reduction of impacts since 1980
excavation in river flood-plains and terraces	-creation of pools -diversion and entrapment of water -blockage of flow -alteration of flow regime -creation of undergravel flow rather than surface flow during low water	-numerous excavation sites in North Slope rivers left altered slope, increased ponding, increased capacity, and lower velocity even 2 or more years excavation (Woodward-Clyde 1980, Smith 1982) -entrapment of water in many excavation holes (Pamplin 1979)	-avoidance of active channels and buffer zones ineffective, many active channels mined, buffer zones insufficient to avoid erosion -use of riprap and gravel-fill ramps to avoid bank cuts and rehabilitation partially effective
withdrawal of river, stream, and lake water	-not predicted	-for development, about 1.7-2.0 million gallons per well -1.2-1.5 million gallons per mile for ice roads -7-8 million gallons for construction and maintenance of each airstrip (USDI 1987) -during operation, 36 million gallons/yr required by support service industry (ADEC unpbl.) -roughly 100-184 million gallons/yr total fresh water use for Prudhoe Bay oilfield and support services and 22 million gallons for Endicott oilfield, based on water right applications (ADNR unpbl.) -initially, water needs exceeded permitted supplies -reliable winter water sources not identified	-State Title 16 requirements prohibit impeding fish passage and degrading aquatic habitat -State encourages use of water from roadside impoundments for road watering -sufficient non-fish-bearing lakes available in Prudhoe Bay area to meet Title 16 requirements (Carl Hemming, ADF&G, pers. comm.)
withdrawal of groundwater	-negligible impact	-negligible impact due to limited usable sources -only four wells drilled in Sagavanirktok River with less than 14,700 gallons/yr removed (Balding 1976)	-none
tapping of river water to create reservoirs in adjacent gravel pits	-not predicted	-Kuparuk and Sagavanirktok Rivers tapped both accidently and purposely; 191 surface acres of "reservoirs" created with more than 5.5×10^{14} gallons of river water (ADF&G Notice of Violation dated June 16, 1986; ADF&G unpbl.)	-State and Federal agencies currently negotiating with oil industry to enhance gravel pit reservoirs for fish and birds -mitigation effectiveness unknown until projects implemented
flooding/ impoundment of water by roads, pads, snowbanks	-no quantitive predictions -predicted impacts include blockage, diversion of flow due to inadequate culverting, frozen culverts, culvert failure, etc.	-3,412 terrestrial acres flooded in Prudhoe Bay as of 1983 (Walker et al. 1986b) -in cases of deep water, reduced productivity -in cases of shallow flooding, increased productivity (Walker et al. 1986a)	-properly placed and sized culverts usually effective, but chronic history of poorly placed, inadequately sized, iced culverts with numerous documented cases of blocked flow and permanently impounded waters (ADEC et al. 1984-1987)
discharge of excess water from excavations	-not predicted	-1984-1986, about 736 million gallons of water discharged to lakes, ponds, streams and tundra from dewatering of gravel pits, trenches, impoundments (ADEC 1987c) -impacts on water quality unknown -rich salt content in water of certain pits (Entrix 1987; Carl Hemming, ADF&G, pers. comm.)	-general effluent restrictions on hydrocarbons, garbage, contaminants in State Excavation Dewatering Permit, but no applicable monitoring requirements for discharge to surface water except for solids
contamination of surface water by reserve pit fluids	-not predicted	-discharge of 47-101 million gallons/yr reserve pit fluids directly to tundra (ADEC 1987c) -contamination of some tundra ponds, lakes by metals and/or hydrocarbons through seepage, breaching and direct discharge to tundra, roads, and pads (West & Snyder-Conn 1987, Woodward in press) -violations of State wastewater discharge/EPA water quality criteria common from 1983-1986 (ADEC unpbl.) -seepage through pit walls documented at 17 reserve pits (ADEC unpbl.)	-State Wastewater Discharge Permit required in 1983 -road/pad discharge permit instituted in 1985 (ADEC 1987c) -since initial permits, increased chemical characterization, pre- and post-monitoring requirements added to permits -early spring dewatering permit added in 1987 to facilitate discharge of early meltwater -snow/liquid management reduced need to dewater -above measures more effective in reducing contamination -seepage remains a problem (ADEC unpbl.)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
sewage	-not predicted	-excluding drill rig camps, 6 minor and 8 major sewage treatment facilities/lagoons, 3 of which discharge into natural lakes (USFWS unpbl.) -total discharge under 41 permits allow up to 1 million gallons per day (ADEC 1987c) -receiving lakes eutrophic (USFWS unpbl.) -enrichment of roadside ponds from sewage sludge disposal on roads likely, 683,000 gallons in 1986, (ADEC 1987c)	-secondary or tertiary treatment moderately effective according to ADEC monthly reporting -sludge generally disposed by incineration -facilities enhanced bird use, other mitigation not sought -some non-compliance by discharge of poor quality effluent, breaches of lagoon dikes, etc. (ADEC 1987a)
produced water	-not predicted	-by 1981, more than 15.8 billion gallons injected for disposal or waterflooding (AOGCC 1987) -only one highly local brine spill documented, none to surface water -groundwater already poor quality (high total dissolved solids) so impacts negligible	-injection below permafrost strata required and highly effective
hazardous, non-hazardous, and RCRA- exempt oilfield wastes	-not predicted, except hydrocarbons	-most of average 7 million gallons waste per year (ADEC 1987c) successfully injected below permafrost barrier -several small surface spills, leaks from barrels, tanker truck spills (ADEC 1987a) -water quality degradation not monitored or quantified -since 1985, hazardous wastes not accepted for injection from service support industries, increasing possibility of illegal discharge to surface waters (ADEC unpbl.)	-tank storage required and usually used -water quality impacts/ cleanups not assessed -truck rinsate probably important source of contamination of surface water but impact local, often to impoundments
oil spills plus glycol, methanol	-not quantified -number of small spills in oilfields during construction -no specific predictions on large spills	-early statistics on oil spills poor -for TAPS and oilfields in 1985-86, 953 reported spills including 66 spills of more than 500 gallons and 22 spills of more than 1,000 gallons, mostly of crude and diesel oil and mostly in oilfields (ADEC 1987b; ADEC unpbl.) -amounts of spills/impacts to surface water not quantified -oil entered surface waters from reserve pit discharges (West & Snyder-Conn 1987; Woodward in press) and from oil spills near East Dock reserve pits (USFWS unpbl., SAPC 1986) and at Storkerson Point (Bergman et al. 1977) -Storkerson Point spill destroyed plant and invertebrate life and contaminated water and sediment -other chronic spills caused slicks in Sagavanirktok River (ADEC unpbl.) -use of oil on roads contaminated adjacent tundra ponds (Smith 1982) -impacts not studied, but recovery slow based on experimental spills to Arctic ponds (Barsdate et al. 1980)	-oil spill contingency plans -rapid reporting/cleanup requirements -formation of oil-industry sponsored oil cleanup company based in Prudhoe Bay -mitigation moderately effective in oil industry spills, but ineffective in case of service industry, where failure to report/cleanup spills common (ADEC 1987a, ADEC unpbl.)
erosion/ sedimentation	-not quantified -siltation and sedimentation from erosion during construction	-as predicted, but not quantified on area-wide basis -many recurring road washouts cause annual siltation/ sedimentation/gravel outwashing episodes (e.g., Kuparuk River bridge) -additional serious siltation from poor siting of overburden material at gravel excavation sites (ADEC et al. 1984-1987) -serious erosion/sedimentation problems from active excavation of stream/river channels (see excavation impact category)(Woodward-Clyde 1980)	-riparian/erosion protection measures required at stream and river crossings -seasonal restrictions on construction -State enforcement of statutes for activities in anadromous fish streams -mitigation effectiveness dependent on location, enforcement, compliance

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
discharge of drilling effluents	-not predicted	-Endicott development first offshore production facility -approximately 120,000 cu yd of materials to be discharged from 120 wells (USACE 1984) -suspended effluent to cover up to 3,720 acres of sea floor (USACE 1984) -some effect expected on benthos -potential for contaminants effects (heavy metals)	-standard NPDES offshore stipulations on composition and rates of discharge -additional conditions on location and timing of discharge -effectiveness not yet assessed
oil spills	-possibility of spill reaching Beaufort Sea via streams, but probabilities not predicted	-no major offshore spill to date from Endicott development or any exploration wells -numerous unquantified minor spills, but effects not measured (USFWS unpbl.)	-development of oil spill contingency plans
discharge of sea water treatment chemicals	-not predicted	-addition of seawater intakes and treatment plants at Prudhoe Bay and Oliktok Point (Kuparuk field) for secondary oil recovery requires discharge of treatment chemicals into marine environment -total discharge of 9 million gallons/day includes up to 170,000 lbs of solids/day (EPA unpbl.) -chemicals are largely chlorine reaction products (organochlorides), coagulants, and clarifiers -elevated levels of such chemicals in water column and detectable changes in density and diversity of benthic infauna near plants (NORTEC 1986)	-NPDES stipulations on composition, rates, and timing of discharges -effectiveness not yet assessed
alteration of oceanographic conditions	-not predicted	-West Dock and Endicott causeways altered oceanographic conditions (temperature and salinity) over thousands of acres in nearshore zone (Envirosphere 1987, Gilbertson et al. 1987) -depending upon wind conditions and freshwater input, temperatures and salinities may diverge 4-6°C and 10-20ppt respectively across West Dock causeway (Envirosphere 1987) -effects of Endicott causeway not yet assessed, but expected to be more extensive (Gilbertson et al. 1987) -oceanographic conditions important component of anadromous fish habitat, since they alter prey abundance and fish physiological requirements (Envirosphere 1987)	-causeway breaching (primarily for fish passage) has resulted in minimal effectiveness (Moulton et al. 1986)

FRESHWATER INVERTEBRATES (TRANS-ALASKA PIPELINE SYSTEM)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
erosion/ sedimentation	-reduced total productivity -reduction of benthic organisms	-not studied during construction when erosion/ sedimentation effects most significant -post-construction studies in a few stream found impacts highly variable, ranging from insignificant impacts to decreased standing crop and taxonomic diversity (Woodward-Clyde 1980) -in general high gradient mountain streams less impacted than lower gradient, productive streams (DeaBeste & McCart 1984) -in Sagavanirktok River tributary, increased densities of most taxa in river sections impacted by previous gravel mining, as compared to control sites (Woodward-Clyde 1980) -in Kuparuk River, gravel mining decreased densities of all taxa (Woodward-Clyde 1980) -impacts highly variable, but in general, impact on benthic invertebrate communities more significant in stable tributary streams than in large braided streams (DeaBeste & McCart 1984)	-See FRESHWATER QUALITY AND QUANTITY (TAPS)
oil spill	-see oil spill impacts under FRESHWATER QUALITY AND QUANTITY (TAPS) -impacts contingent on magnitude and duration of spill and other variables	-overall reduction of aquatic organisms (Nauman & Kernodle 1975) -reduced numbers of benthic invertebrates in all taxonomic groups at one North Slope study site (Nauman & Kernodle 1975) -impacts at other oil spill locations not studied	-see FRESHWATER QUALITY AND QUANTITY (TAPS)
thermal effects of heated pipeline buried in streams or rivers	-increased productivity	-not studied	-see FRESHWATER QUALITY AND QUANTITY (TAPS)

FRESHWATER INVERTEBRATES (PRUDHOE BAY OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
contamination from reserve pit fluid discharges, seepages, etc.	-not predicted	-1983 study found decreased taxonomic diversity and abundance of most invertebrates within 375 ft of drill pad effluent discharge/seepage sites with predominance of chironomids in ponds adjacent to reserve pits, indicating contamination (West & Snyder-Conn 1987) -chronic and subacute toxicity of certain reserve pit fluids demonstrated, even when diluted (Woodward in press)	- State wastewater discharge regulations applied to reserve pit fluids in 1983 and strengthened in subsequent years - mitigation effectiveness for invertebrates not studied, but water quality improvements noticed (USFWS unpubl.)
oil spills/oily waste discharges	-localized toxic response by invertebrates depending on timing, volume, flushing	-most discharges from dilute reserve pit fluids and contaminated snow bulldozed from pads -some slicks from road oiling (Smith 1982) -loss of crustaceans in tundra ponds statistically correlated with aromatic hydrocarbon concentrations (West & Snyder-Conn 1987) -total loss of pond invertebrates observed from one spill (Bergman et al. 1977)	- see above and FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS)
sedimentation/ turbidity	-local losses/burial of aquatic invertebrates	-probably as predicted, but not studied or quantified	- see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct loss of invertebrate infauna and/or habitat	-not predicted	-total seafloor covered by gravel fill or dredged during causeway construction: West Dock: 180 acres Endicott: 328 TOTAL LOSSES: 508 acres	-none
alteration of nearshore aquatic habitat	-not predicted	-not quantified -alteration of oceanographic conditions (temperature and salinity) caused localized shifts in abundance of marine epibenthic invertebrates (Envirosphere 1987)	-none
alteration of benthic habitat	-not predicted	-not quantified -in general, conditions in immediate vicinity of causeways (oceanography and sediments) sufficiently altered to cause changes in benthic community diversity and relative abundance (Envirosphere 1987, NORTEC 1987) -long-term implications not yet assessed	-none
discharge of drilling fluids	-not predicted	-not quantified -Endicott development first to discharge large quantities of drilling fluids into marine environment -only 1 year of drilling so far, too early to detect impacts (NORTEC 1987) -some changes in benthic communities expected -potential for bioaccumulation of contaminants (heavy metals and hydrocarbons) in prey species important to anadromous fish and waterfowl, but not studied	-standard NPDES restrictions -discharge to be confined to north (seaward) side of drill-sites, flow rate restricted, and all materials to be discharged above-ice at least 1,000 m from sensitive benthic communities -extensive monitoring requirements -effectiveness not yet assessed, some lack of compliance
entrainment in seawater intakes	-not predicted	-15-30% mortality of entrained invertebrates (Dames & Moore 1986, 1987) -no measurable effects on species' abundance	-Marine Life Return System (bypass) reduced mortality 70 to 85% (Dames & Moore 1986, 1987)
discharge of seawater treatment effluents	-not predicted	-not quantified -measurable decline in infaunal abundance within mixing zone for plant discharges weakly correlated with water quality changes (NORTEC 1986)	-NPDES restrictions on discharge rates

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
habitat modifications	-not predicted	-impacts extensive but not quantified -in construction section 6 (Pump Station 4 to Prudhoe Bay) 1,243 acres vegetated and 3,638 acres unvegetated floodplain impacted by construction activities, as of July 1976; substantial but unquantified acreage of riparian habitat since modified; above acreage impacts do not include aquatic habitat impacts (Pamplin 1979) -extensive sedimentation of substrate within mined areas and downstream of construction activities -increased unstable substrate common, but changes in substrate vary with characteristics of stream and mining practices (Woodward-Clyde 1980) -loss of bank cover (vegetation and undercut banks) -loss of instream cover and alteration of stream flow (Woodward-Clyde 1980) -reduction of habitat diversity in material sites where gravel deposits scraped below water line (Woodward-Clyde 1980, DenBeste and McCart 1984) -alteration in channel cross sections with increased wetted perimeters and shallower, more uniform depths (increased braiding), where gravel scraped over large areas (Woodward-Clyde 1980) -increased habitat in a few instances where material site excavation tapped into ground water (Woodward-Clyde 1980, Elliott 1982, DenBeste and McCart 1984) -increased unstable substrate	-erosion control required -buffer strips -fish passage requirements -stabilization of disturbed areas -rehabilitation, revegetation of disturbed areas -avoid channel changes in fish spawning beds -prior mining plan and design approvals (Burger & Swenson 1977) -mitigation only partially effective due to inadequate enforcement and irregular application (JFWAT unpbl., Lemansky 1983, Morehouse et al. 1978)
habitat loss	-not predicted	-localized reduction, and in some cases, loss of surface flow (Elliott 1982, DenBeste and McCart 1984) -elimination of numerous stream meanders with resultant habitat loss in many locations, but magnitude of loss not quantified (JFWAT unpbl.) -numerous fish blockages along Haul Road, which eliminate fish use of upstream aquatic habitat by all fish or certain species and/or certain age/size classes of fish (Elliott 1982, JFWAT unpbl., ADF&G unpbl.)	-see above
fish mortality	-mortality of salmonid eggs and embryos	-various levels of fish mortalities along several streams resulting from fish entrapment upstream of areas where surface flows lost to permeable substrate caused by instream mining and stream flow interception by pipeline trench and/or thaw bulb (Elliott 1982) -fish entrapment occurs during low flow periods when fish attempt migration to wintering areas (Elliott 1982) -in one case, an estimated 3,000 fish entrapped due to loss of surface flows resulting from gravel removal from stream (ADF&G unpbl.) -instream gravel removal in one Atigun River tributary caused discontinuous surface flows in late summer and stranded estimated 75% of peak summer resident Arctic grayling population (Elliott 1982) -fish mortalities from increased stress under winter conditions caused by very high sedimentation (suspended solids) from upstream construction (buried pipe crossing) but extent of such impacts not studied (EPA unpbl.) -localized impacts possibly significant, but overall impacts on regional fish populations not quantified -in 1978, several thousand Arctic grayling unable to swim downstream through outwash gravel barrier (ADF&G unpbl.) -fish egg and embryo mortality likely, but not studied	-see above -screened pump intakes -abandoned diversions plugged and stabilized -fish bypass structures -mitigation effectiveness limited by enforcement problems (Morehouse et al. 1978, JFWAT unpbl.)
changes in species composition	-not predicted, except as minor effects from thermal changes	-varying impacts depending on species present, location, type and scope of mining operations, and time since disturbance (Woodward-Clyde 1980)	-see habitat modification above

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
changes in fish densities or distributions	-reduction in total productivity	-effects on fish densities not quantified, but probably variable and localized -very low fish use documented in channelized section of some streams (Elliott 1982) -fish densities averaged 1.7 times higher in undisturbed stretch than in gravel mined stretch of one stream (Elliott 1982) -in Sagavanirktok River, large areas of floodplain scraped for gravel, increased Arctic grayling, reduced round whitefish, loss of Arctic char habitat (Woodward-Clyde 1980) -in similar situations elsewhere, Arctic grayling decreased (Woodward-Clyde 1980) -in Kuparuk River, reduced diversity and early age classes of Arctic grayling (Woodward-Clyde 1980) -in some situations, creation of overwintering habitat and increased habitat diversity probably resulted in localized increases in fish densities (Woodward-Clyde 1980)	-see above
erosion and siltation	-reduced total productivity -reduced fish food organisms	-unquantified fish mortality downstream from winter instream construction probably the result of high sediment loads (EPA unpbl.) -siltation of fish spawning areas common and impacts on fisheries productivity very likely but not quantified -heavy sedimentation from construction and subsequent repair and maintenance activities known to cause abrasion of gill tissues, loss of fish food organisms, inability to feed, loss of primary productivity, decrease in substrate quality, avoidance, and increased stress on fish, but magnitude of impacts not quantified	-avoid construction in/or near streambeds -erosion control measures -temporary fill ramps to access streams -mitigation effectiveness limited by poor enforcement and inadequate Arctic engineering experience (JFWAT unpbl.) -bridges and riprap for stabilization, stilling basins
blockages or interference with fish passage	-fish passage problems negligible, if mitigation applied	-one of most common and extensive problems during and after construction (Morehouse et al. 1978, Burger & Swenson 1977) -problem still persists, particularly along Haul Road (ADF&G unpbl.) -various levels of fish mortalities at many North Slope streams from fish entrapment above fish blockages during fall emigrations (Elliott 1982, DenBeste & McCart 1984) -fish entrapment in deep mined pits, left near streams and rivers (Woodward-Clyde 1980, JFWAT unpbl.) -upstream migration or movements blocked by inadequate stream crossing facilities and icing problems (JFWAT unpbl.) -impacts on fish productivity and population levels not quantified -significant reductions in available fish habitat (Elliott 1982)	-prohibit use of artificial structures or stream channel changes that trap or block fish -require fish passage structures when channel altered or blocked -construction timing restrictions on 20 anadromous fish streams to avoid fish runs -mitigation effectiveness limited by poor enforcement and inadequate Arctic engineering experience
fish harvest	-access would increase harvest of fish resources north of Yukon River -diminish quality wilderness fishing opportunities -reduce size and rate of catch	-increased fishing pressures observed but not unquantified (ADF&G unpbl.)	-Haul Road corridor closed to fishing during construction -increased fishing pressure when fishing closure lifted after construction
oil spill	-see FRESHWATER QUALITY AND QUANTITY (TAPS) -death of fish embryos or young through deoxygenation or loss of fish food, could cause negligible impacts unless large spill or in location of spawning run	impacts not quantified -reduction in standing crop and diversity of aquatic fish food organisms documented in areas affected by spills (see FRESHWATER INVERTEBRATES - TAPS)	-see FRESHWATER QUALITY AND QUANTITY (TAPS)
thermal effects of pipeline buried under rivers or streams	-biological adjustments in life histories of bottom dwelling fish and associated organisms may cause changes in species composition	-fall fish emigration blocked in Atigun River headwaters by surface flow lost to pipeline (Elliott 1982) -fish attracted to warm waters created by pipeline trapped and died as stream froze (Elliott 1982) -possible enhancement of overwintering conditions, but not studied	-see FRESHWATER QUALITY AND QUANTITY (TAPS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
changes in fish densities or distributions	-reduction in total productivity	-effects on fish densities not quantified, but probably variable and localized -very low fish use documented in channelized section of some streams (Elliott 1982) -fish densities averaged 1.7 times higher in undisturbed stretch than in gravel mined stretch of one stream (Elliott 1982) -in Sagavanirktok River, large areas of floodplain scraped for gravel, increased Arctic grayling, reduced round whitefish, loss of Arctic char habitat (Woodward-Clyde 1980) -in similar situations elsewhere, Arctic grayling decreased (Woodward-Clyde 1980) -in Kuparuk River, reduced diversity and early age classes of Arctic grayling (Woodward-Clyde 1980) -in some situations, creation of overwintering habitat and increased habitat diversity probably resulted in localized increases in fish densities (Woodward-Clyde 1980)	-see above
erosion and siltation	-reduced total productivity -reduced fish food organisms	-unquantified fish mortality downstream from winter instream construction probably the result of high sediment loads (EPA unpbl.) -siltation of fish spawning areas common and impacts on fisheries productivity very likely but not quantified -heavy sedimentation from construction and subsequent repair and maintenance activities known to cause abrasion of gill tissues, loss of fish food organisms, inability to feed, loss of primary productivity, decrease in substrate quality, avoidance, and increased stress on fish, but magnitude of impacts not quantified	-avoid construction in/or near streambeds -erosion control measures -temporary fill ramps to access streams -mitigation effectiveness limited by poor enforcement and inadequate Arctic engineering experience (JFWAT unpbl.) -bridges and riprap for stabilization, stilling basins
blockages or interference with fish passage	-fish passage problems negligible, if mitigation applied	-one of most common and extensive problems during and after construction (Morehouse et al. 1978, Burger & Swenson 1977) -problem still persists, particularly along Haul Road (ADF&G unpbl.) -various levels of fish mortalities at many North Slope streams from fish entrapment above fish blockages during fall emigrations (Elliott 1982, DenBeste & McCart 1984) -fish entrapment in deep mined pits, left near streams and rivers (Woodward-Clyde 1980, JFWAT unpbl.) -upstream migration or movements blocked by inadequate stream crossing facilities and icing problems (JFWAT unpbl.) -impacts on fish productivity and population levels not quantified -significant reductions in available fish habitat (Elliott 1982)	-prohibit use of artificial structures or stream channel changes that trap or block fish -require fish passage structures when channel altered or blocked -construction timing restrictions on 20 anadromous fish streams to avoid fish runs -mitigation effectiveness limited by poor enforcement and inadequate Arctic engineering experience
fish harvest	-access would increase harvest of fish resources north of Yukon River -diminish quality wilderness fishing opportunities -reduce size and rate of catch	-increased fishing pressures observed but not unquantified (ADF&G unpbl.)	-Haul Road corridor closed to fishing during construction -increased fishing pressure when fishing closure lifted after construction
oil spill	-see FRESHWATER QUALITY AND QUANTITY (TAPS) -death of fish embryos or young through deoxygenation or loss of fish food, could cause negligible impacts unless large spill or in location of spawning run	impacts not quantified -reduction in standing crop and diversity of aquatic fish food organisms documented in areas affected by spills (see FRESHWATER INVERTEBRATES - TAPS)	-see FRESHWATER QUALITY AND QUANTITY (TAPS)
thermal effects of pipeline buried under rivers or streams	-biological adjustments in life histories of bottom dwelling fish and associated organisms may cause changes in species composition	-fall fish emigration blocked in Atigun River headwaters by surface flow lost to pipeline (Elliott 1982) -fish attracted to warm waters created by pipeline trapped and died as stream froze (Elliott 1982) -possible enhancement of overwintering conditions, but not studied	-see FRESHWATER QUALITY AND QUANTITY (TAPS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
erosion and siltation from pipeline and road construction	-all pipeline and road crossings of streams may cause erosion and siltation *effects temporary, maximum of 2 years *siltation impact most severe in river deltas and marine areas -stream substrate alteration may cause moderate siltation with short term impacts of 2 years or less	-fieldwide impacts from erosion and siltation caused by construction of roads, pipelines and pads (ADF&G, USFWS unpbl.) -alteration of stream hydrology (ADF&G, USFWS unpbl.) -blockages to fish movement (ADF&G, USFWS unpbl.) -loss of spawning, rearing and feeding habitat from above impacts (ADF&G, USFWS unpbl.) -erosion of gravel into streams often resulted in permanent impact (USFWS unpbl.) -streams with vegetated substrate covered with gravel, long-term effect (USFWS unpbl.) -winter instream activity increased turbidity upstream of overwintering areas resulting in impacts to overwintering fish (ADF&G unpbl.) -loss of fish spawning, rearing and feeding habitat (grayling, stickleback, sculpin)(Craig and Poulin 1975) -impacts unquantified	-road culverts designed for peak flows at all stream crossings -design often inadequate, large percentage of road/stream crossings annually washed out (ADF&G, USFWS unpbl.)
thermal erosion of stream banks and beds	-not predicted for oilfield activities	-stream channel configuration and hydrology altered by thermal erosion caused by gravel mining (ADF&G, USFWS unpbl.) -stream flow captured by thermokarst action (ADF&G, USFWS unpbl.)	-after-the-fact mitigation used t retard or stop erosion by coveri thermally exposed soils -some cases of thermal erosion continue despite attempts to rec (McClelland-EBA 1985)
instream barriers to fish movements from road and pipeline crossing construction	-adequate culvert design and construction stipulations would minimize impacts	-extensive fish blockages (ADF&G unpbl.) -in Kuparuk Field all fish streams totally or partially blocked in at least one location during low summer flows (ADF&G unpbl.	-culverts designed for peak flows, however designs often inadequate for breakup flows (ADF&G, USFWS unpbl.)
oil spills in fish streams	-see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS)		
contaminants released in aquatic systems	-see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS)		
fish stock reduction	-improved access would increase harvest and reduce fish stocks, impact not quantified	-fish stocks believed to be reduced, but inadequately studied (ADF&G unpbl.) -impact not quantified	-none applied
stream blockage from ice formation	-icing predicted but not as potential direct impact to fishery resources	-blockages to spring movement of grayling (Woodward-Clyde 1980) -loss of spawning habitat (Woodward-Clyde 1980) -delayed spawning movements (Woodward-Clyde 1980) -quantity of habitat affected not assessed	-culvert design used that prevents icing -mechanical removal of ice blockages -when problems predicted or anticipated, action can be effective
siltation from gravel mining	-short-term siltation increase during normal flows -longer term increase during high flows	-siltation increase generally of short duration (Woodward-Clyde 1980) -reduced primary productivity in streams (Woodward-Clyde 1980) -alteration of substrate with impact to spawning and feeding habitat (Woodward-Clyde 1980)	-timing restriction for instream activity to avoid presence of fish
altered stream hydrology	-changes in stream hydrology resulting in habitat alteration	-extensive areas in lower Sagavanirktok and Kuparuk rivers altered from gravel mining in river, (Woodward-Clyde 1980)resulting in *unstable substrates *braiding of channels *channel blockages *increased Arctic grayling numbers, reduced round whitefish, loss of Arctic char habitat, fish stranding -in Kuparuk River, mining reduced number of fish species and life history stages and caused fish entrapments (Woodard-Clyde 1980)	-seasonal restrictions for instream activities -buffers from active parts of channels -mitigation effective, but not always applied or enforced

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
impacts to fish overwintering	-stress impacts to overwintering fish from changes in water quality caused by instream activities	-gravel extraction and installation of pipelines in stream during winter caused elevated turbidity levels (ADF&G unpbl.) -extent of impact not documented	-timing restrictions partially effective
winter water withdrawal from rivers	-impact would be minimal or none due to stream protection regulations	-impacts to overwintering fish occurred, extent not documented (ADF&G unpbl.) -total water use of oilfield operations estimated at 122-204 million gal/year (ADF&G unpbl.) -total water withdrawals from river years to date, for all oilfield operations more than 3.3×10^{14} gallons -see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS) for a quantification of water withdrawals	-since 1982, use of reservoirs as water sources reduced need for water from natural ponds and streams -need more baseline information regarding fish resources of water bodies to assess potential impacts of water withdrawals

MARINE FISH (PRUDHOE BAY OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
oil spills	-where fish come into direct contact with spilled hydrocarbons, high mortality expected -degree of impact dependent upon quantities spilled, time of year, and proximity to fish concentrations -up to 50,000 bbl expected to be spilled during a single pipeline spill, but impacts to fish populations not predicted	-not quantified -numerous small spills of non-pipeline hydrocarbons, (USFWS unpbl.) but impacts to anadromous fish populations in streams or the marine environment not documented	-development of oil spill contingency plans
alteration of nearshore habitat	-not predicted	-expansion of existing facilities and development of adjacent reservoirs required construction of gravel-fill causeways perpendicular to shoreline (USACE 1980, 1984) -causeways altered water quality (temperature and salinity) by altering distribution of brackish water and invertebrate prey in nearshore zone, and thus extent and quality of summer feeding habitat (Envirosphere 1987) -extension of West Dock causeway for docking and location of seawater intake and treatment plant detrimentally altered approximately 67,000 acres of nearshore aquatic habitat (Envirosphere 1987) -studies indicate similar habitat impacts resulting from presence of Endicott causeway (Gilbertson et al. 1987) -cumulative impact of both causeways on marine habitat not yet quantified	-small breaches in causeways to permit fish passage expected to have some beneficial effect on habitat continuity (USACE 1980, 1984) -breaches at West Dock have not mitigated habitat losses or improved fish passage (Envirosphere 1987) -insufficient information from ongoing Endicott causeway monitoring studies to assess mitigation effectiveness
interruption of nearshore fish movement	-not predicted	-presence of causeways described above and their effect on habitat continuity interrupts or delays summer longshore movements of anadromous fish (cisco, whitefish, and char) in nearshore brackish water zone (Envirosphere 1987) -this effect believed to limit feeding and delay returns to overwintering sites in major coastal rivers (Envirosphere 1987) -total impact of both causeways on migration not yet quantified	-breaching minimally effective (generally less than 10% efficiency) at West Dock (Moulton et al. 1986) -insufficient information from ongoing Endicott causeway monitoring studies to assess mitigation effectiveness
entrainment in seawater intakes	-not predicted	-two seawater intakes (West Dock and Oliktok) supply water for secondary recovery of oil -third (Endicott) under construction -monitoring of West Dock intake indicates approximately one million larval fish (marine and anadromous) are entrained annually with mortality up to 40% (Benne & Moore 1986)	-Marine Life Return System (bypass) minimizes losses of larger fish (greater than 100 mm) -low intake flow rates to reduce entrainment

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct loss by removal or fill	-39,215ac total -11,600ac for North Slope (estimated)	-33,500ac total (Pamplin 1979) -10,500ac for North Slope (measured)	-revegetation with introduced grasses over approximately 7,000ac -grass cover generally less than 40% and declining 3-5 years after seeding; reinvasion by native species only on lowland sites (Native Plants 1980) -upland material sites and workpads remain largely unvegetated 10-12 years after abandonment (Native Plants 1980) -revegetation efforts with native woody plants on North Slope riparian habitats ineffective (Densmore et al. 1987)
thermokarst	-expected, but not quantified	-not quantified -common occurrence where surface temperature disturbed by variety of effects (compression of vegetative cover, dust, impoundments, etc.; Walker et al. 1987a) -usual effects observed range from alteration of species composition to total loss by deep flooding	-none; vegetation lost where soil temperatures stabilized by fill to prevent engineering problems
impoundments (drainage alteration)	-expected, but not quantified	-not quantified -observed effects of flooding range from changes in species composition to total loss of plant community (Walker et al. 1987a) -problem compounded by thermokarst effects	-facilities siting to avoid alteration of surface flow -culverts to improve drainage -culvert maintenance during operational phase -mitigation generally successful where surface flow well-defined
erosion/redeposition of exposed soil or fill	-expected, but not quantified	-not quantified -zone of direct disturbance expanded by runoff/outwash from roads, pads, and material sites -snow removal practices also contribute to spread of gravel fill	-construction/maintenance of drainage channels -surface stabilization through revegetation ineffective -erosion control usually achieved by physical means
dust	-not predicted	-dust deposition up to $5kg/m^2$ within 5m of Haul Road (Brown & Berg 1980) -dust effects up to 1000m from road (Walker et al. 1987a) -total loss of vegetation less than 5m from road -alteration of species composition, soil texture and pH, and snowmelt patterns up to 1000m from road (Brown & Berg 1980)	-periodic road watering ineffective
icing	-expected, but not quantified	-not quantified -some alteration of streamflow and streambed led to perennial icing and loss of riparian vegetation (Pamplin 1979)	-none (some natural restabilization of stream courses)
snow accumulation	-not predicted	-trapping of windblown snow by elevated structures and accumulation from snow removal cause late-lying snowbeds adjacent to facilities (USFWS unpubl.) -ultimately leads to localized changes in plant species composition, lowered productivity	-none
oil spills	-probability of pipeline oil spill not predicted; for any possible leak, an estimated 64,000 bbl would be discharged onto adjacent vegetation; total mortality expected from direct exposure; 25,000 bbl spill expected to affect 6.6 level acres	-not quantified for entire North Slope -total of 16,000 spills occurred along TAPS between 1974 and 1977 (953 in 1985-86, including 64 greater than 500 gal.) which presumably led to vegetation losses (ADEC 1987b) -effects of spill cleanup efforts often exacerbate effects of oil on vegetation -one 1,500 bbl spill covered 21 level acres, or 3 times predicted due to high line pressure (Walker et al. 1987a) -a second 1,500 bbl spill reached a major stream, extended 15-25 miles downstream, killing riparian vegetation (APO 1979, USFWS unpbl.)	-none -in summer, spill cleanup efforts generally increase impacts to vegetation

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
ORV use (public)	-significant impacts to North Slope if public access permitted, few if access restricted -plant death, compression of vegetative mat would lead to thermokarst erosion, alteration of species composition	-not quantified -little measurable impact	-restricted public access to North Slope largely successful while enforced
spread of introduced weeds	-not predicted	-enhanced migration along transportation corridor or introduced with contaminated revegetation materials (Kubanis 1980)	-none
SO_2 emissions (from pump stations)	-possible localized impacts to some plant species (e.g., lichens)	-none measured	-none

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct loss by removal or fill	-total of 8,745 acres for development of Prudhoe Bay, Kuparuk, and Lisburne fields -Milne Point, Endicott and other proposed addition not predicted	-Prudhoe Bay: 6,405 acres (Table 2) Kuparuk: 3,017 Lisburne: 300 Milne Pt.: 295 Endicott: 345 Proposed Additions: 665 TOTAL LOSSES: 11,027 acres	-facilities consolidation only partially achievable due to engineering considerations (USFWS unpbl.) -siting to reduce loss of "high value" vegetation types did not reduce net losses of vegetation
thermokarst	-expected, but not quantified	-intensively studied areas of thaw adjacent to roads and pads included approximately 200 acres of thermokarst disturbance directly related to approximately 500 acres of roads and pads (40% increase in affected area; Walker et al. 1987b)	-none
impoundments (drainage alteration)	-expected, but not quantified	-in the Prudhoe Bay field, approximately 5,200 acres of gravel fill structures created approximately 3,450 acres of flooded tundra (66% increase in affected area; impacts to vegetation not quantified, but presumably ranged from alteration of plant species composition to total loss of plant cover (Walker et al. 1984, 1987b)	-facilities siting -culvert placement and maintenance successful only where surface flow well defined (usually not) -more successful culverting in Kuparuk than Prudhoe Bay
erosion/redeposition of fill	-not predicted	-not quantified -zone of direct disturbance and loss of vegetation expanded by erosion, road maintenance, and snow removal (USFWS unpbl.)	-snow removal plans reduced area of impact from snow removal operations
dust	-not predicted	-along heavily traveled roads all vegetation eliminated within 5 m of road (Walker et al. 1987a) -changes in species composition within 20 m of road (Walker et al. 1987a) -alteration of soil characteristics and snowmelt patterns within 100 m of road (Walker et al. 1987a) -within one intensively studied area of the Prudhoe Bay field, 134 acres of gravel roads generated approximately 11 acres of dust-affected tundra vegetation (8% increase in roadway impacts; Walker et al. 1986b, 1987b)	-summer road watering has limited effect, since winter dust fall is 10 times that of summer dust fall
snow accumulation	-not predicted	-not quantified -reduced growth and productivity of vegetation covered by late-lying snowbeds adjacent to elevated structures, and other effects similar to those created by impoundments (above)	-none
oil spills	-spill probabilities not predicted -no spills predicted specifically for oilfield (TAPS only)	-totals not quantified for oilfields -numerous small spills have occurred, presumably causing loss of vegetation and/or thermal erosion (ADEC unpbl.) -during a 21-month period (1985-87), 25 spills of various hydrocarbons covered between 5 and 10 acres of tundra vegetation (USFWS unpbl.)	-see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIELDS)
winter tundra travel/ operations	-not predicted	-construction of winter trails and ice roads or pads common for occasional seismic work or temporary access/facilities (e.g., work pads, delineation wells) -impacts largely visual, but may range from crushing of live plants, compression of live/organic layer and increased thermal subsidence, and alteration of plant community composition, to localized massive thermal erosion, inundation, and loss of vegetative cover (Walker et al. 1987a)	-State restrictions on tundra travel/operations and guidelines for ice road/pad construction generally effective in minimizing significant vegetation impacts -occasional unauthorized tundra travel within oilfields unmitigated -temporary to long-term visual effects evident in most cases
discharge of hazardous or domestic wastes	-not predicted	-approximately 8 acres of wet tundra vegetation killed by spills or discharges of hazardous (particularly solvents) or domestic wastes from service facilities in Deadhorse area (USFWS unpbl.) -residence time and recovery of vegetation cannot be predicted	-none

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct habitat loss	-39,215 acres of habitat destroyed or modified for entire TAPS route (acres for North Slope not stated in EIS; estimated at 11,600 acres) -displaced birds assumed lost from population, but not quantified -greater losses predicted where habitat limited -additional habitat loss from roads, mining, logging, and wildfires resulting from Haul Road and airstrip access to previously undeveloped areas	-33,300 acres of habitat destroyed or disturbed for entire TAPS route (Pamplin 1979) -10,900 acres, or 33% of total disturbance, in northern 18% of TAPS corridor (Pamplin 1979) -loss of 5,36? acres vegetated habitat (Pamplin 1979) resulting in loss or displacement of approximately 2,500 breeding bird pairs, based on McCaffery et al. (1982) census data -1,243 acres riparian willow lost (high bird habitat value; Garner & Reynolds 1986) -no loss of peregrine falcon breeding habitat (USFWS unpbl.) and minimal loss of prey habitat -possible loss of some prey habitat for other cliff-nesting raptors, but not significant (R.E. Ambrose, USFWS, pers. comm.) -amount of habitat lost for tree-nesting raptors not determined -total loss or displacement of 7,200 birds due to direct and secondary habitat loss (USFWS estimate based on McCaffery et al. 1982)	-revegetation of disturbed areas in material sites and above buried pipeline, but effectiveness not assessed -for peregrine falcons-Section 7 Consultation (Endangered Species Act) and recommended protection measures (described in Recovery Plan; USFWS 1982) very effective *within 1 mile of nest sites prohibit habitat alterations or construction of permanent facilities *within 15 miles, prohibit alteration of limited, high quality habitat which could significantly reduce prey availability -other cliff-nesting raptors benefited from protection afforded peregrine falcons -relocation of Pump Station 2 away from peregrine falcon nests at Sagwon Bluffs
changes in species composition or density from changes in habitat quality	-not predicted	-steady increase in nesting bird density from 1976 to 1981 at Mile 12 on the Haul Road suggests bird populations re-establishing territories in areas disturbed by development (McCaffery et al. 1982) -no change in density of raptor populations attributed to habitat change; only peregrine falcons, gyrfalcons, and rough-legged hawks surveyed (Ambrose et al. 1987) -peregrine falcon populations increased due to restrictions on DDT in 1972 (Ambrose et al. 1987)	
impoundments, dust shadow, and "snow-fence" effects	-changes in drainage patterns predicted but changes in bird habitat values not predicted	-nesting densities reduced in Haul Road dust shadow area (McCaffery et al. 1982) -snow and water accumulations made habitat unavailable to nesting birds along pipeline, but later provided feeding area for brood-rearing (Rohsenberger et al. 1980) -geese stage in Haul Road dust shadows very early in season, using some previously unavailable habitat (Murphy et al. 1987) -see BIRDS (PRUDHOE BAY OILFIELDS) for additional documentation of similar effects	-culverts reduced some impounding -no mitigation of dust shadow effects
disturbance	-all birds driven from construction sites, at least temporarily -tolerance to disturbance not quantified -geese, swans, loons, cranes, raptors less tolerant of disturbance than passerines, shorebirds, some ducks -disturbance of females on nests could cause abandonment or predation	-not assessed for most bird species -high nest predation by foxes along Haul Road (Hanson & Eberhardt 1981, Brink 1978) -nesting success of peregrine falcons and other cliff-nesting raptors not reduced by construction activities (R.E. Ambrose, USFWS, pers. comm.) -recreational activities of workers may have reduced peregrine falcon nesting success to small degree (R.E. Ambrose, USFWS, pers. comm.)	-pipeline access roads gated to restrict access and decrease disturbance -prohibition of wildlife feeding an requirement for proper garbage containment, not effective, fox populations increased along roads and near facilities (Milke 1977) -for peregrine falcons, Section 7 Consultation and recommended protection measures (described in Recovery Plan; USFWS 1982) effective, but some lack of compliance with timing restriction (JFWAT unpbl.): *within 1 mile of nest sites require aircraft to maintain minimum altitudes of 1500' above nest level from April 15-August 31; prohibit all ground level activity from April 15-August 31 except on existing thoroughfares *within 2 miles of nest sites prohibit permanent facilities having sustained human activity and prohibit activities having high noise levels from April 15-August 31 -other cliff-nesting raptors benefited from protection afforded peregrine falcons

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
hunting	-potential impacts on peregrine falcon by shooting adults and robbing young for falconry -hunting pressure on waterfowl and raptors could be locally severe -hunting pressure on ptarmigan would be self-regulating through density dependence	-raptors susceptible to disturbance during breeding season but hunting activity concentrated in August and September when most young already fledged -take for falconry not documented in TAPS area north of Brooks Range -public awareness/hunter education reducing incidental shooting of raptors nationwide and probably in Alaska -bird hunting levels not studied, but effects probably minor due to hunting restrictions in pipeline corridor	-Migratory Bird Treaty Act restrictions on shooting raptors -large game hunting prohibition in 5-mile zone on each side of pipeline likely discouraged significant levels of bird hunting
oil spills	-detrimental to birds and habitat, but not quantified -spills in upper Sagavanirktok River drainage could damage habitat and kill waterbirds in internationally important waterfowl area	-Atigun River Spill of 1,500 barrels of crude oil affected 15-25 miles of riverine and riparian habitat (APO unpbl., USFWS unpbl.) -oiled birds found: 15 mew gulls, 2 semipalmated plover nests and incubating adult, solitary sandpiper and other bird nests (white-crowned and tree sparrows) in oiled willows (USFWS unpbl.) -effects of contamination on reproductive success not studied, but probably localized and short term effects due to clean up efforts -loss of nesting habitat in riparian willows probably of longer duration (USFWS unpbl.) -effects of other spills not assessed	-see FRESHWATER QUALITY AND QUANTITY (TAPS)

BIRDS (PRUDHOE BAY OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct habitat loss by gravel fill and extraction	-6,745 acres in oilfield would be destroyed or modified	-11,025 acres total habitat lost from existing or currently proposed gravel fill and excavation in Prudhoe Bay and surrounding oilfields (Table 2): *Prudhoe Bay and Lisburne existing: 6,705 acres *Kuparuk and Milne Point existing: 3,310 acres proposed: 665 acres *Endicott existing: 345 acres	-consolidation of facilities -use of winter ice pads for pipeline construction, not done for many major projects (Prudhoe Bay, Lisburne) but done for Endicott and proposed for Kuparuk expansion
change in habitat associated with secondary effects of gravel fill	-not predicted	-as of 1983, within 3 study blocks of Prudhoe Bay oilfield, 10% habitat loss to gravel fill, 25% habitat modified by impoundments, dust, gravel spray, debris, tracks, thermokarst, and other disturbances (Walker et al. 1986b)	-road routing and pad placement to avoid highest value wetland types (Classes III, IV, VI, Bergman et al. 1977) to minimize waterfowl habitat loss and avoid impoundment problems -minimal mitigation for shorebird nesting habitat loss
population decrease due to habitat loss	-displaced birds assumed lost from population, but not quantified -greater losses expected where habitat limited	-as of 1978 loss of 2,500 acres of habitat equated with loss of 1,000-2,000 pairs of nesting shorebirds (Connors et al. 1984) -as of 1985 direct loss of 3,440 acres of habitat in Prudhoe Bay oilfield which would support 3,200 shorebirds (about 5% of local population) (Meehan 1986) -as of 1987 loss or displacement of 13,300 birds due to direct and secondary habitat loss (USFWS estimate based on Troy 1987)	-see above
changes in species compositions or density from changes in habitat quality	-not predicted	-in 1984-85 lower bird densities for 6 shorebird species found in Prudhoe Bay oilfield compared to control site, 13% reduction in numbers, 11% reduction in nests (Meehan 1986) -loss not quantified for other species -greater white-fronted goose and king eider nesting densities lower in oilfield than in control area (Troy 1987) -oldsquaw and Pacific loon found breeding only in control area (Troy 1987)	-none

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
road dust shadow effects	-dust covering vegetation predicted, but loss of bird habitat value not predicted	-significantly lower densities of nesting shorebirds and passerines (especially semipalmated sandpiper, red phalarope, dunlin, Lapland longspur) documented in areas affected by dust shadows adjacent to heavily travelled roads, compared to adjacent areas (Connors et al. 1984, Troy 1986, 1987) -estimated road effects triple number of birds lost due to direct habitat loss (Connors et al. 1984)	-road watering for dust control only in summer -despite heavy watering on Endicott road, heavy dust up to 150' away (Burgess & Ritchie 1987)
early snowmelt resulting from dust shadows	-not predicted	-bird density on heavily dusted side of lightly travelled roads is higher than on less dusted side, indicating roads act as snow fences and dust offsets effect by facilitating snow melt (Troy 1987) -early snowmelt areas induced by dust shadows along roads attract and concentrate migratory birds (especially waterfowl and red-necked phalaropes) in the oilfield early in the nesting season (Troy 1987, Murphy et al. 1987) -benefit (early feeding habitat) or detriment (increased disturbance and exposure to contaminants) not documented	-none
late snowbank melt along roads	-not predicted	-densities of early nesting species (semipalmated sandpiper, dunlin, Lapland longspur) reduced in roadside areas affected by persistent snowbanks and impoundments (Troy 1986, 1987)	-none
impoundments along roads	-alteration of drainage patterns predicted, but resulting loss of bird habitat not predicted	-3,453 acres of construction-related impoundments in Prudhoe Bay oilfield as of 1983, acres not quantified for other adjacent oilfields (Walker et al. 1986b) -reduced shorebird breeding densities but increased densities of late summer migrants (Connors et al. 1984) -eliminated habitat or reduced suitability for 6 of 15 species during the breeding season (greater white-fronted goose, king eider, semipalmated sandpiper, dunlin, buff-breasted sandpiper, and Lapland longspur) (Troy 1986) -provided "preferred" feeding habitat for northern pintail, red-necked phalarope, and red phalarope during breeding season, but not "preferred" nesting habitat for any species (Troy 1986)	-culverts to maintain drainage patterns variably effective -culverts not possible for large pads
road effects on bird densities from combined sources of impact (disturbance, impoundments, dust)	-not predicted	-overall breeding season bird use and nesting population density lower within 320' of roads than away from roads (Troy 1986, 1987) -higher than expected use within 320' of road by long-billed dowitchers, red-necked phalaropes, and snow buntings (Troy 1986) -semipalmated sandpipers and red phalaropes significantly lower nesting densities adjacent to roads than away from roads (Troy 1987) -lower nesting densities along roads shown for Lapland longspurs, dunlins, stilt sandpipers, and greater white-fronted geese (Troy 1987) -lesser golden-plovers avoided roadside areas for nesting (Troy 1987) -red-necked phalarope only species with higher nesting densities adjacent to roads (Troy 1987)	-some pipeline pads and roads gated to minimize traffic induced dust and disturbance
road effects on bird reproductive success	-not predicted	-poor reproductive success for Canada geese in 1986 within 300' of roads (Murphy et al. 1987) -successful greater white-fronted goose nests located more than 150' from roads with moderate traffic (Murphy et al. 1987)	
population increases for some species from habitat changes or artificial feeding	-not predicted	-pipelines and debris along roadsides provided nest sites for snow buntings (Troy 1986) -glaucous gulls in high concentrations at North Slope Borough landfill in Prudhoe Bay (Murphy et al. 1987) -feeding by work crews (Hanson & Eberhardt 1981)	-environmental education program for work crews to discourage feeding of wildlife largely ineffective (USFWS unpbl.)

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
modification of estuarine and shoreline habitats by gravel removal	-estuaries which attract waterfowl may be modified by gravel removal from islands, reefs, and spits	-no documented effects due to minor amounts of gravel removal prior to State regulation	-State regulations prohibit gravel removal from islands, reefs, and spits due to conc for modification of lagoon a estuarine habitats and loss (island nesting habitat for eiders, gulls, terns, and ge
modification of marine and shoreline habitats by construction of gravel causeways and artificial islands	-not predicted	-artificial gravel pier (West Dock) used less than adjacent mainland shorelines by passerines and several shorebird species, but densities of red-necked phalaropes extremely high (Connors et al. 1984) -molting oldsquaw densities in Stump Island Lagoon reduced in 1981 and 1982 by West Dock causeway extension; no adverse effects suggested by 1983 data (Envirosphere 1987) -changes in water quality could affect bird prey species availability and could modify saltmarsh habitat used by brood-rearing and staging geese, but effects not documented	
oil spills	-detrimental to birds and habitat, but threat not quantified -migratory birds restricted to coastal habitats especially vulnerable to oil -tens of thousands of molting oldsquaw and lesser numbers of common eiders, glaucous gulls and arctic terns potentially affected -ducks concentrated on rivers during migration particularly vulnerable to oil on water	-no assessment of spill effects on birds -few reports of oiled birds	-see FRESHWATER QUALITY AND QUANTITY (PRUDHOE BAY OILFIEL
contaminants onshore	-oil sumps or pools may attract and cause mortality of ducks, shorebirds, songbirds, and raptors, especially early migrants -other contaminant effects not predicted	-birds use reserve pits particularly during spring staging (open water earlier than tundra sites) when pits collect hydrocarbons from winter spills (Brad Fristoe, ADEC, pers. comm.; USFWS unpbl.) -no study of extent of bird use of reserve pits or effects of contaminants on reproductive productivity -reserve pit fluids have adverse effects on tundra pond water quality and macro-invertebrate communities (West & Snyder-Conn 1987) which may affect bird food supply, but not studied	-ADEC regulations reduced quantity of produced fluids, and required better containment in pits -no studies of effectiveness in mitigating impacts to birds
contaminants offshore	-not predicted	-USFWS data show persistent heavy metal and hydrocarbon contamination from offshore drilling effluent disposal in benthic sediments of shallow-water, low-energy environments; local effects on birds more likely than on other marine organisms since benthic infauna is food source for marine birds, but not studied	-NPDES permits limit disposal within 2-m isobath, effective only in moderate and high-ener environments
hunting (recreational and subsistence)	-new pressures on relatively untouched breeding populations	-not studied, expected to be minor in oilfields -subsistence hunting pressure likely increased in Colville Delta from establishment of village of Nuiqsut in 1970 due to Prudhoe Bay development	-company policies prohibit firearms in oilfield -State game regulations prohibit big game hunting in most of oil field -prohibitions apparently effective in limiting bird hunting opportunities

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
increased predation from higher predator populations	-not predicted	-observed high predation to brant and Canada goose nests by fox and glaucous gulls (unnaturally high predator populations in oilfield): *arctic fox depredated 5% of active goose nests in 1985 and 14% in 1986 *glaucous gulls depredated 32% of active goose nests in 1985 and 2% in 1986 (Murphy et al. 1986, 1987) -shorebird nesting success higher in 1972 in Prudhoe Bay after fox populations deliberately reduced by trapping (Norton et al. 1975)	-occasional trapping of foxes -garbage management ineffectiv
barriers to bird movements	-not predicted	-of 17,000 birds estimated flying over 7.8 mile section of new powerline, 15-150 (.09-.89%) estimated collisions (Murphy et al. 1987) -severe behavioral responses to pedestrian and vehicle traffic during road-crossing attempts by brood-rearing snow geese along Endicott Road (Burgess & Ritchie 1987) -23 snow geese collided with West Dock Seawater Treatment Plant (ARCO, pers. comm.)	-some powerlines buried or hung from pipelines
road and construction disturbance effects on nesting waterfowl	-all birds driven from construction sites, at least temporarily -tolerance to disturbance not quantified -geese, swans, loons, cranes, raptors less tolerant of disturbance than passerines, shorebirds, some ducks -disturbance of females on nests could lead to abandonment or predation	-oilfield activity and disturbance possibly altering tundra swan distribution and decreasing reproductive effort (Murphy et al. 1986, 1987) -oilfield disturbance one factor influencing low Canada goose and brant breeding productivity in Lisburne Development Area (Murphy et al. 1986, 1987) -Canada geese and greater white-fronted geese altered behavior patterns near roads during nesting season (Murphy et al. 1986, 1987) -cumulative effects of physiological stress from disturbance impacts may affect survival and reproduction rates but not assessed -disturbance effects on only U.S. snow goose nesting colony predicted in EIS for Endicott development project; monitoring studies thus far indicate noise and vehicle traffic along Endicott road (1 mile from colony) influenced snow goose nesting behavior patterns of nest attendance, and nesting distribution; snow goose nesting success rates lower and gosling mortality rates appear higher subsequent to Endicott construction, but no impact on numbers of geese in colony shown (Burgess & Ritchie 1986, 1987)	-road closures during summer to reduce disturbance from vehicular and human traffic partially effective (Waterflood, Kuparuk pipeline road, Lisburne pipeline pads) -winter construction of roads and pads to avoid construction impacts; not for most recent major projects (Lisburne, Endicott) but proposed for Kuparuk expansion
road and construction disturbance effects on brood-rearing geese	-see above	-brood-rearing snow geese rarely fed undisturbed within 300' of Endicott road during heavy construction traffic in 1985 and avoided road in 1986 (Burgess & Ritchie 1986, 1987) -mild but statistically detectable effect on brood-rearing snow geese activities up to 2.2 miles from Endicott road (Burgess & Ritchie 1987)	-see above
aircraft disturbance effects on goose behavior	-see above	-fixed-wing aircraft overflights caused reactions by 33% of male and 19% of nesting snow geese (Burgess & Ritchie 1987) -less than 20% of greater white-fronted geese and Canada geese reacted to fixed-wing and jet aircraft, but 40% reacted to helicopters (Murphy et al. 1987) -brood-rearing snow geese reacted to 52%-72% of aircraft disturbance events (Murphy et al. 1987)	-flight corridors and flight ceilings established for Endicott development to avoid disturbance to nesting and brood-rearing areas generally effective, but some compliance problems with non-oilfield aircraft, and weather condition often necessitate lower flight ceilings for safety reasons (Burgess & Ritchie 1987, Garner & Reynolds 1986)
human pedestrian disturbance effects	-see above	-more than 50% of Canada geese reacted to pedestrian disturbance events, including trash clean-up crews (Murphy et al. 1987)	

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct disturbance	-disturbance/harassment by human activity, noise, vehicles, aircraft etc. during TAPS construction and operation with adverse physiological effects on individuals and likely avoidance of disturbance areas	-disturbance of individuals and groups during pipeline construction and oilfield development, and continues with operational activities (Cameron et al. 1979, Shideler 1986) physiological stresses not studied -disturbed areas avoided (Cameron et al. 1979, Shideler 1986)	-restrictions on low-level aircraft operations and wildlife harassment implemented and monitored during TAPS construction -compliance not 100%, but over-all harassment impacts reduced -noise, ground vehicles, and human presence disturbance not completely avoided
obstruction of movements	-oil pipeline on gravel berms for major portions of TAPS could result in: *delay or failure to reach traditional habitats *reduce efficiency of range utilization *isolate from essential ranges, ultimately reduce populations *combined TAPS/Prudhoe Bay oilfield infrastructure could substantially influence summer range utilization along arctic coast -above ground pipeline on berms in vicinity of upper Sagavanirktok and Atigun Rivers could obstruct large spring migrations -road traffic as additive influence to pipeline on movement -above ground elevated pipeline with frequent provision of best available design animal crossing facilities, partial barrier to movements still predicted	-most above-ground sections ultimately supported by vertical support members which allow caribou passage (see mitigation) -TAPS route generally parallels caribou migrational routes, not perpendicular barrier to migration routes (routes not well known when predictions made) -spring and early summer movements across TAPS abnormally low (Whitten & Cameron 1983) -normal east-west movements during summer in Prudhoe Bay coastal area essentially blocked by intensive industrial structures and activities (Whitten & Cameron 1983) -no large spring migration since TAPS construction -cause of no post-construction large spring migrations unknown -large migrations of Western Arctic Herd occurred prior to construction -actual impacts on large spring migrations unknown -caribou less successful in crossing elevated pipeline when paralleled by road with traffic (Curatolo & Murphy 1983) -Central Arctic Herd spring and early summer movements across TAPS partially restricted in spite of extensive elevated pipelines (Whitten & Cameron 1983)	-design modification from original on-the-ground pipeline design to elevated pipeline reduced impact -stipulations implemented for minimum pipe elevation in most above ground sections in known movement corridors -caribou movements partially facilitated by adequately elevated pipe -effectiveness of elevated pipe greatly reduced where road traffic adjacent to pipeline (Curatolo & Murphy 1983) -moderate consolidation of facilities without significant benefit to caribou -separation of roads and pipelines partially incorporated in recent oilfield development design -road/pipeline separation effectiveness variable based on: *intensity of industrial infrastructure *environmental factors *specific movement patterns (Curatolo & Murphy 1983) -extensive elevated pipeline accomodates fall and winter moves -mitigation only partially effecti for spring and early summer movements (Whitten & Cameron 1983
displacement from preferred habitats	-disturbance from TAPS and Prudhoe Bay construction and operation could cause avoidance of activity areas -increased mortality of displaced animals or displacement of other animals in adjourning habitats	-females with young calves avoid industrial activity areas (Cameron et al. 1979, K.W. Whitten, pers. comm.) during calving and post-calving seasons (late May-August) -effects of displaced calving on survival and population dynamics not adequately studied -removal of wolves and brown bears may partially compensate for calving displacement impacts (Milke 1977)	-timing restriction of constructio activities and traffic restrictio partially effective (K.W. Whitten ADF&G, pers. comm.)
direct mortality	-small amount of mortality from entrapment in mud ditches, pipe trenches and snowdrifts if left unattended and caribou not disturbed by other human activity -increased mortality from collisions with road vehicles if caribou periodically attracted to roads by differential snow and vegetation conditions -general increase and concentration of hunting pressure if TAPS corridor north of Livengood opened to public use	-little mortality from entrapment -disturbance kept caribou from encountering these risks -low incidence of mortality from vehicular collisions -relationship between vehicular collisions and attraction factors not studied -in spite of Department of Transportation restrictions on public access, hunting closures, and prohibition of off-road vehicles, estimated harvest increased from less than 300 in 1983 to over 1,000 in 1985 (K.W. Whitten, ADF&G, pers. comm.)	-field monitors patrolled TAPS during construction, identified potential environmental hazards and made recommendations to appropriate authorities -implementation of stricter ADOT&PF and Alaska Game Code provisions on hunting from Haul Road resulted in substantially reduced harvest i 1986 (K.W. Whitten, ADF&G, pers. comm.)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
reduced growth and survival of lichens (important winter forage) from atmospheric pollutants released by TAPS pump stations	-local atmospheric conditions at TAPS pump stations could reduce or completely eliminate lichens in some cases -extensive winter ranges make local effects negligible -if intermediate levels of atmospheric pollutants from pump stations more widely dispersed, lichen growth could be reduced over large area and thus reduce carrying capacity	-effects of atmospheric pollution on lichens not studied; likely negligible due to use of low-sulfur fuels and production of low-sulfur crude	-none

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
disturbance	-disturbance from construction activities would displace animals -lower levels of disturbance would continue through operation -wide ranging species (grizzly bear and wolf) least affected -sheep most affected -mammals may be deterred from pipeline area due to insulation, odor, sound of flowing oil, and differential snow accumulation from drifting around pipeline	-avoidance of construction noted, not quantified -sound of oil in pipeline not a problem due to insulation around pipe (USFWS unpbl.) -odor not a problem	-construction in Atigun Canyon scheduled during mid and late summer when sheep are mostly dispersed to the south -some gravel mining sites withi[n] Dall sheep lambing areas disapproved (Burger & Swanson .
direct mortality	-displaced animals could result in reduced populations -direct mortality to moose from traffic collisions -pipeline construction ditch may entrap hoofed animals and bears -grizzly bear, polar bear and Dall sheep most directly influenced from increased hunting pressure - improved access -habitat loss would displace animals and result in reduced populations	-large numbers of problem bears killed (defense of life and property) during construction (Milke 1977) -many of problem bears continue to be killed (defense of life and property) after construction by maintenance crews -mortality related to animal feeding; animals attracted to right-of-way for handouts struck by vehicles (Milke 1977) -moose mortalities from traffic collisions common occurrance, but unquantified -no entrapment in open ditch reported (USFWS unpbl.) -several reports of furbearers shot by truckers (Milke 1977) -improved access following construction resulted in greater hunting and trapping pressure and reduced numbers of game animals near the Pipeline (ADF&G unpbl.). Illegal hunting recognized as serious problem by State, but implications on large mammal populations not quantified -for Sagavanirktok River valley, 355 acres out of 1,675 acres (21%) of riparian moose habitat was disturbed by TAPS construction; 58% of this habitat (206 acres) could not be rehabilitated (Densmore et al. 1987)	-corridor of five miles on both sides of pipeline centerline closed to hunting with firearms, north of Yukon River -hunting and firearms prohibited during construction -firearms prohibited in oilfield
loss of habitat	-herbivores may be attracted to vegetation over heated pipe and to snow free condition due to heated buried pipe	-impacts of habitat loss on large mammals not quantified -no preferential feeding reported (USFWS unpbl.)	
obstruction of movements	-effect of above-ground portion of pipeline on large mammal movement cannot be conclusively predicted -knowledge of behavior reaction is limited and not a sound basis for design and spacing of animal crossing facilities -above ground pipeline with frequent provisions for animal crossing facilities of best possible design would act as partial barrier to hoofed animals	-crossing difficulties for grizzly bear and moose not reported (USFWS unpbl.) -see CARIBOU (TAPS AND PRUDHOE BAY OILFIELDS)	-stipulation requiring facilities to allow passage of large animals
feeding by humans	-carnivores, particularly bears and to a lesser extent, wolves often create nuisances or destroy property -improper disposal of trash could result in carnivores depending upon an artificial food source and losing fear of man -feeding would not occur with construction but would with public use	-extensive feeding by construction workers and camp personnel (Milke 1977, Follman et al. 1980) -improper garbage disposal and faulty incineration common, garbage as food source readily available (Milke 1977) -buildings and vehicles damaged by bears searching for food (Milke 1977) -notable concentrations of bears and wolves near camps feeding on garbage and handouts (Milke 1977)	-pipeline company anti-feeding policy ineffective due to lack of enforcement -feeding problem termed "out of control" required passage of State legislation prohibiting feeding and setting a fine of $1000 (State Law 5AAL 81.218, Feeding of Game) -relocation of problem animals ineffective
disease transmitted	-not predicted	-several workers bit by problem animals required rabies vaccinations and animal usually destroyed (Follman et al. 1980)	

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
direct impacts from construction	-direct impact of construction on smallest mammals (microtines) of limited magnitude and short duration total 39,215 acres lost, only individual animals with home ranges within or overlapping actual construction zone would be destroyed or displaced	-actual small mammal habitat destroyed or disturbed 33,500 acres for entire TAPS route as of July, 1978 (Pamplin 1979) -approximately 5,262 acres of vegetated habitat (small mammal habitat) lost or significantly disturbed for North Slope (Pamplin 1979) -direct destruction or displacement of small mammals not quantified	-none
habitat alteration within construction zone	-vegetative cover rendered unsuitable for one species replaced relatively quickly by cover favorable to similar or related species, thus minimal net loss to food chain	-impacts on microtine densities and distributions localized and related to impacts on vegetation communities (Brink 1978) -habitat loss greatest impact on microtine rodents, but significance to local population densities unknown -net impacts not quantified	-stabilization and restoration required on all disturbed areas resulted in largely unsuccessfu[l] restoration
indirect habitat impacts from construction	-little measurable indirect impact on total system, therefore small impact on small mammals (microtines) -little adverse direct or indirect impact on larger rodents and small predators	-positive correlation between small mammal population and distance from nearest pipeline structure, probably related to habitat preference (Brink 1978) -habitat alterations affecting microtines caused by gravelled areas, water inundation, dust fallout and coating, revegetation, off-road vehicles disturbance, and oil contamination (Brink 1978) -small mammals absent from study area inundated by water impoundments due to inadequate drainage structures (Brink 1978)	-culverts reduced some impoundin[g] -mitigation of dust shadow effect minimal
increased soil temperature above buried pipeline/ microclimate adjacent to elevated sections of TAPS	-potential for direct and indirect impacts -heat from buried TAPS would favor vegetation growth -would benefit smaller rodents best adapted to favored vegetation -would benefit predators	-impacts not documented	-none
increased trapping pressures on furbearers	-additional trapping harvest acceptable with proper harvest	-increased harvest due to improved access but impact level not documented	-TAPS/Haul Road corridor closed to trapping during construction, probably effective -no subsequent mitigation
oil spills	-direct adverse short-term impact, level of impact contingent on place, habitat and season, ranging from minute to severe -possible mortality to scavengers from ingesting petroleum from oil-killed animals	-no known impacts	-design standards, valves, surveillance and monitoring required to minimize risk of spill -approved oil spill contingency plans required, oil spill reporting requirements -immediate cleanup required of all spills
increased predation	-not predicted	-predation on microtines increased along TAPS and Haul Road corridor due to artificially high densities of Arctic foxes attracted to artificial food sources (i.e. garbage and direct feeding) along pipeline and road (Brink 1978) and direct feeding)	-incineration of solid wastes -animal feeding prohibited -mitigation only partially effecti[ve] due to poor waste management and inadequate enforcement
riparian habitat alteration from material sites	-not predicted	-enhanced ground squirrel habitat and increased ground squirrel populations within disturbed areas, after completion of mining (Woodward-Clyde 1980) -vegetation removal in Arctic floodplains eliminated or drastically reduced local populations of small microtine mammals other than ground squirrels (Woodward-Clyde 1980) -rate of recolonization of mined sites directly related to redevelopment of vegetated habitats (Woodward-Clyde 1980) -microtines did not begin to reuse disturbed areas as primary habitat until development of a multi-layer of vegetation cover with densities of at least 60-70% (Woodward-Clyde 1980)	-stabilization and restoration required on all disturbed areas but largely unsuccessful

SMALL MAMMALS (PRUDHOE BAY OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
gravel fill during construction	-total loss of 6,745 acres of habitat from gravel fill -population loss will be small percentage of total population	-total loss of 11,025 acres of vole, shrew, lemming, pika and squirrel habitat from gravel fill in oilfields (Table 1) -population level impacts unquantified -some Arctic fox den sites covered by gravel fill	-minimize impacts through si considerations -some siting away from fox d
habitat loss due to pad and road maintenance	-not predicted	-vegetation loss from snow removal, spreading gravel, debris, and contaminants off edge of pads and roads (Walker et al 1987a) -loss and change of vegetation from road traffic dust (Brown & Berg 1980) presumed to impact small mammal populations, not quantified	-snow removal plans provide selected snow removal locat -only partially effective, d still put on tundra, but so localized -road watering, only partiall effective, sources limited i some areas, contaminated wat often used for road watering
hydrocarbon or other contaminant spill on tundra	-ingestion of contaminants -high localized mortality, but unquantified -larger predatory mammals prey on contaminated smaller mammals (i.e. fox eating voles)	-many oilfield pit leaks during 1986-87 period, ADEC documented 19 pits leaking (ADEC unpbl.) -impact on mammals not studied	-impermeable containment berm pit clean up schedules -mitigation only partially effective (USFWS unpbl.) -see FRESHWATER QUALITY/ QUANTITY (PRUDHOE BAY OILFIE
increased predation due to increased fox populations	-not predicted	-Arctic fox populations not surveyed, but high bird nest predation documented (Murphy et al. 1986) -likely increases of predation on microtines but not studied	-trash and waste control -generally only partially eff because fox gain access to f sources or purposefully fed workers

MARINE MAMMALS (TRANS-ALASKA PIPELINE SYSTEM AND PRUDHOE OILFIELDS)

IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
oil pollution	-a maximum of 64,000 barrels of oil could reach the marine environment via Sagavanirktok River in event of a major pipeline break -oil wells and feeder pipelines a greater threat of spill than the TAPS line -whales present only seasonally so exposure would be brief -polar bear are highly mobile and could contact an unconsolidated spill -if large quantities of oil became dispersed in the Beaufort Sea, biological productivity throughout the food chain could be affected	-no major spills into the marine environment have been documented	-contingency planning (leak detection and location, minimization of spill, and containment -see MARINE WATER QUALITY
increased hunting pressure	-not predicted	-instances of legal or illegal take of polar bear (USFWS unpbl.) -several bowhead whales taken during subsistence hunts facilitated by improved access and use of construction facilities on islands (USFWS unpbl.)	
attraction to human facilities	-not predicted	-polar bears and other scavengers attracted to facilities, some destroyed as nuisances, also some instances of improperly disposed waste materials (waste products from bowhead whale butchered at West Dock) attracted polar bear (USFWS unpbl.)	-State regulations controlling disposal of wastes generally effective
reduced denning in development area	-not predicted	-polar bears have historically denned in vicinity of Prudhoe Bay; no recent records -ringed seal denning on ice near development area temporarily reduced during construction (Frost & Lowry 1984)	

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
increased human access	-access to 160 mile strip of land from Brooks Range to Beaufort Sea not previously accessible by road (total acreage access not predicted)	-access to about 1,600 square miles used for hunting, recreation, fishing, mining, tourism (BLM 1987) -significant impact from corridor becoming major commercial transportation artery from North Slope to rest of Alaska (ADOT-PF unpbl.)	-land use planning by State, Borough, and BLM -land use restrictions not comprehensive -land use planning not addres[ses] all impacts of TAPS operatio[n]
increased demand for land use and ownership in area adjacent to pipeline corridor	-relatively limited demand due to remoteness and climate severity factors	-high demand for lands adjacent to pipeline corridor, BLM presently addressing demand thru EIS process (BLM 1987) -two areas (Yukon River crossing and Coldfoot) presently developed for pipeline service facilities; more are likely	-comprehensive land use planni[ng] -since the disposal process is ongoing, level of impacts and effectiveness of planning process cannot be assessed for many years
short term and permanent alteration of land values	-temporary and permanent alteration of about 5,500 acres: *reduced scenic value (aesthetics) *reduced recreational value (fish stock depletion, reduced game numbers)	-impact to scenic and recreational values is double the amount predicted, i.e., 10,900 acres (Pamplin 1979) affected during construction -operation and maintenance added additional significant impacts to corridor due to additional gravel extraction and Haul Road upgrade	-construction stipulations (Alaska State Stipulations for the Trans-Alaska Pipeline -joint State/Federal oversite of construction effective in reducing impacts
altered subsistence values	-oil spill could result in major impact to aquatic species used in subsistence, EIS estimated 25,000 bbl would cover 6.6 acres of terrestrial habitat, unknown area in aquatic habitat -disturbance to rivers and floodplains could reduce fish populations important to subsistence	-Atigun River spill (50,000-100,000 gallons) only major TAPS pipeline spill -several spills at camps and other facilities estimates of impacts: -valve spill at Franklin Bluffs (1977) 1,500 bbls over 21 acres -cumulative small spills, estimate 5-10 acres (ADEC unpbl.) -see WATER QUALITY AND QUANTITY (TAPS) -significant disturbance to floodplain area from construction and material extraction -potential game population reductions, not quantified	-see oil spill measures in FRESHWATER QUALITY/ QUANTITY (TAPS)

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IMPACT CATEGORY	PREDICTED BY TAPS EIS	ACTUAL IMPACTS	MITIGATION
altered land use pattern-change in aesthetics	-Alaska North Slope considered largest intact wilderness area in United States -development would reduce space, habitat, and natural scenic qualities -wilderness intrusion would be permanent -placement of 16 million cubic yards of gravel for construction of oilfield development infrastructure	-actual area of impact significantly greater than predicted, 800 square miles of pristine wilderness permantly altered -proliferation of development on-going -placement of 60 million cubic yards gravel (Table 2)	-standard siting, construction, and operation stipulations, including consolidation of facilities to minimize visual impact, only marginally effective
increased human access	-predicted to be both detrimental and beneficial *detrimental from increased presence of man *beneficial by providing greater opportunity for individuals to experience wilderness -increased hunter access and pressure would be minimal due to remoteness and logistical cost to access area	-road access to areas previously inaccessible by vehicular traffic: *during winter about 110 miles of coast from Nuiqsut (64 miles west of Prudhoe Bay) to Point Thomson (32 miles east of Prudhoe Bay) *during summer, about 50 miles of coast accessible -benefit to public wilderness experience not realized because roads severely restricted for official business use or by North Slope residents -Prudhoe Bay now active staging area for hunting and fishing activities by fly-in recreationalists	-access restrictions reduced impact from increased recreational use, but not from local residents and industry use
increase in land use and ownership in areas adjacent to oilfield development	-limited demand beyond oil industry needs in immediate Prudhoe Bay area	-extensive development for support services (Deadhorse) not predicted *98 private leases of state property from ADNR approximate total acreage = 1,500 acres (ADNR unpbl.) *airport and ADOT&PF related activities and leases = 823 acres (ADOT unpbl.)	-State agency regulation of support services activities only partially effective, worst violations of regulations by oilfield service activities (ADEC unpbl.)
winter tundra travel/operations	-see VEGETATION (PRUDHOE BAY OILFIELDS)		
altered subsistence values	-addressed indirectly in EIS, stating that development would cause: *recreational competition with native subsistence activities * greater restrictions on bag limits	-predicted impact of greater hunting pressure occurred -total closure to hunting of large portions of the North Slope within the oilfield, about 525 square miles not predicted	-none
cumulative effect of development of satelite oil-fields as direct result of Prudhoe Bay field and TAPS	-not predicted	-several additional oilfields have or may cause impacts of similar nature and scope as Prudhoe Bay: 1. Endicott 2. Milne Point 3. Seal Island 4. Colville Delta 5. Point Thomson 6. Arctic National Wildlife Refuge	-standard, "state-of-the-art" mitigation with potentially same short comings previously experienced

V. SUMMARY

This discussion summarizes the salient points of the preceding comparison of environmental impacts for each of the resources considered.

A. Air Quality

Predictions for the pipeline and North Slope pump stations were that air quality standards would be met and that gaseous emissions would be low. Modelling of nitrogen oxides, sulfur dioxide, and carbon monoxide levels, based on manufacturer specifications and source performance tests, supported these predictions. However, no ambient air quality monitoring has occurred along the pipeline to verify the modelling results. The most serious air quality problems documented during construction and operation related to dust from wind and vehicular erosion of disturbed areas and roads, particularly the Haul Road. Dust impacts, including impaired visibility, were not predicted.

For the Prudhoe Bay oilfield, no quantitative predictions of emissions were made. Limited ambient air monitoring data from the oil industry (for the periods 1979-1980 and 1986-present) indicate that national standards for nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and total suspended particulates have all been met on an annual basis. However, short-term violations of ozone and total suspended particulate standards have occurred and levels of non-methane hydrocarbons have been high, indicating that temporary deterioration of certain air qualtiy characteristics does occur. The impacts from these short-term variances on habitat or wildlife have not been assessed.

The adequate air quality can be attributed to excellent dispersion conditions (high winds and no physical barriers), the low-sulfur content of the Sadlerochit oil, and agency requirements for best available control technology, inspections, and review. However, the current development of the Lisburne oilfield, with high-sulfur crude oil, as well as the continued addition of other satellite oilfields, may alter the air quality patterns thus far observed.

B. Freshwater Quality and Quantity

The EIS predicted only minor overall effects from the Pipeline System on the physical and chemical quality of water, with qualitative predictions of some impacts during construction, but no impacts on water quality during operation, except the potential for oil spills. Many of the construction and operations impacts did occur; thus, the predictions were accurate in a qualitative sense. However, the frequency and magnitude of impacts resulting from erosion and sedimentation, alteration of natural drainages, losses or impoundments of surface flow (as related to fish passage), and oil spills were frequently understated, and constituted the most significant and pervasive environmental problems caused by construction and operation of the Pipeline System.

In Prudhoe Bay, reduced freshwater quality and quantity were predicted to result from drainage of one lake, gravel extraction, local oil spills, and erosion from construction activities. In addition to drainage of the large lake, numerous other ponds and lakes have been partially filled with gravel for construction of roads and pads, causing substantial losses of aquatic habitat. Unauthorized gravel extraction from active floodplains also had major temporary and some long-term impacts, including siltation, sedimentation, diversion, and impoundment of water and fish. Impoundments due to blocked drainage (an impact not predicted) were extensive, resulting in the flooding of several thousand acres and the drying out of adjacent areas. Other aquatic impacts within the oilfield which were not predicted include: contamination of ponds and lakes adjacent to drill sites by heavy metals and/or hydrocarbons from reserve pit discharges or seeps, lake eutrophication by sewage, and spills of hazardous materials. The biological implications of these changes have not been fully assessed.

The frequency or magnitude of erosion and sedimentation impacts were not quantified in the EIS, although they were considered to be possible. Actual impacts during pipeline, Haul Road, and oilfield construction were widespread and severe, and recurring siltation problems resulted from construction in and near rivers, streams, and lakes, and from stream crossings along the pipeline and Haul Road. Two unpredicted sources of siltation were annual road washouts and erosion of stockpiled overburden at gravel excavation sites.

Pipeline oil spill frequencies were not predicted, their size was underestimated, and their anticipated source was limited to pipeline leaks. Actual impacts occurred from numerous sources, including undetected leaks in buried fuel lines at construction camps and spills from fuel truck accidents. No follow-up studies have assessed the actual water quality impacts from oil spills.

Water consumption at pipeline camps and facilities was estimated, but actual usage has not been fully documented. Predicted use did not include quantities required to construct ice roads and pads along the pipeline or in the oilfields. At the time of the predictions, the technology of ice road/pad construction had not been developed. The quantity of water required for development of the oilfields, for both domestic and industrial use, was not anticipated. Initially inadequate planning led to shortages, indiscriminate water withdrawal, and some fish kills. Upon recognition of the problem, adequate non-fish-bearing sources were identified. Industry also accidentally or purposefully created large reservoirs when breached riverside gravel pits diverted streamflow during breakup.

Recent development of stricter monitoring requirements for wastewater discharge and implementation of Corps of Engineers 404 permitting with agency review and monitoring have been critical to reducing overall impacts to natural waters, as has State compliance monitoring and regulations protecting water quality and anadromous fish streams.

Oil industry reporting and cleanup practices have been relatively effective in reducing oil spill volumes and impacts to tundra and natural water bodies, but service industry compliance has been a problem. Often the specific offending party cannot be identified or located. The recent refusal of oil companies to accept and inject third-party (service industry) hazardous substances can be expected to increase the incidence of illegal disposals to natural waters and wetlands.

C. Marine Water Quality

Since expansion of production into the marine environment was not foreseen in the EIS, the only effect on marine water quality predicted to result from development of the pipeline and the oilfields was the possibility that an oil spill into one of the major streams along the Arctic coast might reach the Beaufort Sea. However, the probability of such an event and its effects on marine systems were not quantified. Although major spills have not occurred, numerous minor spills from heavy equipment operations, support facilities, and drillsites have entered the nearshore zone. The cumulative impacts of these spills have not been assessed.

The additional effects of seawater treatment chemicals, drilling effluents, and other wastewater discharge from offshore drilling islands, and alteration of oceanographic conditions through the construction of causeways, were not predicted. Some adverse effects from these activities have been measured, but their implications for biological systems can only be assessed over the long term. National Pollutant Discharge Elimination System permit stipulations appear to have reduced discharge effects, but effective mitigation of causeway-induced oceanographic changes has not been achieved.

D. Freshwater Invertebrates

Localized toxic responses were predicted for aquatic invertebrates subjected to oil spills or oily discharges. Local losses through burial of invertebrates were also predicted as a result of erosion and sedimentation during construction and maintenance activities. Neither the magnitude nor the duration of these impacts was quantified.

Limited post-construction studies have shown long-term reductions in productivity and taxonomic diversity in some streams adjacent to the pipeline and Haul Road, although no studies were conducted during construction when impacts were most severe. Numerous oil spills contaminated both lotic and lentic freshwater bodies along the pipeline corridor, but neither the extent nor duration of biological effects from oil contamination have been assessed.

There have been few documented spills of oil directly into freshwater in the oilfields. However, contaminated snow bulldozed off the pads and lightly oiled reserve pit fluids have been sources of contamination. Loss of crustaceans from tundra ponds receiving these fluids was statistically correlated with aromatic hydrocarbon concentrations. Decreased taxonomic diversity and abundance of nondipteran invertebrates was also found at these sites and attributed to degraded water quality and contaminant levels. Certain reserve pit fluids were shown to exert subacute and chronic toxicity even when diluted. Sedimentation and turbidity are suspected as having adverse effects, but have not been studied or quantified.

In recent years, more stringent monitoring requirements and wastewater discharge permits have resulted in an overall improvement in wastewater quality, which is likely to reduce invertebrate mortality. However, full compliance has not been achieved.

E. Marine Invertebrates

Impacts on marine invertebrates were not anticipated by the EIS, and it is too early to assess how populations and food webs have been affected by the various alterations of the marine environment which have taken place. Direct loss of habitat or organisms through burial or elimination of habitat, lethal or sub-lethal effects from discharges of drilling effluents and seawater treatment chemicals, and entrainment in seawater intakes have all had documented localized impacts on marine invertebrates. While measures such as discharge limitations and construction of bypass systems in treatment plants have mitigated some of these losses, the net effect remains unknown.

F. Freshwater Fish

Impacts to fish resources were some of the most significant environmental problems directly associated with the construction of the pipeline and oilfields, and were in many cases more serious or of longer duration than implied by the qualitative predictions in the EIS. The most serious and extensive problems involved alteration of natural drainages, erosion, sedimentation, debris and fill in rivers or streams, and blockage of fish passage. Oil spills, which were predicted to be a potential problem, been smaller but more frequent than expected. The primary sources of these problems were road crossings of stream or river channels, erosion control structures, and instream mining for fill material.

Significant fishery resource impacts not predicted for the pipeline included changes in fish density, distribution, and species composition resulting from habitat alterations. In a few cases, rehabilitated material sites enhanced fisheries habitat or created new habitat conditions. However, most habitat modifications resulted in a net decrease of habitat quantity and/or quality. Habitat modifications included changes in substrate characteristics, suspended sediment, loss of bank and instream cover, straightening of stream channels, loss of surface flow, and increased braiding (increased width and decreased depth) where gravel was spread across floodplains.

Barriers to fish movements from road and pipeline crossings and habitat alterations were predicted for Prudhoe Bay oilfield development, but the predictions were qualitative and understated. Similar impacts were not predicted for the pipeline corridor. Obstacles to fish movements eliminated otherwise available fish habitat, and affected different sizes and species of fish with differing severity.

Another impact not clearly addressed was fish mortality. Fish were entrapped and prevented from migrating to winter habitat due to loss of surface flows resulting from instream or adjacent mining impacts, or interception of surface flow by thaw zones around the buried pipeline. Mortalities also resulted when environmental perturbations, such as heavy sediment loads during winter instream construction, or dewatering, rendered additional stresses to fish already subject to natural harsh conditions.

G. Marine Fish

The possibility of oil spills entering the marine environment via coastal rivers was considered, but not quantified. Since the EIS failed to consider oilfield development in the marine environment, causeway-induced impacts on anadromous fish were not predicted. Thus far, thousands of acres of nearshore brackish water feeding habitat have been altered by two causeways. The carrying capacity of this habitat has been reduced by significant changes in oceanographic conditions (lowered temperatures and elevated salinities) and resulting changes in invertebrate prey abundance. Habitat changes and the presence of physical barriers may also limit longshore movements to feeding areas and may interfere with fall movements to traditional overwintering sites in the principal river deltas. Entrainment of larval fish in seawater intakes may also affect recruitment. Effective mitigation of most of these problems has not been implemented, since their long-term impacts have yet to be measured.

H. Vegetation

Fill and excavation accounted for most of the predicted and actual direct losses of vegetation along the pipeline corridor and in the oilfields. Numerous indirect impacts, both expected and unexpected, accounted for additional losses. Predicted indirect effects included thermokarst, erosion and subsequent redeposition of exposed soil or fill, alterations of drainage (washouts and impoundments), stream icing and its effect on riparian vegetation, and increased off-road vehicular travel by the public. Several indirect effects were not addressed in the EIS, including road dust deposition, snow accumulation due to snow removal practices and wind-drifting, and the introduction of non-native weeds to Arctic Alaska. Some contaminant effects were expected but not quantified, such as oil spills and pump station emissions, while the loss or alteration of vegetation due to discharge of human or hazardous wastes in the oilfields was not anticipated. Overall, vegetation losses in the Alaskan Arctic exceeded predictions.

The effectiveness of mitigative measures in reducing the net loss of vegetative cover in the Arctic has been minimal. Initially, revegetation using introduced grasses stabilized and reduced erosion in some areas along the pipeline corridor, but their cover on most sites has gradually declined, while reinvasion by native plants has been extremely slow in all but the most favorable sites. In some cases, indirect losses have been minimized through the incorporation of design features (siting, culverts, etc.), but there is continued loss or alteration of plant cover adjacent to facilities due to dust, thermokarst, snow accumulation, and impoundments.

I. Birds

The greatest impact to birds in the pipeline corridor and oilfields was habitat loss due to gravel fill and excavation, and associated secondary effects. The direct habitat loss for the pipeline corridor was close to that predicted, but for the oilfield nearly twice the predicted amount was lost. Significant additional unpredicted loss of bird habitat value resulted from indirect impacts to vegetation and aquatic habitats, described previously. Consolidation of facilities, siting to avoid high value wetlands, culverting to maintain drainages, and use of winter ice pads for construction reduced habitat loss, but these measures were not always used effectively, and there has been virtually no restoration of lost habitat in the oilfields. Direct and secondary habitat losses resulted in a total estimated loss or displacement of 22,500 birds, with possible additional losses due to unquantified impacts.

It was predicted that oil spills, hunting, and disturbance by construction activities would affect birds, but these predicted impacts were not quantified. Actual impacts of oil spills and hunting have not been assessed but have probably been minor. Restricted public access in the pipeline corridor and oilfield has reduced impacts from human disturbance and hunting, but construction and operation disturbance have resulted in documented behavioral and distributional changes for several waterfowl species in the oilfield. In some cases disturbance was reduced by winter construction. The Endangered Species Act was effective in preventing predicted impacts to peregrine falcons and concurrently minimized effects on other cliff-nesting raptors.

Impacts to birds which were not predicted but have been documented include: changes in bird densities (increase for glaucous gulls and snow buntings, decrease for most other species); increases in predators (glaucous gulls, arctic foxes) resulting in increased predation of birds and nests in the oilfield; collisions of migrating birds with powerlines and buildings; and barriers to movement of brood-rearing geese by roads. The attraction of some birds to early snowmelt areas and impoundments along roads was not predicted, and its effect on populations has not been quantified. The effects of marine causeways and contaminants on birds were not predicted and have not been fully assessed, although effects on bird habitats have been documented. Cumulative effects on survival and reproduction of bird populations from all of the above impacts have not been assessed.

J. Caribou

Caribou were expected to avoid areas of disturbance, and normal herd movement was predicted to be impaired by the presence of pipelines placed on gravel berms or, to a lesser extent, by elevated pipelines. Displacement was predicted to lead to increased mortality. Direct mortality was expected to result from accidents associated with construction and increased hunting pressure. Pump station emissions were predicted to cause localized reductions in lichen cover, thus reducing food availability.

As expected, disturbance was extensive during construction, and has continued at low levels during operations. Some spring and early summer movements of Central Arctic Herd animals across the pipeline corridor have been partially restricted; however, overall movement has been less impaired than predicted, primarily because normal migrational movements tend to parallel the pipeline corridor (a fact not known at the time), but also because above-ground sections of the pipeline were ultimately elevated five or more feet above the surface. In addition, the killing, removal, or displacement of bears and wolves has reduced predation on the Central Arctic Herd, which may account for the recent increase in its numbers. Predicted effects on the large spring movements through the Brooks Range of animals from the Western Arctic Herd were never tested, since the migrational patterns of this herd subsequently changed.

Little direct mortality has resulted from accidents, since the source of disturbance has tended to reduce the potential for conflicts. However, there has been some increase in hunting pressure due to inadequate enforcement of regulations. The predicted effects of pollutants from pump station emissions have not been studied, but are presumed to have been negligible. The observed avoidance of industrial activities by females with young calves was not foreseen.

Pipeline elevation has been the most effective mitigation measure in reducing predicted impacts on caribou, although movement is still affected during spring and early summer, and crossing has been found to be less likely where the pipeline is paralleled by well-traveled roads. Timing restrictions on construction activities during critical life history periods also served to lessen predicted effects. Few adverse impacts have resulted that were not predicted in the EIS.

K. Other Large Mammals

Disturbance during pipeline construction was predicted to displace large mammals, especially Dall sheep. Large mammals did avoid construction activities, but disturbance to Dall sheep was minimized by timing restrictions on construction. Direct mortality was predicted as a result of habitat loss, construction activities, and traffic collisions. Population effects due to the displacement of animals from their habitats are not known. The most significant effect to large mammals is the improved access which has resulted in greater hunting and trapping pressure, although a five-mile wide band on either side of the pipeline corridor is closed to hunting with firearms. A large number of bears were killed in defense of life and property during construction and many continue to be killed during pipeline operation. Moose have been and continue to be killed along the haul road in collisions with vehicles. The pipeline was predicted to be a partial obstruction to movement of hoofed animals. Crossing difficulties north of the Brooks Range have not been reported for moose or bear. The feeding of wildlife was only predicted to be a problem after the Haul Road was opened to public use, but was actually a problem during construction despite the "no feeding" policy. Feeding of wildlife combined with improper garbage disposal resulted in bears and wolves concentrating around construction camps. The State has subsequently passed legislation prohibiting the feeding of wildlife. Notable impacts to large mammals (other than caribou) in the Prudhoe Bay oilfields did not occur since these species are not common in this area.

L. Small Mammals

Impacts to small mammals were predicted to be of limited magnitude and short duration and would likely result from construction-related activities, oil spills, and operation and maintenance of facilities. Where excavation or placement of fill altered vegetation, individual animals with home ranges within or overlapping the actual construction zone would be destroyed or displaced, with limited effects on food chains. Although population level impacts were not assessed, the area of small mammal habitat lost due to gravel fill or excavation was significantly greater than predicted. In addition, impacts from facilities operation and maintenance were significantly greater than predicted.

The EIS predicted minor reductions in predator populations. Actual impacts resulted in increased predator populations, particularly fox. This likely had an indirect impact on prey populations, particularly birds and waterfowl in the oilfield area. Mitigation in the form of strict food waste disposal and control of food sources could have reduced impacts; however, little attempt was made in this regard.

M. Marine Mammals

Oil spills into river systems and/or directly into the marine environment were predicted to be major sources of impacts to marine mammals. Large spills in the Beaufort Sea could potentially have direct impacts on polar bears, seals, and whales, and indirect impacts on marine mammal food sources. No major oil spills have been reported. Numerous small spills have occurred, but impacts have not been documented.

Impacts not predicted by the EIS, but for which actual impacts have been documented, include increased hunting pressure, elimination of nuisance polar bears associated with drilling operations, reduced polar bear denning activity within oilfields, and temporary displacement of denning ringed seals.

N. Wilderness

The region of Alaska traversed by the pipeline, and within which the Prudhoe Bay oilfield development was sited, was considered in 1970 to be the largest single expanse of intact wilderness left in the United States. The EIS predicted that improved access to these lands, increased commercial and recreational demands on lands adjacent to the pipeline corridor, and possible physical alteration from construction and operation of facilities would result in impacts to aesthetics, fish and wildlife resources, and native subsistence values. It was also predicted that impacts would be both temporary and permanent, but the level would be limited by the remoteness of location and the severity of climate. Actual impacts to wilderness have been much greater than predicted due to the unanticipated demand for land by the oil industry, related support services, and local residents. These impacts are presently occurring and will probably increase in the foreseeable future. Land use planning and application of construction stipulations that minimize facility sprawl and visual impact have only been marginally effective in minimizing impacts to wilderness values.

VI. CONCLUSIONS

Fish and wildlife habitat losses resulting from construction and operation of the Pipeline System and Prudhoe Bay oilfields were greatly underestimated in the EIS. They included the direct loss of 22,000 acres from gravel fill and excavation, the even greater indirect losses of habitat quality due to the secondary impacts of construction (dust, siltation, erosion, impoundments, contaminants, etc.), and blockage of fish and wildlife access to habitat by roads, pipelines, and causeways. Some of these indirect impacts were not predicted in the EIS, and the observed magnitude or frequency of others were greater than expected. Although some effort has been made to reduce habitat loss (through siting, consolidation of facilities, culverting, etc.), rehabilitation efforts along the Pipeline System have resulted in little restoration of habitat values, and there has been virtually no concerted effort to restore such values in the oilfields.

The qualitative nature of the EIS predictions made comparison of actual with predicted impacts difficult, and assessment of actual impacts was further confounded by the lack of baseline information and studies designed to specifically address EIS predictions. Monitoring efforts during pipeline construction focused on crisis-level reponses to the most visible and immediate impacts, and did not address the more subtle or latent effects on biological systems. Long-term and cumulative impacts have yet to be assessed, while additional impacts will continue to occur as a result of further oilfield expansion and/or the potential for opening new areas to public or private interests along the pipeline and oilfield roads. The chain of events initiated by these developments continues, and it is difficult to separate their effects from those caused by the many other developments they have set in motion.

The fact that many impacts were either unpredicted, underestimated, or misunderstood may be partially attributable to the EIS being one of the first impact statements prepared under the National Environmental Policy Act, but a similar lack of predictive capability may be expected whenever development moves into new geographical areas or employs new engineering methods and facility designs.

This analysis clearly demonstrates that adequate baseline information and long-term monitoring studies are essential for accurate impact assessment, as well as for improving future predictive capabilities. Onsite monitoring of development activities by well-trained personnel with enforcement authority and adequate funding is also critical for both minimizing anticipated impacts and timely assessment of unexpected impacts.

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