EXECUTIVE SUMMARY

Background

The Department of Transportation (DOT), Government of the NWT (GNWT) is preparing a Highway Strategy which encompasses four road proposals in the NWT. One of the road proposals under consideration is an all weather road between Inuvik and Tuktoyaktuk.

The existing transportation infrastructure in Inuvik and Tuktoyaktuk consists of: a seasonal ice road between Inuvik and Tuktoyaktuk, which is in operation approximately 3 months each year; year round scheduled and charter air access into each community; and all weather road access to Inuvik via the Dempster Highway #8, with ferry crossings/ice bridges on the Mackenzie River at Fort McPherson and on the Arctic Red River at Tsiigehtchic.

The idea of improving the transportation infrastructure in this area has been on-going since the late 60s. The first route survey took place in 1974 when oil and gas activity was occurring in this area. A 140 km land route was identified in 1977. This route is known as the 1977 Public Works Canada alignment. Preliminary engineering and environmental studies were undertaken on this route in 1975 and 1976. In general, this is still the preferred route for the residents of the area.

To provide a long term plan for the development of transportation infrastructure in the NWT, DOT developed the Northwest Territories Transportation Strategy in 1990. The Strategy was updated in 1994. A road corridor from Wrigley to Tuktoyaktuk, which includes the Inuvik to Tuktoyaktuk section, was identified as infrastructure which would be needed to support resource and other economic development activities in the region.

In March 1998, the GNWT announced its new roads initiative and dedicated funds for the socio-economic, environmental, regulatory, engineering, benefit/cost and economic impact investigations of four road proposals, including the Inuvik to Tuktoyaktuk road.

The proposed road would be considered an all-weather road, with two construction standards under consideration: the first option is based on a design speed of 80 km/hr, and the second is designed for 60 km/hr. The allowable gradient, stopping sight distance and fill required are the parameters that vary with design speed.

Environmental Scoping of the Road Proposal

Rescan™ Environmental Services Ltd., in association with Terriplan Consultants Ltd., Dillon Consulting, Arc Wildlife Services, Points West Heritage Consulting Ltd., and Aimm North Heritage Consulting, were retained by DOT to conduct an environmental scoping study for the road proposal. The results of the scoping study would be used to assist in preparing an environmental assessment of the potential project.

The purpose of the scoping study was the identification of the biophysical, social, economic and cultural issues and concerns of project stakeholders regarding the potential development. In addition, the consultants were required to identify the likely regulatory review process that would be launched should the road be constructed.

Stakeholder Concerns

Project stakeholders, including residents, elders, government, aboriginal organizations, land owners and regulators were consulted. Community consultations and discussions for traditional knowledge acquisition were held in January, 1999 in the communities of Fort McPherson, Tsiigehtchic, Aklavik, Tuktoyaktuk and Inuvik. Interviews with the remaining stakeholders took place throughout the project.

Overwhelming support was expressed by community residents during the consultation sessions, however, some concerns with the potential project were identified.

The major issues resulting from these sessions can be categorized as follows:

- potential social costs and benefits;
- potential economic costs and opportunities;

- project and routing issues;
- land claims and regulatory issues; and
- effects of the project on fish, wildlife, habitat and traditional land uses.

Table I at the end of the Executive Summary summarizes the issues raised during the consultations and identifies where further information on each topic can be found in the body of the report.

Regulatory Process

An important consideration in the planning for the development of a road between Inuvik and Tuktoyaktuk includes an examination of the regulatory requirements which must be satisfied to achieve project approval.

The permits, licences and authorizations required for the construction and operation of the road have been identified. Two possibilities for regulatory review exist: one possibility would be followed if the road were constructed entirely within the Inuvialuit Settlement Region (ISR), and the other would be followed if the road were constructed in both the Gwich'in Settlement Region and the ISR.

The regulatory review process would be simplified if the entire road corridor was located within the physical boundaries of the Inuvialuit Settlement Region. This can be achieved by starting the proposed new road at the present terminus of the existing Old Navy Road. Although there would be transboundary implications which must be considered, the paramount environmental impact assessment process to be satisfied would be that embodied in the Inuvialuit Final Agreement (IFA).

In the event that the final road alignment was located on both Gwich'in Settlement Area and Inuvialuit Settlement Region lands, the project would likely be determined to be a Transboundary Project and would need to satisfy the review process requirements of both the IFA and the Mackenzie Valley Resource Management Act (MVRMA). It was recommended that the two regulatory review agencies enter into an agreement to coordinate the review process. The details of the process to be followed would need to be defined, but in general are expected to involve both joint screening, followed by more detailed review of the project by a joint review panel established under the authorities of the IFA and the MVRMA.

Data Gaps

The scoping project involved the identification of information sources related to the development of an all weather road between Inuvik and Tuktoyaktuk. Available documentation was reviewed and summarized in this report. In general, sufficient background information exists for most subject areas. However, data gaps exist for some aquatic resources, vegetation information, wildlife and habitat information related to local resource harvesting, caribou habitat use, grizzly bear use of the area, denning areas and raptor sites.

Should the project proceed and require an environmental review, field work would likely be required to address the lack of information for these subject areas.

Table I
Summary Issues Table

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
<u>Potential Social Costs and Benefits</u>			
A land road is safer than the ice road	Fort McPherson Inuvik Tuktoyaktuk	TK CC CC, TK	7.3.3 6.3.1, 7.3.2 6.3.5, 7.3.5
Ice road is dangerous and has killed people	Aklavik	TK	7.3.2
The ice road is dangerous and can cause seasonal depression when it closes	Tuktoyaktuk	CC, TK	4.3.5, 6.3.5, 7.3.5
Aklavik has concern about the ice road if Tuk no longer needs it	Aklavik	CC	6.3.2
Road needs to be of a standard to prevent accidents	Inuvik	TK	2.3, 7.3.1
Road will improve year-round access and commerce between Aklavik and Tuk	Aklavik Inuvik	CC, TK CC, TK	2.1, 6.3.2, 7.3.2 2.1, 6.3.1, 7.3.1
The road will facilitate year-round access between Tuk and Fort McPherson	Fort McPherson	CC, TK	2.1, 6.3.3, 7.3.3
Road will improve year-round access for public, businesses, medical services, *etc.*	Tsiigehtchic	TK	2.1, 7.3.4
Road will improve year-round access, commerce and will reduce costs of goods and services in Tuk	Tuktoyaktuk	CC, TK, SC	4.4, 6.3.5, 7.3.5
Commercial construction is preferred over community building program	Aklavik	CC	6.3.2
Increased road access may cause an increase in crime at cabins	Aklavik Tuktoyaktuk	TK TK	7.3.2 7.3.5
Road may have negative effects on youth, culture, alcohol and drugs and the community	Tuktoyaktuk	CC, TK	6.3.5, 7.3.5
Social problems already exists (alcohol and drugs) and may increase as a result of the road	Tsiigehtchic	TK	4.4, 7.3.4
Road may increase intermarriages between Gwich'in and Inuvialuit	Tsiigehtchic	CC, TK	4.4, 6.3.4, 7.3.4
Good project, should have been done long ago	Fort McPherson	TK	7.3.3

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
<u>Potential Economic Costs and Opportunities</u>			
Good project which will benefit the region	Inuvik	CC	6.3.1, 7.3.1
Money is wasted on ice road	Aklavik	TK	7.3.2
Selected route is shortest and least costly	Tuktoyaktuk	CC, SC	2.2, 6.3.5
Commercial construction is preferred over community building program	Aklavik	CC	6.3.2
How much in royalties would be paid to the Inuvialuit for gravel and who would pay	Aklavik	CC, TK	6.3.2, 7.3.2
Project will provide training and jobs and contribute to a new way of life	Inuvik Aklavik Fort McPherson Tsiigehtchic Tuktoyaktuk	TK TK CC, TK TK CC	4.4, 7.3.1 4.4, 7.3.2 4.4, 6.3.3, 7.3.3 4.4, 7.3.4 4.3.5, 4.4, 6.3.5
Road will reduce costs of groceries to Tuk and will facilitate access to medical services in Inuvik	Inuvik	TK	4.4, 7.3.1
Community members and construction contractors should both benefit from project	Tuktoyaktuk	CC, TK, SC	6.3.5, 7.3.5
People need training *e.g.* heavy equipment operators to participate effectively	Tuktoyaktuk	CC	4.4, 6.3.5
Will draw more tourists to the region (*e.g.* Art Festival, hovercraft project, *etc.*)	Inuvik	CC	6.3.1
Tourists can drive to the Arctic Ocean and will increase tourism in Fort McPherson	Fort McPherson	CC, TK	2.1, 6.3.3, 7.3.3
Road will generate employment opportunities for Gwich'’n and Inuvialuit	Tssigehtchic	CC, TK	6.3.4, 7.3.4
Will draw more tourists to the region (to see Tuk and the ocean)	Fort McPherson	TK	7.3.3
Would provide recreational/touring opportunities	Inuvik	CC	6.3.1
Local people should be trained and employed to patrol and monitor the road	Aklavik	CC	6.3.2
Concern about who will pay for the road	Inuvik	CC, TK	6.3.1, 7.3.1
IRC should help fund the road	Tuktoyaktuk	TK	7.3.5
Road should be built now, funding sources need to be determined	Tuktoyaktuk	CC, TK, SC	6.3.5, 7.3.5
Funding sources and a lead agency are needed to move this project forward	Tuktoyaktuk	CC, SC	6.3.5
Seasonal road access is fine. The year-round road would negatively impact the air transportation industry	Tuktoyaktuk	CC	6.3.5

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
<u>Project and Routing Issues</u>			
Good choice of routing	Tsiigehtchic	CC, TK	6.3.4, 7.3.4
Preference for using old Navy Road as kick-off point	Aklavik Tuktoyaktuk	TK TK	2.2, 7.3.2 2.2, 7.3.5
Close to existing snowmobile trails	Inuvik	CC	6.3.1
Keep route away from Noell Lake to protect cabin owners and fisheries	Inuvik	CC	3.4.5, 6.3.1
Highest ground, most gravel and most level ground located along proposed corridor	Tuktoyaktuk	CC, TK	3.2.3, 3.2.4, 6.3.5, 7.3.5
High ground, most level ground, and gravel on the Tuk Peninsula located along Husky Lakes	Tuktoyaktuk	CC	3.2.3, 3.2.4, 6.3.5
Interior power line route more hummocky with steep slopes, more water and permafrost	Tuktoyaktuk	CC, TK	3.2.2, 3.2.4, 6.3.5, 7.3.5
Some preferred that the route follow the powerline north of Parsons lake	Tuktoyaktuk	CC, TK	
Three critical areas identified where the road should be realigned at least 2.5 km from the shore to protect local interests	Tuktoyaktuk	CC	3.4.5, 6.3.5
The road provides good access to Husky Lakes area but avoid locating the road too close to the lakeshore	Fort McPherson	CC, TK	3.4.5, 6.3.3, 7.3.3
Construction camps should be a certain distance from the highway and preplanned	Fort McPherson	CC	6.3.3
Some preferred the route follow the Mackenzie River	Tuktoyaktuk	CC, TK	6.3.5, 7.3.5
Impacts Benefits Agreements (IBA) will be needed	Yellowknife	DIAND	8.4.6
Gwich'in want to be involved in road construction and maintenance	Fort McPherson	CC, TK	6.3.3, 7.3.3

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
Land Claims and Regulatory Issues			
IFA Section 8(1) outlines special considerations which must be satisfied for the Husky Lakes area	Inuvik	CC, JS	3.4.5, 6.3.1, 8.4.7
Frequent regulatory monitoring should be conducted to protect the resources in the Husky Lakes area	Tsiigehtchic	CC, TK	3.4.5, 6.3.4, 7.3.4
Tourist use of the road and natural resources, especially around Husky Lakes needs to be carefully controlled	Tuktoyaktuk	CC, TK, ILA	6.3.5, 7.3.5, 8.4.8
Husky Lakes issues must be reviewed by the EIRB	Tuktoyaktuk, Inuvik, Yellowknife	ILA, JS, DIAND, EC, GNWT	8.4.7, 8.4.8
Project will require screening and review by ILA, EISC, EIRB, GLWB and other stakeholders	Inuvik	JS, GLWB	8.4.7, 8.4.9
Inuvialuit Game Council should play an important role in providing people to monitor and patrol the road	Fort McPherson	CC	6.3.3
Inuvialuit regulatory agencies should ensure the project is properly regulated especially around Husky Lakes, pingos and other critical areas	Tuktoyaktuk	ILA	6.3.5, 8.4.8
Inuvialuit would have to work with RWED and other regulators to ensure protection	Tuktoyaktuk	CC	6.3.5
An agreement should be developed between the Inuvialuit and the Gwich'in for hunting quotas, protection measures, etc.	Tsiigehtchic	CC	6.3.4
If the project has transboundary implications the MVEIRB will become more involved in reviewing the project. An agreement will be required	Yellowknife	MVEIRB, MVLWB	8.4.1, 8.4.2
Review of alternatives will be required	Yellowknife	MVEIRB	8.4.1
Socioeconomic issues require equal assessment with environmental issues	Yellowknife	MVEIRB	8.4.1
Cumulative effects and possible impacts beyond the ISR would need to be assessed.	Yellowknife Yellowknife Inuvik	MVEIRB EC JS	8.4.1 8.4.3 8.4.7
Sources of aggregate and associated infrastructure would need to be considered	Yellowknife	EC	8.4.3
Regulators and aboriginal organizations should work together to establish zoning/restrictions/enforcement issues	Fort McPherson	CC	6.3.3
DFO and the Inuvialuit co-manage fisheries within the ISR	Yellowknife	DFO	8.4.5

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
Land Claims and Regulatory Issues (Continued)			
Impacts Benefits Agreements (IBA) will be needed	Yellowknife	DIAND	8.4.6
DIAND Minister will receive and approve joint panel reports and will authorize or license approvals under its jurisdiction	Yellowknife	DIAND	8.4.6
Authorizations to destroy or alter fisheries habitat will be regulated under Section 35(2) of the Fisheries Act	Yellowknife	DFO	8.4.5
RWED would encourage one project-one process approach	Yellowknife	RWED	8.4.4
Road will enhance hunting opportunities which must be managed	Tsiigehtchic	CC, TK	3.6.1, 6.3.4, 7.3.4
Hunting by Gwich'in and Inuvialuit on each other's land will increase and must be managed	Tsiigehtchic	TK	7.3.4
Hunting off the road should be carefully regulated and monitored	Fort McPherson	TK	3.6.1, 7.3.3
Hunting, fishing and trapping must be managed	Inuvik	CC, TK	6.3.1, 7.3.1
Hunting along the road must be more carefully regulated than on the Dempster	Fort McPherson	CC	3.6.1, 6.3.3
Strict environmental rules and enforcement will be required	Inuvik	TK	7.3.1
Signage outlining offenses and fines should be posted along road, especially in sensitive areas	Fort McPherson	CC	6.3.3
Regulations and enforcement needed for tourists	Tsiigehtchic	TK	7.3.4
People should be educated on measures to protect the environment	Fort McPherson	CC, TK	6.3.3, 7.3.3
Apply lessons learned from the Dempster Highway to protect natural resources	Aklavik	CC	3.6.1, 6.3.2
Tourists will need to follow regulations including HTO Requirements	Aklavik	TK	7.3.2
Tourists need to be monitored and regulations need to be developed and enforced	Tsiigehtchic	TK	7.3.4
Littering and pollution issues must be managed	Inuvik Tuktoyaktuk	TK CC, TK	7.3.1 7.3.5
Mammoth tusks and fossils are found along the proposed route	Inuvik	TK	7.3.1
Land exchanges with the Inuvialuit may be needed as it will be a public road	Tuktoyaktuk	CC, SC	6.3.5

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
<u>Effects of Project on Fish, Wildlife, Habitat and Traditional Land Uses</u>			
Tourist use of the road and natural resources, especially around Husky Lakes needs to be carefully controlled	Tuktoyaktuk	CC, TK, ILA	6.3.5, 7.3.5, 8.4.8
The natural resources of the Husky Lakes area must be protected	Tuktoyaktuk	CC, TK, ILA	6.3.5, 7.3.5, 8.4.8
Caribou need to be protected	Tuktoyaktuk	CC, TK	3.6.1, 3.6.2, 6.3.5, 7.3.5
Hunting along the road must be more carefully regulated than on the Dempster	Fort McPherson	CC	3.6.1, 6.3.3
Road will enhance hunting opportunities which must be managed	Tsiigehtchic	CC, TK	3.6.1, 6.3.4, 7.3.4
Hunting off the road should be carefully regulated and monitored	Fort McPherson	TK	3.6.1, 7.3.3
Hunting, fishing and trapping must be managed	Inuvik	CC, TK	6.3.1, 7.3.1
Apply lessons learned from the Dempster Highway to protect natural resources	Aklavik	CC	3.6.1, 6.3.2
Caribou unlikely to be affected except by increased hunting	Aklavik	CC, TK	3.6.1, 6.3.2, 7.3.2
Caribou, moose and other wildlife unlikely to be affected by the road, based on experience with Dempster	Inuvik Fort McPherson Tsiigehtchic	CC, TK CC, TK CC, TK	3.6.1, 6.3.1, 7.3.1 3.6.1, 6.3.3, 7.3.3 3.6.1, 6.3.4, 7.3.4
Reindeer herd management issues can be managed	Inuvik	CC, TK	3.6.2, 7.3.1
Employ suitable designs for stream crossings to protect fish, rats and beavers	Fort McPherson	TK	3.3.1, 7.3.3
Road will place increased harvesting pressure on fish lakes which must be managed	Aklavik	TK	7.3.2
Road will increase harvesting access to fish, lakes and may impact fish at stream crossings	Tsiigehtchic Tuktoyaktuk	TK CC, TK	3.4.6, 7.3.4 3.4.6, 6.3.5, 7.3.5
Impacts on hunting and fishing camps need to be considered	Inuvik	TK	3.4.6, 3.6.1, 7.3.1
Road will improve access to berries	Aklavik Inuvik Tsiigehtchic Inuvik	TK TK CC, TK TK	7.3.2 3.6.1, 7.3.1 3.5.2, 6.3.4, 7.3.4 7.3.1

(continued)

Table I
Summary Issues Table (Continued)

Issue	Where Issue Raised	Party	Where Issue Addressed in Report
Effects of Project on Fish, Wildlife, Habitat and Traditional Land Uses (Continued)			
Use of calcium on roads may be harmful to vegetation and ptarmigan	Fort McPherson	TK	7.3.3
Littering and pollution issues must be managed	Inuvik Tsiigehtchic	TK TK	7.3.1 7.3.4
Owners of cabins near proposed road alignment need to be consulted	Tuktoyaktuk	TK	7.3.5
Some historic sites (habitation and graves) in the area (although not near the route). These should be protected	Tuktoyaktuk	TK	5.2, 7.3.5
Other Issues			
What other routes are being studied? Deviations from the preferred route may delay decisions	Tuktoyaktuk	CC, SC	6.3.5
An oral history program to educate public would be useful	Tuktoyaktuk	TK	7.3.5
Should be a road from the Dempster to Aklavik	Fort McPherson	TK	7.3.3
Community survey reported 267 people in favor, 29 opposed to year-round road	Tuktoyaktuk	CC	4.3.5, 4.4, 6.3.5
Will the route be finalized by March 31	Tuktoyaktuk	CC	6.3.5

CC: Community Consultation participant
DIAND: Department of Indian and Northern Affairs
EC: Environment Canada
GLWB: Gwich'in Land and Water Board
ILA: Inuvialuit Land Administration
JS: Joint Secretariat
MVLWB: Mackenzie Valley Land and Water Board
RWED: Resources Wildlife and Economic Development
SC: Inuvik-Tuktoyaktuk highway Stakeholder Committee
TK: Traditional Knowledge elder interviewee

PROPOSED INUVIK TO TUKTOYAKTUK ROAD
ENVIRONMENTAL AND SOCIO-ECONOMIC BASELINE REPORT

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1. INTRODUCTION

In March 1998 the Government of the Northwest Territories identified funds for the 1998/1999 fiscal year to prepare background studies for four new road projects in the Northwest Territories. One of the roads being considered is the proposed Inuvik-Tuktoyaktuk Road. Construction of the Inuvik-Tuktoyaktuk Road has been a long-term objective of the Department of Transportation since the first Transportation Strategy was published in 1990. Both the Town of Inuvik and the Hamlet of Tuktoyaktuk have been actively promoting construction of an all-weather road for many years. Enthusiasm for the project has renewed with the formation of the Inuvik-Tuktoyaktuk Highway Committee in 1997.

As a result, the Department of Transportation awarded two contracts for third party studies to assess the viability of the Inuvik-Tuktoyaktuk Road: an Environmental Scoping Study and a Benefit/Cost Study.

Rescan Environmental Services Ltd. was retained to conduct the Environmental Scoping Study. The purpose of this study was to:

- identify environmental, socioeconomic and cultural concerns associated with the proposed road;
- collect and update existing environmental and socioeconomic data and identify any data gaps; and
- determine the likely regulatory process that will be required to address environmental/socioeconomic Issues pertaining to the construction of the proposed road.

The project team members who contributed material for this environmental scoping report were:

Rescan Environmental Services Ltd. (Project Manager)

- Climate and Air Quality
- Hydrology and Water Quality
- Aquatic Biota
- Regulatory Process

Dillon Consulting

- Surficial Geology
- Regulatory Process

ARC Wildlife Services Ltd.

- Wildlife and Habitat

Points West Heritage Consulting Ltd.

- Heritage Resources

Terriplan Consultants

- Community Socioeconomic Profiles

Aimm North Heritage Interpretation Consulting

- Traditional Knowledge

Other Key Contributors:

- Mr. Knute Hansen of Western Arctic Trade and Tourism who provided local liaison and coordination services;
- Ms. Bertha Francis who served as a translator and facilitator for the Gwich'in communities and elders; and
- Ms. Agnes White who served as a translator and facilitator for the Inuvialuit communities and elders.

In addition, Mrs. Leslie Green and Ms. Colleen English of the GNWT Department of Transportation managed and provided direction to the Project Team.

2. ROAD PROPOSAL

2.1 Background

Currently the community of Tuktoyaktuk is accessible by road only during the winter months via a 187 km ice road constructed annually by the GNWT (Figure 2.1-1). The operating period is weather dependent and the road typically opens from mid to late December and closes from mid to late April.

Discussions about the merits of an all-weather road between Inuvik and Tuktoyaktuk have been ongoing since the late 60s. The first route survey began in 1974 when oil and gas exploration activities were in progress in the Parsons Lake area, south of Tuktoyaktuk. Based on this early work a 140 km land route was identified by Public Works Canada (Figure 2.1-1).

Preliminary engineering and environmental studies were undertaken on this route in 1975-1976 and it became known as the 1977 PWC Surveyed Route. The incentive to build the road was diminished with the downtown in petroleum exploration activities which followed the release of the recommendations of the Berger Commission on the Mackenzie Valley Gas Pipeline.

During the 1980s interest in the proposed road continued to rise and fall in relation to economic and political factors and two other possible road alignments were considered. Following some reference in 1985 that an alternate route was desired by the Inuvialuit, early in 1986 DIAND received a suggested road alignment that would be located almost entirely within Inuvialuit lands. This proposed alignment traversed through the Caribou Hills along the east bank of the Mackenzie river and was approximately 33 kilometres longer (total of 173 km) than the 1977 Surveyed Route. Public Works Canada did not support this proposed alignment because of economic and geometric reasons but put forward an alternate route that was 27 kilometres longer than the original 1977 PWC Surveyed Route. However, this route was located without field data, would have required completely new preliminary engineering studies and because of its longer length, would have been considerably more costly to construct.

No further work was done on the proposed road for a number of years but recently new interest has risen amongst the communities of Tuktoyaktuk and Inuvik to make the road a reality. An Inuvik Tuktoyaktuk Highway Steering Committee was established in 1997 comprised of Council members from both communities. In 1998, the Department of Transportation struck a Stakeholder Advisory Committee, whose purpose was to provide the Minister with advice with respect to the studies being undertaken for the Inuvik-Tuktoyaktuk road proposal. The Stakeholder Advisory Committee incorporates the membership of a Steering Committee, as well as including business, youth and elders from each community. Based on consultation with the Stakeholder Advisory Committee, the 1997 PWC Surveyed route has been reconfirmed as the best route to investigate and develop.

2.2 Proposed Alignment

The 1977 PWC Surveyed Route (Figure 2.1-1) passes through rolling tundra with an elevation approaching 200 metres above sea level just north of Inuvik and then gradually decreasing in elevation as it proceeds northward towards the lowlands of the Tuktoyaktuk Peninsula. The route passes west of Noell Lake, follows the western shore of Husky Lakes and generally meanders northward around small peninsula lakes en route to Tuktoyaktuk. The area around Husky and Parsons lakes harbours important fish and wildlife resources which must be protected and sustained.

To further optimize the route, an alternate point of departure from Inuvik, at the end of Navy Road, is also currently under consideration (Figure 2.1-1). This alternate, if adopted, would shorten the total length of road to be constructed by about 5 kilometres with resultant cost savings.

2.3 Design Considerations

Two standards of proposed road service are currently under consideration and both are referred to as all-weather road options. The first option is based on a design speed of 80 km/hr while the second option would be designed for a speed of 60 km/hr.

Both design options would have a roadtop width of 8.4 metres built on a minimum of 1.5 metres of embankment fill with 3:1 sideslopes. The 80 km/hr design option would have a lower maximum gradient (8%), compared with an 8-10% gradient for the 60 km/hr option. The lower maximum gradient for the 80 km/hr option would result in an increased stopping sight distance (140 m), compared with 85 m for the 60 km/hr option. The 80 km/hr option would also require more general fill and crushed granular base material than the 60 km/hr option.

The GNWT Department of Transportation is currently reviewing all of the engineering work completed on the 1977 PWC Surveyed Route and is in the process of updating the information as necessary.

3. BIOPHYSICAL CONDITIONS

This chapter of the Baseline Report presents an updated review of the existing biophysical conditions in the area of the proposed Inuvik-Tuktoyaktuk road.

In presenting the available information the reader should note that the physical boundaries employed vary depending on the discipline described. For some parameters, such as surficial geology, vegetation and watershed habitat ratings, the information provided is generally limited to the 1977 PWC Surveyed Route corridor. For hydrology, water quality and aquatic biota, the boundaries of the discussion generally focus on the streams and lakes crossing the proposed route and their associated watersheds. Wildlife information is presented on the basis of previous studies carried out in the broader region of the Tuktoyaktuk Peninsula, and for migratory species such as caribou, data are presented which covers their full range of distribution. The climate data presented are derived primarily from the meteorological stations located at Tuktoyaktuk and Inuvik, but the discussion of synoptic controls affecting the region is drawn from information available for the western Arctic.

3.1 Climate and Air Quality

The climatic regime encompassed by the proposed road from Inuvik to Tuktoyaktuk is that of the Marine Tundra Climatic Zone (Slaney, 1974). This climatic zone is characterized by long cold winters and short cool summers. The most influential topographical feature that affects the regional climate of the Mackenzie Delta and Tuktoyaktuk Peninsula is the Arctic Ocean. Its proximity is responsible for the differences between the Marine Tundra and Continental Tundra climate zones. The result is that mean daily temperatures tend to be higher in marine areas during the winter because of heat gained by sea ice, and lower in the summer because of heat loss to the sea surface (Public Works Canada, 1975).

Most climatological records for the area of interest have been produced at the two local communities, Inuvik and Tuktoyaktuk. Analysis of the local climate characteristics responsible for the microclimatic variation along the length of the road is impractical and unnecessary. Hence, this section will highlight some of the most relevant meteorological records from the weather stations in Inuvik and Tuktoyaktuk, and present a general analysis of current macro-climatic conditions. Historical data are also presented to allow discussion of long term trends in climatic conditions. The trends in climatic conditions are useful for the engineering design of the proposed road.

The nearest automated climate stations operated by Environment Canada – Atmospheric Environment Service (AES) are located at the Inuvik Airport and in the Hamlet of Tuktoyaktuk. There is also a climate station at the Tuktoyaktuk Airport, however, it does not collect continuous data.

There is a large annual variation in air temperatures for both recording stations. The maximum mean monthly temperature for Inuvik is 14.9ºC for July with the minimum mean monthly temperature being –26.3ºC in January. Similarly, the maximum mean monthly temperature for Tuktoyaktuk is 11.5ºC and the minimum is –26.6ºC. Mean annual temperatures for Inuvik and Tuktoyaktuk are –7.5ºC and –9.5ºC, respectively. These data are based on the most recent period of record, 1991 to 1997.

Precipitation varies between Inuvik and Tuktoyaktuk, but both stations record less than 30 cm per year. The lower annual precipitation on the coast (*i.e.* 153 mm, Tuktoyaktuk) may be attributed to a lesser effect of local topography on most coastal stations. Slaney (1974) noted that "…approximately 39% of total yearly precipitation falls as rain between May and September at Inuvik compared to 57% at Tuktoyaktuk." The most recent period of record (*i.e.* 1991 to 1997) indicates a more even distribution of precipitation for the two locations. Approximately 45% of the yearly precipitation falls as rain at Inuvik, compared to 44% at Tuktoyaktuk. The inherent nature of snow cover (*e.g.* highly variable temporal and spatial structure related to land cover and terrain and redistribution by wind) and of snowfall (varying density, significant errors in gauge measurements due to wind, wetting and evaporation losses) make snow much more difficult to measure than rainfall (Metcalf and Ishida, 1994). Hence, the precipitation normals for 1961 to 1990 have been corrected to account for biases in measurement method and wind induced error.

The mean annual precipitation for Inuvik is 275 mm based on the most recent seven years of available data. Inuvik receives approximately twice as much precipitation annually as Tuktoyaktuk, therefore, it may be concluded that Inuvik also receives more snow than Tuktoyaktuk.

Wind direction is often affected by local topography. The wind directions for the Inuvik weather station are predominantly from the north during the entire year. For Tuktoyaktuk the predominant wind directions during winter are generally from the north and east. The predominant wind direction during the summer for Tuktoyaktuk is from the east. The yearly average wind speed for Inuvik and Tuktoyaktuk are 10 and 17 km/hr, respectively.

The driving mechanisms for the climatic patterns in the Mackenzie Delta and the prevailing conditions for Inuvik and Tuktoyaktuk are discussed as follows with respect to air temperature, precipitation, and wind speed and direction.

3.1.1 Synoptic Controls

The following description of the synoptic controls was extracted from a description of the Beaufort Sea – Mackenzie Delta region in an Environmental Impact Statement prepared by a consortion of oil companies in the 1980s for hydrocarbon development in the Beaufort Sea – Mackenzie Delta region.

The normal upper level airflow over the region is westerly in summer and northwesterly in winter. Severe weather is often associated with abnormal departures from this pattern caused by major shifts in the circulation patterns of the upper atmosphere. For example, such shifts may result in southerly flows which introduce warm moist air into the region, producing record high temperatures and increased instability. On the other hand, persistent blocking of circulation patterns may prevent surface lows from entering the region, resulting in long periods of drought and, in winter, stagnation of cold Arctic air with accompanying record low temperatures (Dome Petroleum Ltd. *et al.*, 1982).

Winter

In winter, a semipermanent upper air ridge over Alaska typically results in a relatively strong mean northwesterly flow of air aloft. At the surface, the Northwest Territories and the Polar Basin are a region of continuous snow and ice cover. As a consequence, Arctic air typically predominates throughout the winter (December-March) and results in an anticyclonic circulation pattern or atmospheric high at the surface.

The cold dome of continental Arctic air over the region acts as an effective barrier against any penetration by maritime air masses. Migrating frontal lows are usually forced to follow trajectories around the edge of the continental Arctic air mass well to the north of the Beaufort Sea coastal zone. Low pressure centres which originate in the Aleutians generally migrate across the Beaufort Sea between 73°N and 75°N latitude. These systems produce blizzards along the coast and within the Mackenzie Delta. They occur primarily in January and March, but may also occur in other months of the winter.

The high pressure systems which are dominant in the region from November to March originate over the polar ice pack in the Beaufort Sea or in northern Alaska. Their primary trajectory is southeastward along the Mackenzie Valley. Typically by February, these systems tend to stagnate over the valley resulting in prolonged cold spells (Dome Petroleum Ltd. *et al.*, 1982).

Spring

Spring in the Mackenzie Delta and Coastal Plain generally begins with the gradual eastward shift of the dominant high pressure system, from over the Mackenzie Valley to the region lying between approximately 107°W and 103°W longitude. High pressure systems still originate in the north and follow southeastward trajectories. However, whereas in February these systems tend to stagnate over the Mackenzie Valley, by March they typically begin to move to the east of the Valley over Great Bear and Great Slave lakes.

The eastward displacement of high pressure centres allows more frequent penetrations of frontal lows, bringing maritime Arctic and maritime polar air masses to the region and resulting in a general increase in instability. The continental Arctic air mass generally begins to retreat northward along the Mackenzie Valley, while increased solar heating and low albedos begin to warm the southern portions of the Arctic air. The progression of spring is gradual from south to north and usually does not reach the Mackenzie Delta until late April or early May.

In May frontal lows from northern Alaska typically begin to follow trajectories through the northern Yukon and down the Mackenzie Valley, resulting in increased precipitation (Dome Petroleum Ltd. *et al.*, 1982).

Summer

The semipermanent upper level ridge which usually lies over Alaska in winter tends to shift eastward to over the Yukon in the summer. The strong northwesterly flow of winter is replaced by weak westerlies. This produces a surface trough along the length of the Mackenzie Valley and the Coastal Plain.

With the break-up of the pack ice along the coast, the climate of the Coastal Plain becomes more maritime and the source region of the Arctic air mass is reduced to the area covered by the polar ice pack. Outbreaks of Arctic air are modified during their passage over the open water between the polar pack and the coast; then cloud cover and stable air become dominant features of the coastal climate. However, in general, as the maritime air penetrates into the Mackenzie Delta it is further warmed and becomes unstable, resulting in more frequent precipitation.

From May to July frontal lows typically follow a trajectory from northern Alaska, through the Northern Yukon, and southeastward along the Mackenzie Valley. Cyclonic activity in the region usually reaches a peak in July and August, so that in August and September the region receives precipitation from storms which usually develop north of Alaska and travel along the coast between 70°N and 72°N latitude (Dome Petroleum Ltd. *et al.*, 1982).

Autumn

The autumn season, from September to December, is the reverse of the spring season. The summertime upper level ridge over the Yukon typically begins to shift westward back to its winter position over Alaska. Airflows aloft change from relatively weak westerlies to a strong northwest flow by the end of the fall.

At the surface, outbreaks of cold Arctic air become more frequent and colder, penetrating further south along the Mackenzie Valley. As freeze-up begins along the coast in late September, "steaming" of open waterbodies introduces moisture into the atmosphere, usually resulting in overcast skies and snow flurries. Also, cyclonic activity generally begins to decline from the July peak. Major snowfalls along the coast and within the Delta tend to accompany low pressure centres which travel eastward between 70°N and 72°N latitude in September, but they usually occur less often after October, as these storm trajectories shift to higher latitudes between 73°N and 75°N.

Typically beginning in November, high pressure systems originating in either northern Alaska or over the Beaufort Sea typically travel southeastward along the Mackenzie

Valley. By December, anticyclonic circulation is usually reestablished as Arctic air once again dominates the region (Dome Petroleum Ltd. *et al.*, 1982).

3.1.2 Inuvik

The Town of Inuvik is located 1,100 km northwest of Yellowknife and 200 km north of the Arctic Circle. The following discussion is based on climatic data collected by the Environment Canada – Atmospheric Environment Service (AES) weather station located at the Inuvik Airport.

3.1.2.1 Inuvik – Air Temperature

Overall the trend for the last 40 years of available data for air temperature for Inuvik has been an increase in mean monthly air temperatures, especially during the first four months of the year.

For the most recent period of record, 1991 to 1997, the mean annual air temperature recorded at the Inuvik airport was –7.5ºC (Table 3.1-1). The two previous periods of available records have recorded slightly cooler mean annual temperatures. The 1961 to 1990 Environment Canada Climate Normals list a mean annual air temperature for Inuvik of –9.5ºC (Table 3.1-2). The 1951 to 1980 Climate Normals list a mean annual air temperature of –9.8ºC (Table 3.1-3). The trend in monthly mean temperatures is illustrated in Figure 3.1-1. Over the past 46 years the mean annual air temperature at Inuvik has increased by approximately 2.3ºC. The relative high temperatures during the summer at Inuvik are a result of the long hours of daylight during June and July (Lawford and Cohen, 1989).

Several studies have been published that have documented a slight warming of the air temperatures in the Mackenzie River Delta. Lawford and Cohen (1989) reported that emissions of carbon dioxide, methane and other radiatively-active

Table 3.1-1
Summary of Inuvik Climatological Data (1991-1997)

Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-21.9	-21.3	-15.0	-5.0	7.4	17.9	20.7	17.2	6.8	-3.8	-15.1	-20.9	-2.6
Daily Minimum	-30.6	-30.7	-26.7	-16.2	-2.8	5.6	9.0	6.7	-1.0	-10.9	-23.6	-29.3	-12.4
Daily Mean	-26.3	-26.0	-20.9	-10.6	2.3	11.8	14.9	11.9	2.9	-7.3	-19.4	-25.1	-7.5
Precipitation													
Rainfall (mm)	0.0	0.0	0.0	0.0	5.7	23.2	30.6	40.9	20.8	1.8	0.0	0.0	123.0
Snowfall (cm)	20.0	22.7	21.0	12.3	13.0	2.5	0.1	1.7	15.5	32.0	24.4	25.5	190.6
Total Precipitation (mm)	16.7	18.2	17.3	9.7	16.1	25.6	30.7	42.6	34.1	25.5	18.5	19.8	275.0
Moisture													
Relative Humidity – 0600 L (%)	68	67	64	66	67	62	65	74	81	84	75	69	70
Wind													
Speed (km/hr)	7	9	9	10	12	12	10	10	10	8	7	7	10
Most Frequent Direction	N	N	N	N	N	N	N	N	N	N	N	N	N
Maximum Hourly Wind Speed (km/hr)	65	56	48	33	37	46	44	37	39	39	44	44	65
Direction	NW	W	NW	SE	N	NW	NE	N	NW	NW	NW	NW	NW

Source: Environment Canada, 1998.

Table 3.1-2
Historical Climate Data for Inuvik Airport (1961-1990)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-24.1	-23.4	-18.2	-8.0	4.2	16.6	19.5	15.7	7.5	-4.8	-17.1	-21.4	-4.5
Daily Minimum	-33.5	-33.7	-30.3	-20.2	-5.7	4.5	8.0	5.3	-0.9	-11.8	-26.0	-31.0	-14.6
Daily Mean	-28.8	-28.5	-24.1	-14.1	-0.7	10.6	13.8	10.5	3.3	-8.2	-21.5	-26.1	-9.5
Corrected Precipitation (Metcalf and Ishida, 1994)													
Rainfall (mm)	0.2	0.0	0.0	0.1	7.2	22.0	36.8	42.1	16.7	2.5	0.1	0.0	127.9
Snowfall (cm)	19.1	14.1	14.2	15.6	15.0	2.3	0.4	4.0	10.8	34.8	23.7	21.3	175.2
Total Precipitation (mm)	23.7	17.7	17.5	18.2	24.8	25.0	37.3	48.6	29.1	39.8	25.9	25.4	332.9
Extreme Daily Rainfall (mm)	1.8	0.2	0.8	0.3	19.3	19.1	38.4	33.0	22.9	13.2	0.8	0.4	
Date	1981/19	1982/03	1989/13	1958/28	1976/26	1972/10	1989/16	1970/16	1976/29	1964/09	1967/21	1988/16	
Extreme Daily Snowfall (cm)	11.4	13.7	13.0	17.8	24.9	10.2	4.8	22.6	12.2	44.2	21.0	18.6	
Date	1963/19	1962/26	1967/12	1961/28	1966/28	1970/07	1974/01	1969/16	1967/11	1971/17	1990/05	1986/09	
Extreme Daily Precipitation (mm)	10.4	13.7	10.8	17.8	24.2	19.3	38.4	42.9	30.7	29.2	14.4	15.8	
Date	1968/03	1962/26	1990/06	1961/28	1987/02	1962/05	1989/16	1969/16	1976/29	1971/17	1990/05	1986/09	
Month-end Snow Cover (cm)	52	56	60	48	1	0	0	0	1	22	33	43	

(continued)

Table 3.1-2
Historical Climate Data for Inuvik Airport (1961-1990) Completed

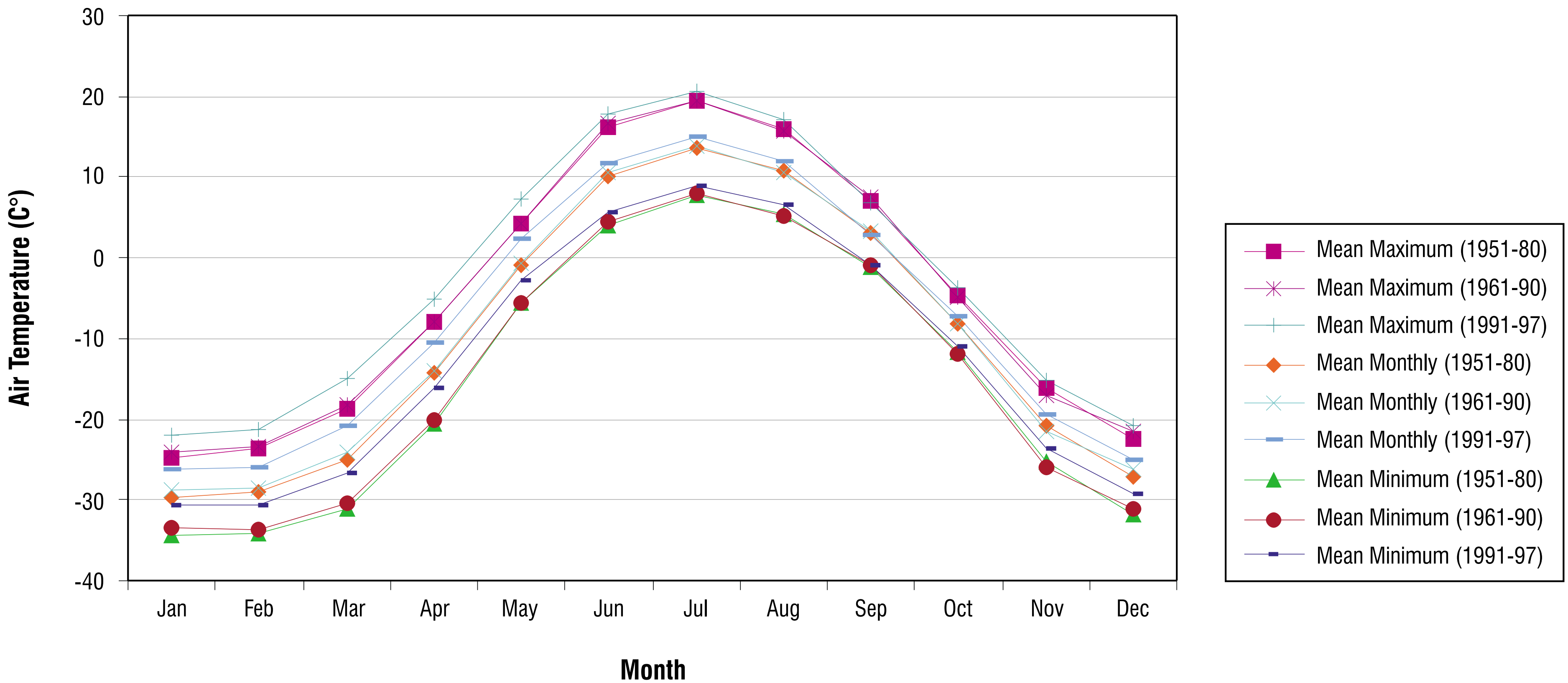
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Days With													
Maximum Temperature >0 °C	*	*	*	6	21	30	31	31	27	7	*	*	154
Measurable Rainfall	*	*	*	*	2	7	10	12	7	1	*	*	40
Measurable Snowfall	12	11	11	9	6	1	*	1	6	15	13	14	98
Measurable Precipitation	11	10	10	9	7	8	10	12	11	15	12	13	129
Freezing Precipitation	*	*	*	*	2	*	0	0	*	3	*	*	9
Fog	2	1	*	1	4	2	1	3	4	3	1	*	24
Thunderstorms	0	0	0	0	*	*	*	*	*	0	0	0	2
Station Pressure (kPa)	101.18	101.19	101.18	100.93	100.79	100.42	100.48	100.37	100.41	100.30	100.72	100.83	100.73
Moisture													
Vapour Pressure (kPa)	N	N	N	0.19	0.43	0.76	1.01	0.92	0.62	0.31	N	N	N
Rel. Humidity – 0600L (%)	N	N	68	74	78	74	78	85	86	84	75	72	
Rel. Humidity – 1500L (%)	N	66	62	64	63	51	54	62	68	78	74	72	
Wind													
Speed (km/hr)	7	7	9	10	12	13	12	11	11	10	7	7	10
Most Frequent Direction	C	C	E	E	E	NE	NE	NW	E	E	C	C	E
Maximum Hourly Speed (km/hr)	56	48	61	45	47	45	42	56	48	56	56	64	64
Direction	NW	NW	NW	N	W	NW	NW	N	W	E	NW	NW	NW
Maximum Gust Speed (km/hr)	97	78	84	83	77	63	70	89	77	78	80	109	109
Direction	N	W	NW	NW	NW	W	NW	W	N	NW	NW	NW	NW

Source: Environment Canada, 1993
Notes:
*** = amount less than 0.5 except 0**
N = some data exist, but not enough to calculate a value
T = trace
C = calm winds with no predominant wind direction

Table 3.1-3
Historical Climate Data from Inuvik Airport (1951-1980)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-24.7	-23.7	-18.8	-7.9	4.2	16.2	19.4	15.9	7.1	-4.6	-16.2	-22.4	-4.6
Daily Minimum	-34.4	-34.1	-31.1	-20.6	-5.7	4.1	7.8	5.4	-1.1	-11.6	-25.3	-31.9	-14.9
Daily Mean	-29.6	-28.9	-25.0	-14.3	-0.8	10.1	13.6	10.7	3.1	-8.1	-20.7	-27.2	-9.8
Extreme Maximum Temperature	2.8	2.8	6.1	13.3	23.4	31.7	31.1	30.0	25.6	15.0	10.6	5.0	31.7
Years of Record	23	23	24	24	24	24	24	24	24	24	24	24	
Extreme Minimum Temperature	-54.4	-56.7	-50.6	-46.1	-27.8	-6.1	-3.3	-6.1	-18.9	-35.0	-46.1	-50.0	-56.7
Years of Record	23	23	24	24	24	24	24	24	24	24	24	24	
Precipitation													
Rainfall (mm)	0.1	0.0	0.0	T	5.9	21.4	33.2	38.4	13.4	2.1	0.1	T	114.6
Snowfall (cm)	20.4	12.6	15.0	17.0	13.0	2.2	0.5	3.3	12.0	37.2	22.6	20.8	176.6
Total Precipitation (mm)	17.9	10.5	12.0	14.8	17.6	23.5	33.6	43.6	23.9	33.4	17.9	17.4	266.1
Greatest Rainfall in 24 Hours (mm)	1.5	T	T	0.3	19.3	19.1	22.1	33.0	22.9	13.2	0.8	T	33.0
Years of Record	23	23	24	24	24	23	23	23	24	23	24	24	
Greatest Snowfall in 24 Hours (cm)	11.4	13.7	13.0	17.8	24.9	10.2	4.8	22.6	12.2	44.2	10.4	12.2	44.2
Years of Record	23	23	24	24	24	23	23	24	24	23	24	24	
Greatest Precipitation in 24 Hours (mm)	10.4	13.7	10.7	17.8	22.1	19.3	22.1	42.9	30.7	29.2	10.4	10.9	42.9
Years of Record	23	23	24	24	24	23	23	23	24	23	24	24	
Days with Rain	*	0	0	*	2	7	9	11	6	1	*	0	36
Days with Snow	12	10	11	10	6	1	*	1	6	15	13	14	99
Days with Precipitation	12	10	11	10	7	8	9	11	11	15	12	14	130

Source: Environment Canada, 1982
Notes:
*** = amount less than 0.5 except 0**
N = some data exist, but not enough to calculate a value
T = trace



Northwest Territories

FIGURE 3.1-1

Historical Air Temperatures for Inuvik Airport

Rescan

Sources: Environment Canada 1980, 1993, 1998

trace gases have led to increased atmospheric concentrations. General Circulation Modeling (GCM) has shown that for the projected increases in greenhouse gases, the global mean annual temperature could rise by 1.5 to 5.0ºC by the middle of the 21st Century. Much greater warming and generally higher precipitation have been projected for high latitudes during winter. The Canadian Arctic, including the Mackenzie Delta, would be one of the regions to experience changes of this magnitude. Any change in mean annual temperature would most certainly affect the distribution of permafrost and thermokarst processes (Lawford and Cohen, 1989) in the region.

Environment Canada (1997a, 1997b) agrees with these observations when they state that scientists predict the global average surface air temperature may increase from 1.0 to 3.5ºC over the next century due to the predicted effects of greenhouse gases and other causes of climate change. Some regions will experience more warming than others. The greatest warming is expected to occur in high northern latitudes in winter, however, these areas are not expected to experience as much additional warming in summer. Warming is also expected to be greater over land than over the sea. Winter precipitation and soil moisture are expected to increase over much of the North. Evidence of this trend has already been documented. Over the past 100 years, the average temperature of the Mackenzie Basin and most other taiga areas of the Arctic has risen by about 1.5ºC, with the greatest warming occurring in winter and spring (Environment Canada, 1997a and 1997b).

3.1.2.2 Inuvik – Precipitation

Approximately 45% of the total precipitation at Inuvik originates as rainfall during the months of May to September. The mean annual total precipitation for the 1990 to 1997 period of record was 275 mm (Table 3.1-1). This value is lower than the previous period of record 1961 to 1990 (Table 3.1-2) which reported an annual total precipitation of 333 mm. It should be noted that this value was obtained from Metcalfe and Ishida (1994) who published a revised precipitation database for the 1961 to 1990 period of record. The revision was required to correct biases in measurement method and wind induced error.

A third period of record, 1951 to 1980, reported an annual total precipitation of 266 mm (Table 3.1-3) which is lower than the previous two. Lawford and Cohen (1989) indicated that the annual precipitation rates for Inuvik have shown significant variability with totals ranging from 180 to 360 mm. There are no clearly identifiable trends in precipitation amounts. The monthly distribution of total precipitation and rainfall for Inuvik for the three periods of record are summarized in Figure 3.1-2.

All three sets of data agree that the month with the highest precipitation rate is August. Approximately 15% of the total annual precipitation occurs during August. The data sets also agree that the months with the lowest precipitation rates are February, March and April.

Lawford and Cohen (1989) have indicated that the trend in increasing ambient air temperatures due to global warming may have an effect on the precipitation pattern in the Mackenzie Delta, and specifically at Inuvik. The seasonal distribution of monthly precipitation shows a maximum in the month of August at Inuvik.

August recorded the highest monthly precipitation because the storms tend to track over the Delta area more frequently during August than for any other month of the year. The distribution of precipitation for the first two periods of record (*i.e.* 1951 to 1980 and 1961 to 1990) shows a secondary maximum in October, presumably associated with the peak occurrence of winter storms. This secondary maximum is not evident in the most recent precipitation data (*i.e.* 1991 to 1997) because it has been corrected by Metcalfe and Ishida (1994) for biases in measurement method and wind induced error. The precipitation amounts in each month are not high; consequently the amount of evaporation in the summer exceeds the summer and even the annual precipitation totals.

Peak rainfall events are often used by hydrological design engineers to estimate peak streamflows. Although precipitation gauge records may not be representative of precipitation over large areas for individual storms, the general characteristics of precipitation usually vary in a regular manner. Therefore, parameters like frequency of precipitation above a given value, can be transposed or interpolated to areas with no data. The most common parameters for describing peak rainfall events are; a) the extreme 24-hour precipitation and associated return periods; and b) rainfall intensity-duration-frequency (IDF) curves.

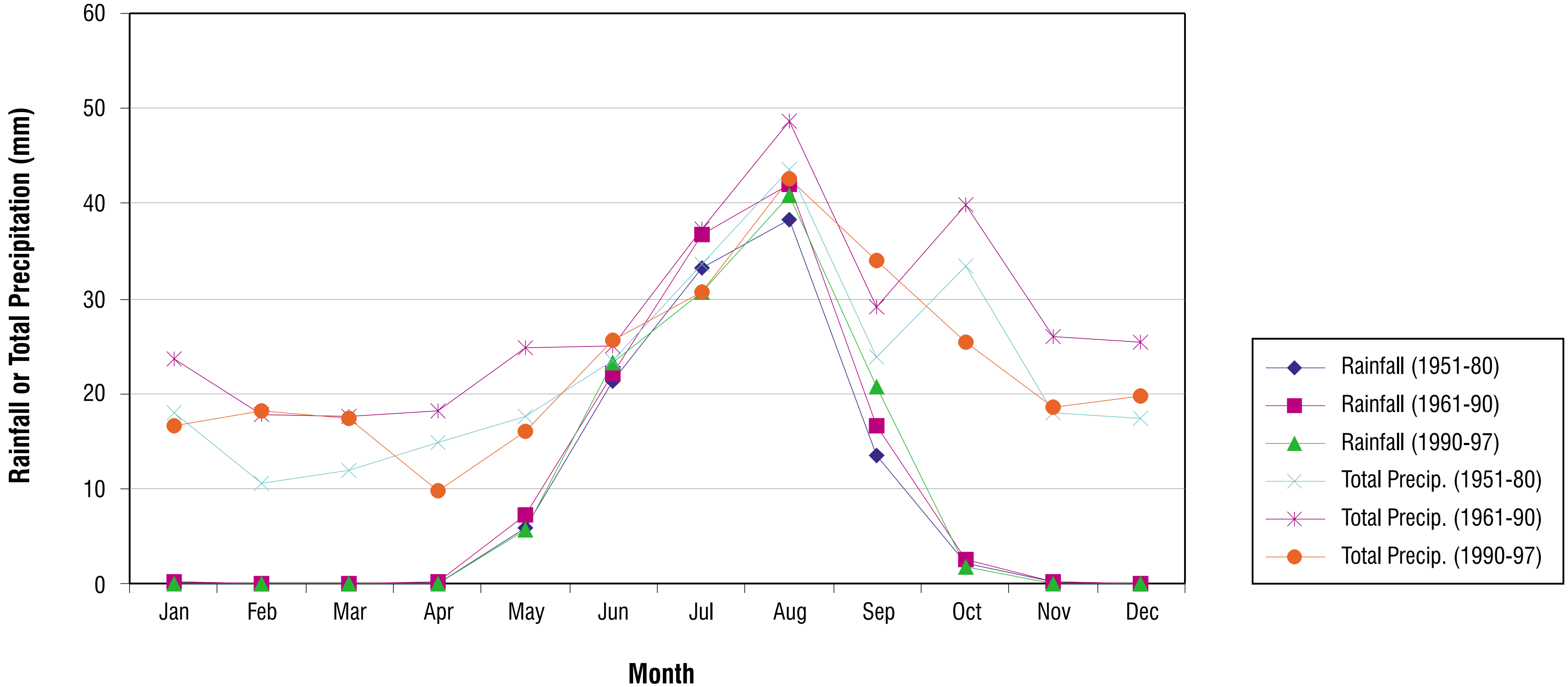


FIGURE 3.1-2

Historical Precipitation for Inuvik Airport

Northwest Territories

Rescan

Sources: Environment Canada 1980, 1993, 1998

The extreme 24-hour precipitation and associated return periods for Inuvik airport are summarized in Table 3.1-4. Three different sets of estimates are provided. The values in the third row of the table are based on data from 1972 to 1990 and are considered the most accurate.

Table 3.1-4
Extreme 24-Hour Precipitation (mm) and Associated Return Periods for Inuvik Airport

	Return Period (years)							
Station	**2**	**5**	**10**	**15**	**20**	**25**	**50**	**100**
Inuvik A[1]	16.8	23.0	27.1	29.4	31.1	32.3	36.1	40.0
Inuvik A[2]	20.3	30.5	35.6	n/a	40.6	n/a	n/a	n/a
Inuvik A[3]	17.3	26.2	32.1	n/a	n/a	39.5	45.0	50.5

Sources:
1: Calculated from Hogg and Carr, 1985 (Rainfall Frequency Atlas for Canada)
2: Burns, 1974 (estimated) in Dome Petroleum Ltd. *et al.* 1982.
3: Environment Canada 1998b

The IDF curves for Inuvik airport weather station are summarized in Figure 3.1-3. These curves are useful for engineers to design and construct hydrological structures (*e.g.* culverts, bridges and storm sewer systems) to carry water runoff from small catchments. The design engineer must select a frequency with which the capacity of the runoff structure can be exceeded. This is usually expressed in terms of return period, which is the average interval between occurrences of events equaling or exceeding a given magnitude. Figure 3.1-3 provides six different return periods; 2, 5, 10, 25, 50 and 100 years. The return period that design engineers select depends upon a number of factors such as a cost-benefit analysis, government regulations, and public convenience and safety (Hogg and Carr, 1985).

Since June 1997, Environment Canada (AES) has collected rainfall and snowfall from Inuvik for chemical analyses. Inuvik was one station in the initial Canadian Network for Sampling Precipitation (CANSAP) however, it has only operated sporadically. Table 3.1-5 summarizes the results of chemical analyses performed on precipitation collected at Inuvik.

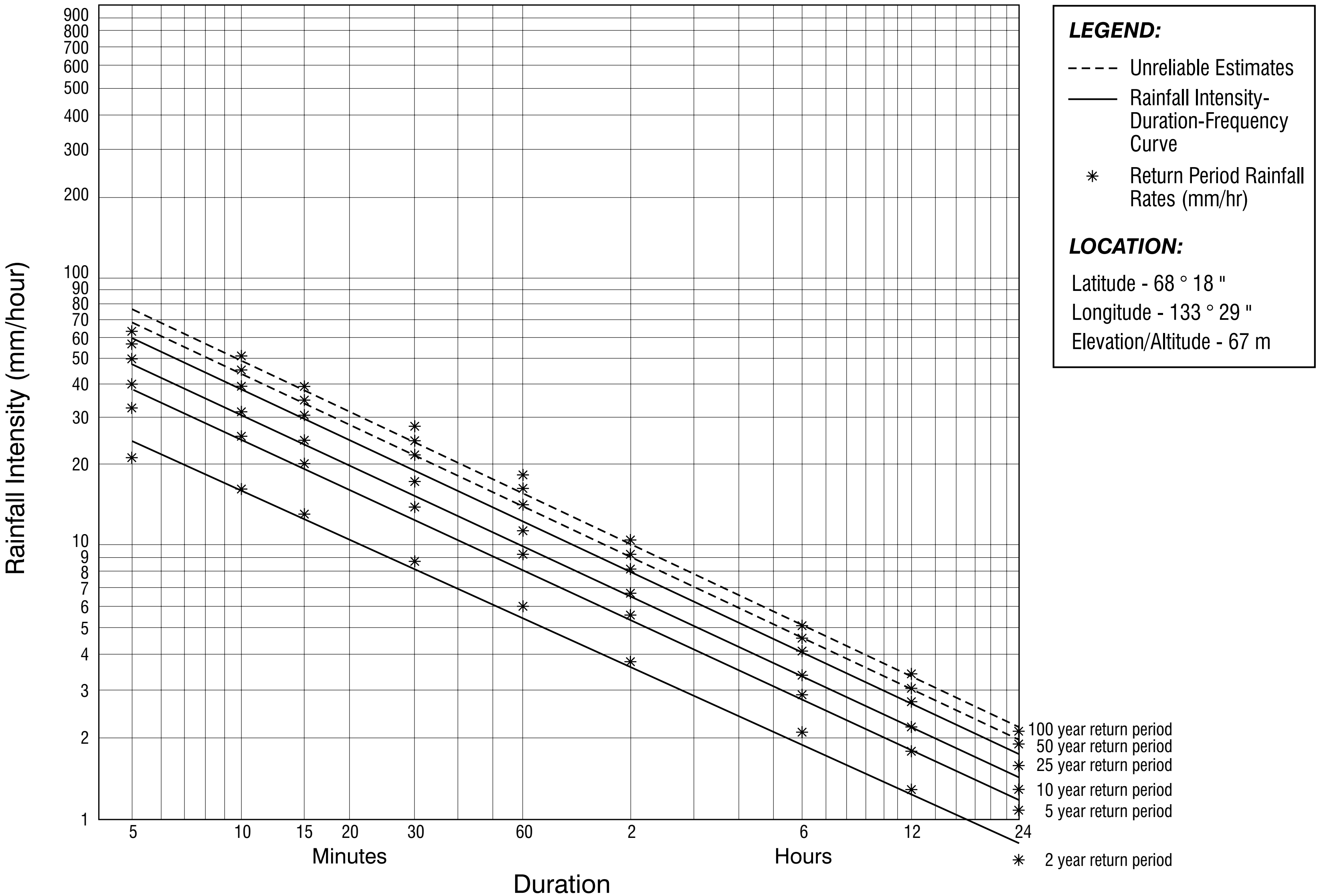
The results of the CANSAP program for Inuvik show that ion concentrations vary depending on previous weather, wind directions and precipitation. Hence, analysis of bulk (*i.e.* monthly) precipitates may not be appropriate for northern locations. Therefore, no obvious trends or conclusions may be drawn from the data.

3.1.2.3 Inuvik – Wind Speed and Direction

The mean annual wind speed for the most recent period of record, 1991 to 1997, was 10 km/hr (Table 3.1-1). The same mean annual wind speed was recorded for the previous period of record, 1961 to 1990 (Table 3.1-2). Wind speed and direction were not monitored for the period 1951 to 1980. The data presented by Dome Petroleum Ltd. *et al.* (1982) are consistent with the most recent period of record for wind speed and directions at Inuvik.

The most frequent wind direction for the most recent period of record was from the north. This is slightly different than the period of record from 1961 to 1990 that indicated the most frequent wind direction was from the east. Dome Petroleum Ltd. *et al.* (1982) indicated that there was great variability in wind directions at Inuvik. The easterly component is typically infrequent in summer and constant throughout the rest of the year. Northeasterly, northerly and northwesterly winds tend to be more frequent in the summer and least common in winter. Westerlies remain more or less constant throughout the year.

The highest mean monthly wind speeds at Inuvik occur during the summer (May and June). However, the maximum hourly wind speeds occur during the winter. The highest mean monthly wind speed recorded at the Inuvik airport for the most recent period of record was 12 km/hr for the months of May and June. The maximum hourly wind speed for Inuvik airport for the 1991 to 1997 period of record was 65 km/hr. This maximum occurred in January. The winter months, especially January and February recorded the maximum hourly average wind speeds. The data from 1961 to 1990 agree with the most recent data that the maximum hourly average wind speed was 64 km/hr from the northwest. The maximum instantaneous wind gust, according to the 1961 to 1990 climate normals, was 109 km/hr from the northwest during December. Maximum gust speeds were not available for the other two periods of record (*i.e.* 1991 to 1997 and 1951 to 1980).



Note: The methodology used to generate these IDF curves was Gumbel - Method of Moments.
These curves are based on recording rain gauge data for the period 1972-1990 (18 years).

FIGURE 3.1-3

Rainfall Intensity-Duration-Frequency Curves for Inuvik, NT

Northwest Territories

Rescan

Source: Environment Canada, 1998

Table 3.1-5
CANSAP Precipitation Data Summary

Station:	**Inuvik**															
Year:	**1977**		**1978**							**1979**		**1980**				
Month:	**Jun.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Jun.**	**Jul.**	**Sep.**	**Oct.**	**Feb.**	**Nov.**	**Jan.**	**Feb.**	**Apr.**	**May**	**Jun.**
Sampling Period (Days)	8	19	31	28	32	31	31	30	32	30	34	32	29	31	31	30
Catch of Collector (mm)	18	5	2	2	3	15	6	14	15	3	9	7	3	15	4	3
Catch of Standard	65	5	4	4	12	40	24	34	32	4	15	10	6	31	17	4
pH	5.5	7.1	-	6.9	6.6	7.7	7.5	6.9	6.7	6.5	6.9	7.0	6.7	6.5	7.1	7.5
Conductance (µs/cm)	4.8	-	-	-	-	56.0	97.0	47.6	17.7	21.6	24.2	21.1	25.4	10.5	50.9	59.0
Acidity (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate (SO_4*)(mg/L)	0.6	-	1.1	1.9	-	1.1	1.7	0.8	0.9	3.5	0.5	2.2	3.3	0.4	3.2	2.8
Nitrate (NO_3-)(mg/L)	0.35	-	0.35	0.58	-	0.41	0.96	0.13	0.12	0.58	0.04	BD*	0.66	0.22	0.62	0.55
Chloride (Cl-)(mg/L)	0.13	-	1.89	2.61	-	0.30	0.62	1.70	0.59	1.67	1.67	3.20	1.80	0.16	4.48	2.61
Ammonium (NH_4+)(mg/L)	0.02	0.01	0.25	0.35	-	0.04	0.13	0.12	0.13	0.06	0.22	0.01	0.26	0.07	0.67	0.57
Sodium (Na+)(mg/L)	0.1	-	0.8	2.0	-	0.2	-	1.0	0.4	1.5	1.5	1.7	1.1	0.3	3.5	2.2
Potassium (K+)(mg/L)	0.06	0.96	1.80	1.60	-	0.15	-	BD*	0.08	0.32	0.87	0.35	0.68	0.12	1.63	1.30
Magnesium (Mg++)(mg/L)	0.02	0.46	0.70	0.65	-	2.00	-	2.20	0.65	0.27	0.80	0.50	0.40	0.33	0.68	1.02
Calcium (Ca++)(mg/L)	0.15	1.40	2.3	1.80	-	8.30	-	4.55	1.65	1.40	2.30	1.56	1.84	1.07	3.00	5.86

Source: Dome Petroleum Ltd. *et al.* 1982
***BD = values that were below detection limits.**

3.1.3 Tuktoyaktuk

The terrain surrounding the Hamlet of Tuktoyaktuk consists of generally flat, barren tundra with shallow lakes. The Tuktoyaktuk Peninsula generally experiences cooler temperatures and higher wind speeds than the rolling and sparsely treed topography at Inuvik.

Currently there are two weather stations operated by Environment Canada – AES in Tuktoyaktuk, one in the Hamlet and one at the airport. The station at the airport does not collect data 24 hours per day, therefore, only data from the Hamlet station are presented below.

3.1.3.1 Tuktoyaktuk – Air Temperature

Overall the trend for the last 46 years of available data for air temperature for Tuktoyaktuk has been an increase in mean monthly air temperatures, especially during the first six months of the year.

For the most recent period of record, 1991 to 1997, the mean annual air temperature for the Hamlet of Tuktoyaktuk was –9.5ºC (Table 3.1-6). The two previous periods of available records recorded slightly cooler mean annual temperatures. The 1961 to 1990 Environment Canada Climate Normals list a mean annual air temperature of –10.5ºC (Table 3.1-7). The 1951 to 1980 Climate Normals list a mean annual air temperature of –10.9ºC (Table 3.1-8). Hence over the past 46 years the mean annual air temperature has increased by approximately 1.4ºC. The trend in gradually increasing air temperatures is shown in Figure 3.1-4.

There have been several studies published that have documented a slight warming of the air temperatures in the Mackenzie Delta. These studies were presented earlier in the section discussing air temperatures for Inuvik.

3.1.3.2 Tuktoyaktuk – Precipitation

As with Inuvik, approximately 44% of the total annual precipitation at Tuktoyaktuk falls as rainfall between the months of May and September. Tuktoyaktuk receives approximately 50% of the total annual precipitation at Inuvik. The mean total annual precipitation for the most recent period of record, 1991 to 1997, was 153 mm (Table 3.1-6). This is lower than the mean total precipitation for the 1961 to 1990 period of record, 174 mm (Table 3.1-7). It should be noted that this value was obtained from Metcalfe and Ishida (1994) who published a revised precipitation database for the 1961 to 1990 period of record. The precipitation normals were corrected to account for biases in measurement method and wind induced error. Both of these values are higher than the mean total precipitation reported for the 1951 to 1980 period of record, 138 mm (Table 3.1-8).

The highest precipitation rates were recorded during September, and the lowest during the months of November, December, January, February, March and April. All three sets of historical data agree with this trend. The rainfall and total precipitation data for the three available periods of record are summarized in Figure 3.1-5.

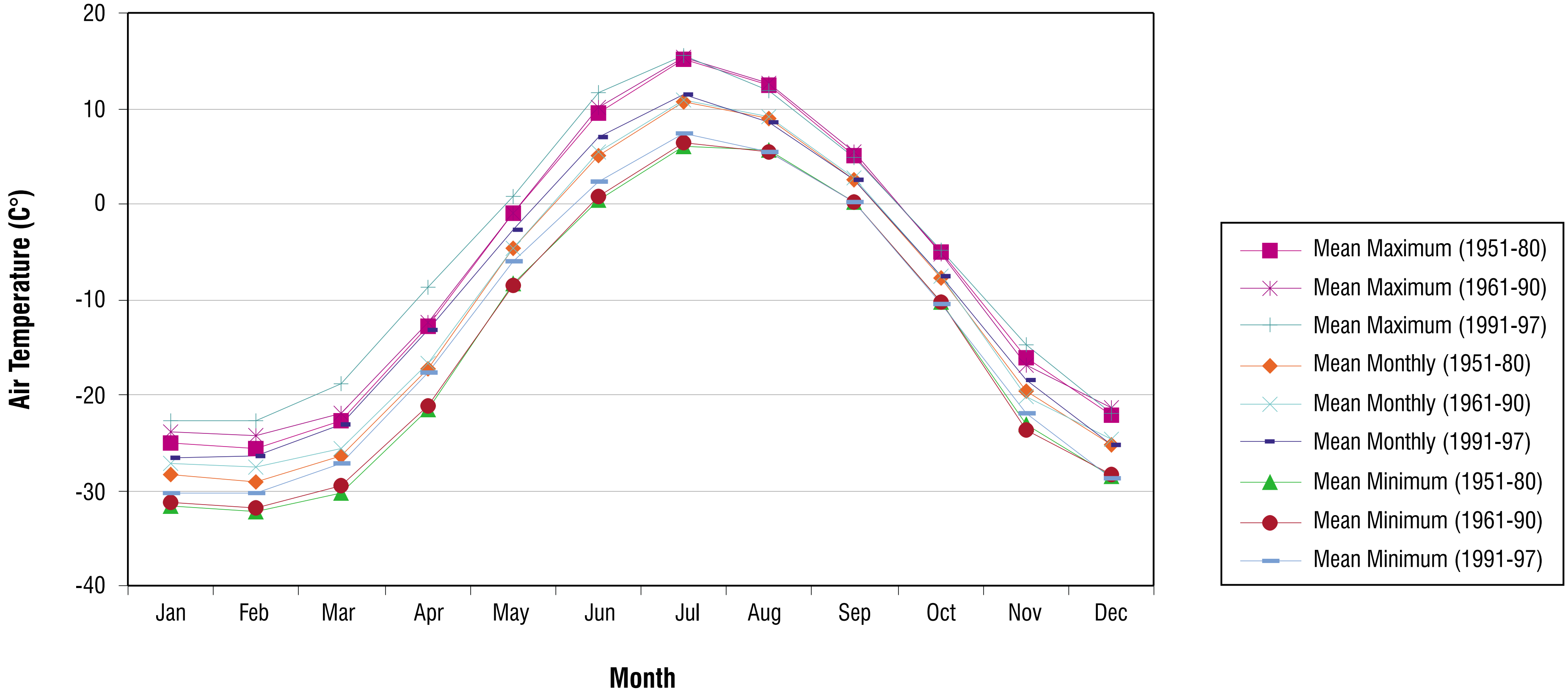
3.1.3.3 Tuktoyaktuk – Wind Speed and Direction

The mean annual wind speed at Tuktoyaktuk for the most recent period of record was 17 km/hr (Table 3.1-6). The months with the highest average wind speeds are August and September each with 18 km/hr. The most frequent wind direction was from the east. Mean monthly and annual wind speeds are not available for Tuktoyaktuk for the other two periods of record.

Generally winds are stronger at Tuktoyaktuk than at Inuvik because Tuktoyaktuk is closer to the Beaufort Sea and less sheltered by topography and vegetation. Tuktoyaktuk is approximately 75 km north of the treeline and Inuvik is on the northern border of the treeline. The maximum hourly average wind speed for Tuktoyaktuk was 78 km/hr. This maximum occurred in January and the wind direction that coincided with it was from the northwest. For comparison, the maximum hourly average wind speed for Inuvik was 65 km/hr for the month of January. There are no data available indicating the maximum gust speeds at Tuktoyaktuk.

3.1.4 Air Quality

Previous air quality studies in the Mackenzie Delta have focused on dustfall, particulate matter, and miscellaneous parameters. The results of an air sampling program conducted in 1972 and 1973 by Slaney are summarized in Table 3.1-9.



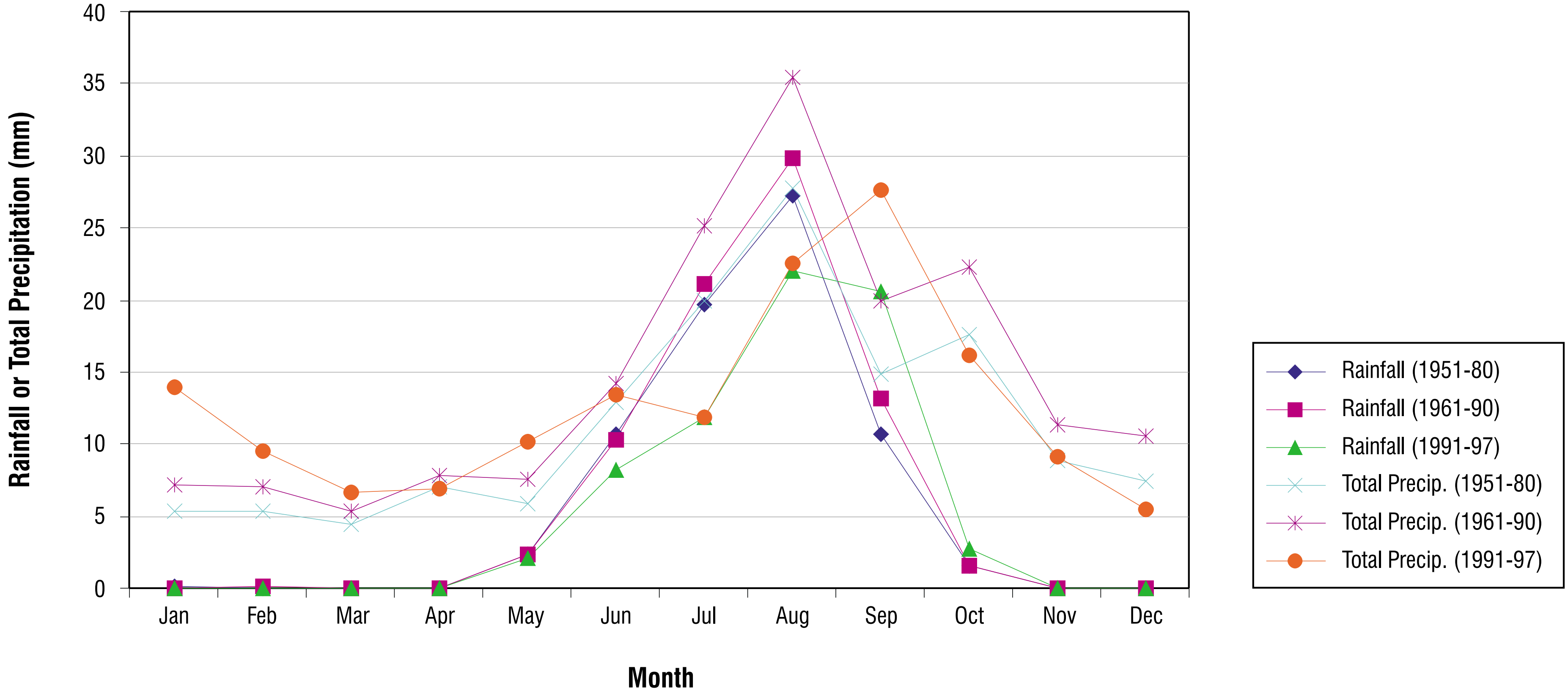
Northwest Territories

FIGURE 3.1-4

Historical Air Temperatures for Tuktoyaktuk

Rescan

Sources: Environment Canada 1980, 1993, 1998



Northwest Territories

FIGURE 3.1-5

Historical Precipitation for Tuktoyaktuk

Rescan

Sources: Environment Canada 1980, 1993, 1998

Table 3.1-6
Summary of Tuktoyaktuk Climatological Data (1991-1997)

Element	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-22.7	-22.7	-18.9	-8.7	0.7	11.7	15.6	11.8	4.8	-4.8	-14.8	-21.9	-5.8
Daily Minimum	-30.3	-30.3	-27.2	-17.6	-6.1	2.3	7.3	5.4	0.1	-10.4	-21.9	-28.7	-13.1
Daily Mean	-26.6	-26.4	-23.1	-13.2	-2.7	7.0	11.5	8.6	2.5	-7.6	-18.4	-25.3	-9.5
Precipitation													
Rainfall (mm)	0.0	0.0	0.0	0.0	2.1	8.2	11.8	22.0	20.6	2.7	0.0	0.0	67.4
Snowfall (cm)	13.9	9.5	6.7	6.9	8.1	5.2	0.0	0.5	7.1	13.5	9.1	5.5	86.0
Total Precipitation (mm)	13.9	9.5	6.7	6.9	10.1	13.4	11.8	22.5	27.6	16.2	9.1	5.5	153.4
Moisture													
Relative Humidity – 0600 L (%)	77	76	72	74	78	78	77	81	87	88	83	78	79
Wind													
Speed (km/hr)	17	17	16	15	17	17	16	18	18	16	16	15	17
Most Frequent Direction	N	N	W	E	E	E	E	NW	E	E	SE	N	E
Maximum Hourly Wind Speed (km/hr)	78	74	63	43	46	54	46	74	74	69	63	59	78
Direction	NW	NW	NW	E	W	NW	NW	NW	NW	NW	N	W	NW

Source: Environment Canada, 1998.

Table 3.1-7
Historical Climate Data for Tuktoyaktuk (1961-1990)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-23.9	-24.2	-22.0	-12.4	-1.0	10.1	15.4	12.6	5.4	-5.2	-16.8	-21.3	-6.9
Daily Minimum	-31.2	-31.8	-29.6	-21.1	-8.5	0.8	6.4	5.4	0.2	-10.3	-23.7	-28.4	-14.3
Daily Mean	-27.2	-27.6	-25.7	-16.7	-4.7	5.5	10.9	9.1	2.8	-7.6	-20.2	-24.7	-10.5
Corrected Precipitation (Metcalf and Ishida, 1994)													
Rainfall (mm)	0.0	0.1	0.0	0.0	2.4	10.3	21.1	29.9	13.2	1.6	0.0	0.0	78.8
Snowfall (cm)	7.1	7.0	5.4	7.9	4.7	2.1	0.2	0.5	4.7	20.7	11.2	10.6	82.0
Total Precipitation (mm)	7.2	7.1	5.4	7.8	7.6	14.2	25.1	35.5	20.0	22.3	11.3	10.5	174.0
Extreme Daily Rainfall (mm)	2.5	4.0	0.0	0.4	12.4	27.9	20.3	29.5	13.6	14.7	1.0	0.0	
Date	1974/05	1982/04	1990/31+	1979/22	1961/27	1972/10	1957/21	1961/25	1982/20	1973/02	1967/21	1990/31+	
Extreme Daily Snowfall (cm)	10.2	7.6	11.0	11.2	9.0	11.4	4.1	3.6	12.7	18.0	10.7	8.0	
Date	1967/23	1962/26	1978/19	1977/27	1986/16	1969/01	1964/01	1969/08	1957/27	1981/22	1975/13	1990/19	
Extreme Daily Precipitation (mm)	10.2	7.6	11.0	11.2	12.4	27.9	20.3	29.5	13.6	18.0	10.7	8.0	
Date	1967/23	1962/26	1978/19	1977/27	1982/19	1972/10	1957/21	1961/25	1982/20	1981/22	1975/13	1990/19	
Month-end Snow Cover (cm)	27	30	32	27	3	0	0	0	1	12	19	23	
Days With													
Maximum Temperature >0 °C	*	*	*	2	13	29	31	31	27	5	*	*	138
Measurable Rainfall	*	*	0	*	*	4	7	9	6	*	*	0	27
Measurable Snowfall	4	4	3	4	3	*	*	*	2	9	6	6	43
Measurable Precipitation	4	4	3	4	3	4	7	10	7	10	6	6	69
Moisture													
Rel. Humidity – 0600L (%)	N	N	N	81	89	89	89	90	91	88	79	N	

Source: Environment Canada, 1993
Notes: * = amount less than 0.5 except 0, N = some data exist, but not enough to calculate a value, T = trace

Table 3.1-8
Historical Climate Data for Tuktoyaktuk (1951-1980)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Temperature (°C)													
Daily Maximum	-25.0	-25.7	-22.7	-12.8	-0.9	9.6	15.2	12.5	5.0	-5.0	-16.2	-22.1	-7.3
Daily Minimum	-31.6	-32.3	-30.2	-21.5	-8.4	0.4	6.0	5.6	0.1	-10.2	-23.2	-28.5	-14.5
Daily Mean	-28.4	-29.1	-26.5	-17.2	-4.7	5.1	10.6	9.0	2.6	-7.7	-19.7	-25.2	-10.9
Extreme Maximum Temperature	0.6	-2.8	1.1	5.6	18.9	28.0	30.0	30.0	22.2	10.0	6.1	1.1	30.0
Years of Record	22	22	23	23	23	24	23	24	24	24	24	23	
Extreme Minimum Temperature	-48.9	-50.0	-45.0	-41.7	-27.2	-11.1	-2.2	-1.7	-12.2	-31.1	-38.9	-43.9	-50.0
Years of Record	23	23	23	23	23	24	23	24	24	24	24	22	
Precipitation													
Rainfall (mm)	0.1	0.0	0.0	T	2.3	10.7	19.7	27.2	10.7	1.6	T	0.0	72.3
Snowfall (cm)	5.3	5.4	4.4	7.1	3.5	2.2	0.2	0.6	4.2	16.0	8.9	7.4	65.2
Total Precipitation (mm)	5.4	5.4	4.4	7.1	5.9	12.9	19.9	27.8	14.9	17.6	8.9	7.4	137.6
Greatest Rainfall in 24 Hours (mm)	2.5	T	0.0	0.4	12.4	27.9	20.3	29.5	12.7	14.7	1.0	0.0	29.5
Years of Record	23	23	23	23	23	24	23	24	24	24	24	23	
Greatest Snowfall in 24 Hours (cm)	10.2	7.6	11.0	11.2	5.1	11.4	4.1	3.6	12.7	12.0	10.7	6.6	12.7
Years of Record	23	23	23	23	23	24	23	23	24	24	24	24	
Greatest Precipitation in 24 Hours (mm)	10.2	7.6	11.0	11.2	12.4	27.9	20.3	29.5	12.7	14.7	10.7	6.6	29.5
Years of Record	23	23	23	23	23	24	23	24	24	24	24	24	
Days with Rain	*	0	0	*	1	4	7	8	5	*	*	0	25
Days with Snow	4	4	3	4	3	1	*	*	3	9	6	5	42
Days with Precipitation	4	4	3	4	3	4	7	9	7	9	6	5	65

Source: Environment Canada, 1982
Notes:
*** = amount less than 0.5 except 0**
N = some data exist, but not enough to calculate a value
T = trace

None of the measured air quality indicators were present in harmful concentrations and all were below acceptable limits. However, concentrations of dustfall, sulphur dioxide and hydrocarbons were all higher at Inuvik than at Richards Island due to proximity to higher concentrations of anthropogenic sources. It should be noted that the data from Inuvik cannot be considered representative of the region.

According to Sparling (personal comm. 1998) there have been no further air quality baseline studies conducted in the Mackenzie Delta since the earlier work by Slaney. The baseline concentrations of SO_2 in the region are approximately 4 $\mu g/m^3$ and less than 10 $\mu g/m^3$ for both total suspended particulate (TSP) and respireable particulate or "PM10." PM10 refers to particulates that have an aerodynamic diameter of less than 10 microns. These fine particulates are a human health concern because they are small enough to penetrate past the nasal and oral passages and into the lungs.

Table 3.1-9
Air Quality Parameters Measured at Inuvik and Richards Island During 1972-1973

Air Quality Parameter	Richards Island	Inuvik
Dustfall	0.007-1.52 tonnes/sq. km/month[1]	0.69-10.16 tonnes/sq. km/month[1]
SO_2	0.000008 ppm[2]	0.00002 ppm[2]
H_2S	<0.0003-0.036 ppm	-
Ozone	<0.0003-0.017 ppm	-
NO_2	0.0002-0.006 ppm	-
Hydrocarbons	0.3-2.4 ppm	4.1 ppm

Source: Slaney, 1974 in Dome Petroleum Ltd. *et al.* 1982
[1]Based on weighing of insoluble solids only.
[2]Based on multiplying sulphation index by 0.03.

According to Gulf Canada Resources Inc. *et al.* (1982) low lying areas are more susceptible to ice fog and air pollutant episodes due to cold air drainage or temperature inversions. Slopes and wind swept locations are less likely to experience these episodes.

Atmospheric inversions are common in low lying areas and warrant further discussion since they impact the dispersion of air pollutants. Thermal inversions occur when a cold Arctic air mass increases in temperature with height, generally within 1000 m above the land surface. Inversions are caused by the negative radiation balance over snow and ice surfaces which predominate at high latitudes over much of the year. Thermal inversions are accentuated by low sun angle, high albedoes, and short days combining to limit day time heating at the surface, with assistance from subsidence and warm air advection aloft. Table 3.1-10 summarizes the frequency of inversions at Inuvik documented by Burns (1973) in Dome Petroleum Ltd. *et al*. (1982).

Low level inversions also occur when temperatures initially decrease with height for the first few hundred metres and are capped by a shallow inversion layer. Low level inversions are common in the afternoon. No statistics are available for their frequency of occurrence but it may be assumed that some nighttime surface-based inversions are converted to low level inversions by afternoon heating and are not accounted for in Table 3.1-10. The percentage of time that afternoon surface-based inversions occur should not be used as a direct measure of the pollutant potential associated with temperature inversions.

Table 3.1-10
Seasonal Differences in the Frequency of Surface-Based Temperature Inversions (%) Observed at Inuvik Airport, N.T.

Months	Time of Day (GMT)	Frequency of Inversions (%)
December – February	2300	58
	1100	67
March – May	2300	3
	1100	60
June – August	2300	0
	1100	61
September – November	2300	25
	1100	46

Source: Burns, 1973 in Dome Petroleum Ltd. *et al*., 1982.

One other indicator of the potential for air pollution episodes is the mixing height of the atmosphere. The mixing heights summarized in Table 3.1-10 are a measure of the maximum depth of vertical mixing which occurs at the earth's surface as a result of daytime heating. Mixing heights are calculated from a graph of temperature versus height. The mean mixing layer wind speed (Table 3.1-11) is the vertically averaged wind speed between the surface and the top of the mixing layer (*i.e*. mixing height). The mean maximum ventilation coefficient (Table 3.1-11) is the product of maximum mixing height and mean mixing layer wind speed. The ventilation coefficient is a measure of the ability of the atmosphere to disperse pollutants.

The mean maximum afternoon mixing heights vary seasonally. The mixing heights are typically less than 200 m in November and remain low until February. The mixing height generally improves markedly by April and remains good through the summer until September. Although surface-based and low-level inversions occur frequently throughout the year, their pollution potential is minimized by higher mixing heights and wind speeds during the months of March through September. Conversely, based on the ventilation coefficients (Table 3.1-11), the period from October through April would coincide with the most likely time period for pollution producing episodes at Inuvik.

Table 3.1-11
Mean Maximum Afternoon Mixing Heights, Mean Mixing Layer Wind Speeds and Mean Maximum Ventilation Coefficients for Inuvik, N.T.

Month	Mean Maximum Afternoon Mixing Height (m)	Mean Mixing Layer Wind Speed (km/hr)	Mean Maximum Ventilation Coefficient ((m^2/s)/10)
January	119	9.4	39
February	162	9.0	48
March	288	12.6	107
April	445	14.8	187
May	836	17.3	407
June	1221	16.9	559
July	1460	17.6	716
August	1042	15.8	477
September	675	16.6	308
October	280	12.2	104
November	159	11.2	71
December	159	8.3	45
Annual	621	14.0	280

Source: Portelli, 1977 in Dome Petroleum Ltd. *et al.*, 1982

Air quality studies have been completed in the High Arctic as part of the Arctic Environmental Strategy's Northern Contaminants Program (AES-NCP). The NCP works to:

- measure contaminants in the North;

- determine the source of the contaminants and their pathways;
- assess the effects of contaminants on the health of human environments, including humans;
- provide information to assist Northerners' decision making; and
- pursue international agreements on controlling contamination at a global level.

The program involves a database of at least two years of routine observations of the important organochlorides (OCs), polycyclic aromatic hydrocarbons (PAHs) and Mercury (Hg) in the Arctic atmosphere at Alert, NT; Tagish, Yukon; Cape Dorset, NT; and Dunay Island, Russia. The Mackenzie Delta is geographically closest to the Tagish monitoring site. This study concluded that the atmospheric concentrations of many compounds exhibit strong seasonal characteristics and this variability is likely related to air temperature.

The concentration of OCs ranged from almost 100 pg/m^3 for chlorobenzenes and hexachlorocyclohexanes (HCHs), to less than 1 pg/m^3 for mirex, endrin and trifluralin (a fluorinated herbicide). Maximum concentrations at any of the sites do not exceed 1 pg/m^3. The mean OC concentrations for Alert, Dunay and Tagish for 1993 and 1994 are summarized in Table 3.1-12.

The composition of the complex PCB mixture of compounds differs between the North American Arctic and the Russian Arctic. However, more chlorinated compounds were found in Russia. The mean concentrations of PCBs at Alert, Tagish and Dunay for 1993, the year when all three sites were operating concurrently, were 27.9, 17.2 and 34.2 pg/m^3, respectively.

PAHs in the Arctic typically peak in the winter months of December to February, overlapping the Arctic haze season. The most abundant PAH compounds in air were fluorene, phenanthrene, fluoranthene, and pyrene. Table 3.1-13 summarizes PAH concentrations at the three study sites for 1992 to 1994. The most southerly site, Tagish, experienced the lowest mean annual PAH concentration. For 1993 and 1994 the mean ΣPAH concentrations at Tagish were lower than at Alert by factors of 2.3 and 1.3, respectively. Naphthalene was found to be the most

Table 3.1-12
Summary of Mean Organochlorine (OC) Concentrations (pg/m^3) in the Arctic Atmosphere for Alert, Dunay and Tagish (1993 and 1994)

	SCBz	SHCH	OCSTYR	SCHLOR	DIELD	SDDT	MIREX[1]	PCA	ENDOSUL	MEOCL	SCL-VER	ENDRIN	TRIFLU	STOX
Alert														
1993	97.1	71.7	0.60	5.19	1.18	0.82	0.10	2.53	3.61	0.26	0.97	0.18	0.12	4.43
1994[2]	94.3	76.9	0.98	6.65	1.42	1.40	0.10	3.12	4.89	0.28	1.44	0.20	0.13	5.33
Dunay														
1993	85.7	50.9	0.60	4.55	1.11	0.93	0.16	2.92	2.99	0.41	1.93	0.28	0.18	4.70
Tagish														
1993	52.7	91.3	0.44	5.63	0.91	1.39	0.11	2.56	5.76	0.31	2.17	0.22	0.13	5.12
1994[3]	44.0	80.4	0.69	5.19	0.81	1.51	0.10	2.25	6.58	0.28	2.05	0.2	0.12	5.35

1: including photo-Mirex
2: up to week ending the 26th September
3: up to week ending the 25th August

CB = chlorobenzenes
ENDOSUL = endosulfan
MEOCL = methoxychlor
CL-VER = chloro-veratroles
TRIFLU = trifluralin
TOX = Stoxaphene
HCH = Shexachlorocyclohexanes
OCSTYR = octachlorostyrene
CHLOR = Sclordanes
DDT = SDDTs
PCA = pentachloroanisole

Source: Indian and Northern Affairs Canada, 1997

abundant PAH in the arctic atmosphere, however, it was not included in these mean values due to its probable underestimation resulting from a sampling artifact (Indian and Northern Affairs Canada, 1997).

Mercury (Hg) concentrations at Alert, NT were three times higher than concentrations measured in Antarctic air. This was probably due to the fact that there are more natural and anthropogenic sources of Hg in the northern hemisphere than in the southern hemisphere. Prior to the NCP there were no atmospheric measurements of Hg in the Arctic. Results from a 1992/93 weekly integrated sampling of total gaseous Hg at Alert indicated a range of concentrations from 0.67 to 2.8 ng/m^3 with an arithmetic mean of 1.5 ng/m^3. During 1987 to 1989 Hg concentrations in the Antarctic were on average three times lower than in the Arctic. The mean Hg concentration for the Antarctic was 0.55 ng/m^3. Continuous observation over January to April 1995 at Alert indicated that the mean total gaseous Hg in air was approximately 1.5 ng/m^3, concurring with the 1992/93 results (Indian and Northern Affairs Canada, 1997).

Table 3.1-13
Summary of PAH Concentrations for Alert, Dunay and Tagish
Annual Geometric Mean PAH Concentration (pg/m^3)

	1992	1993	1994
Alert	465	444	330
Tagish	n/a	194	249
Dunay	n/a	508	n/a

Source: Indian and Northern Affairs Canada, 1997

It should be noted that the NCP study did not provide baseline data for OCs, PAHs or Hg specific to the Mackenzie Delta. However, the baseline concentrations measured by the NCP are generally applicable to the Arctic region.

3.1.5 Data Gaps

An excellent climatological database has been developed for the Inuvik-Tuktoyaktuk area by Environment Canada. The available information, which will continue to be built upon in the years to come, will be sufficient to meet the environmental assessment and construction/operational needs of the proposed Inuvik-Tuktoyaktuk road.

3.2 Surficial Geology

3.2.1 General

Extensive historical work has been completed on the understanding of the surficial and geophysical properties of the study area. The area is located within the Anderson Plain and the Tuktoyaktuk Coastlands (Rampton, 1988). The Anderson Plain is characteristically undulating and rises inland (Bostock, 1970). The Tuktoyaktuk Coastlands area is characterized by thick unconsolidated sediments, commonly with more than 30% covered by lakes, and rarely less than 15% cover by lakes. (Rampton, 1988). This area has few bedrock outcrops, and is poorly drained due to a deranged drainage pattern because of thermokarst activity. Most of the Tuktoyaktuk Coastlands area is below 60 m in elevation.

The Anderson Plain area is characterized by bedrock relief exerting a control over much of the topography even though there is a thick sediment layer over much of the area. Except for the Caribou Hills, most of the study area lies below 100 m in elevation (Rampton, 1988).

These areas were studied in the late 1960’s and early 1970's as a response to increased exploration interests from the oil and gas industry. The massive ice deposits of the area were of concern to the engineers, geologists and others involved in the northern development activities and environmental protection.

The lack of good borrow sources and the uninterrupted presence of permafrost are critical considerations for the development of the proposed Inuvik-Tuktoyaktuk road. Over the past 10 years, a series of studies have been completed on the potential granular sources in the Tuktoyaktuk and Inuvik areas and for the Inuvialuit Lands Claim block. These studies have revealed that sources are present, although in many cases of relatively poor quality, or at some distance from the communities and the proposed road alignment. The massive ice, silty soils, and the presence of numerous lakes present concerns for the development and use of the identified granular sources.

3.2.2 Permafrost Conditions

The entire proposed road alignment is within the continuous permafrost zone. Permafrost is defined as a layer of earth material which remains below 0^{o}C for longer than one year. Within the permafrost layer there are several forms of frozen ground that occur. The frozen ground can contain excess ice, where the amount of water contained in the soil matrix in a frozen state is higher than would be expected of the soil in an unfrozen state. The excess ice can be found mixed within the soil matrix in percentages from ice inclusion in the soil to soil inclusions in the ice, or as almost pure ice in the form of ice lens and ice wedges. The importance of these ice inclusions is the susceptibility of these to thermokarst (melting) and the resultant ground subsidence.

Above the permafrost is a layer of soil that experiences seasonal thawing and freezing. This layer is referred to as the active layer, and typically ranges from only a few centimetres to a few metres in depth within the subject area (Slaney, 1974). The shallower active layers are generally associated with the dry organic soils at the surface.

The following is a brief description of permafrost related landforms found within the area of interest. These descriptions are taken from Slaney, 1974.

Pingos

Pingos are ice-cored hills that are forced up by hydrostatic pressure in an area underlain by permafrost. Pingos may be from 3 to 50 metres high and have a base of 30 to 600 metres in diameter. Mackay (1963) reported the existence of some 1,400 pingos in the Delta area. Several particularly large pingos are located near Tuktoyaktuk to the west of the proposed road alignment near the Beaufort seacoast (Plate 3.2-1).

Thermokarst Topography

Thermokarst refers to the surface subsidence resulting from the melting of ice rich permafrost, particularly ice lens. The permafrost equilibrium can be disturbed by either climatic change or the disturbance of an insulating ground cover by natural (wild fires, erosion) or human (road development) activities. The ground ice will thaw, and if the resultant water can not drain away, this water may contribute to further degradation of the permafrost. This may result in the creation of small ponds or lakes. The pond/lake edges in the Delta area often have localized slumping, triggered by the destruction of the over layer, (organic layer) due to thermokarst conditions.

Polygons

Polygons are recognizable as a type of ground pattern found primarily in low-lying poorly drained areas. These features are then classified as high or low centred. The low centred polygons consist of central flat terrain enclosed by relatively dry ridges. During the winter, water that has filled the cracks in the ice wedges freezes to expand the wedges. During the summer, melt water fills in the cracks in the ice wedges. In this manner ice wedges grow progressively. Ice wedge growth pushes up the surface soil to form linear ridges. Intersecting ridges form to give the surface of the ground a polygon appearance where the polygons are between 5 to 30 metres on a side.

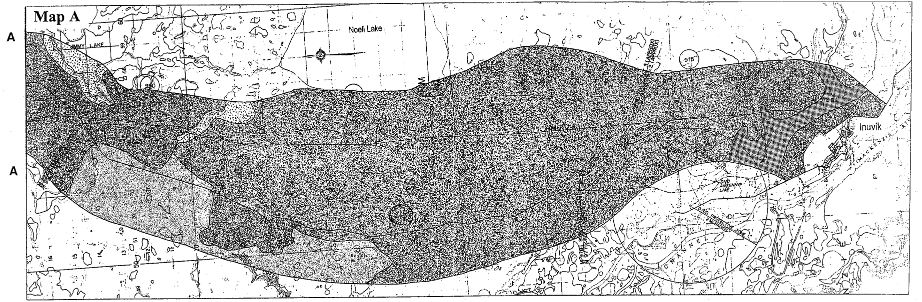
As ice wedges continue to grow, the ridges of soil become broader and encroach in on the centre of the polygon. Over time low centred polygons can become high centred polygons. These features typically form in drained lake beds.

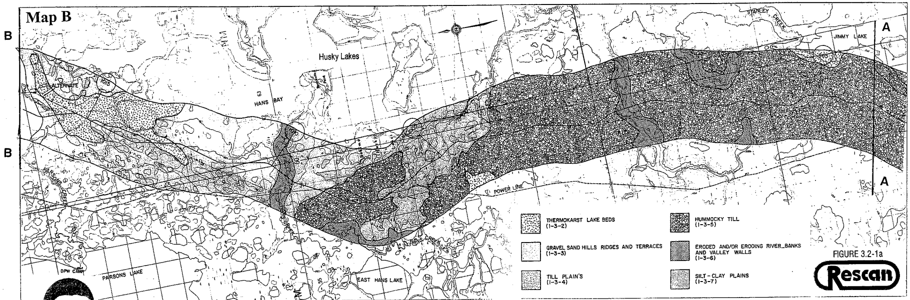
Peat Mounds

Peat mounds usually occur in wet soils that are typically comprised of alluvial silts. Often found near the low centred polygons, peat mounds are oblong formations up to 3 metres in diameter and up to 1 metre in height. Peat mounds are formed when the subsurface ground ice accumulates to produce pressures that buckle the active layer. The peat mounds may continue to grow as organic material is produced, or as the permafrost aggrades into the old peat layer.

3.2.3 Surficial Deposits

The surficial geology of the subject area is well described by Rampton (1982, 1988). The subject area consists of Pleistocene marine and fluvial sediments with estuarine and morainal deposits. The following description of the surficial deposits and landforms encountered by the proposed highway routing is derived from Rampton (1982, 1988). Figure 3.2-1 (reproduced from PWC (1975) Rampton - 1982) shows the location of the deposits and landforms in the vicinity of the proposed Inuvik to Tuktoyaktuk road corridor. Figure 3.2-2 (in map pocket) is Map 1647a produced by Energy, Mines and Resources Canada (Rampton, 1987). This map provides an updated description of the surficial geology of the Tuktoyaktuk coastlands.

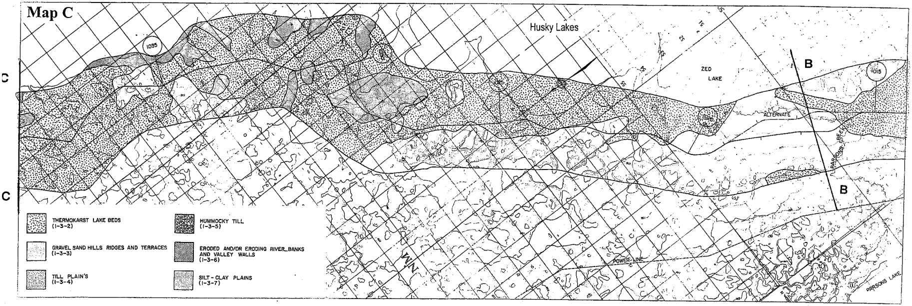


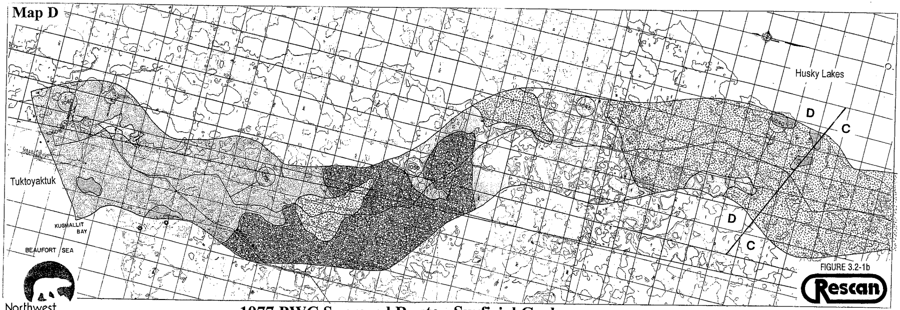


Northwest Territories

1977 PWC Surveyed Route - Surficial Geology

Source: Rampton 1972 cited in PWC 1975





Northwest Territories

Rescan

1977 PWC Surveyed Route - Surficial Geology

Source: Rampton 1972 cited in PWC 1975

3.2.3.1 Organic Terrain

Generally, these deposits occur as peat or fen, or peat-fen complexes, usually as cover for till plain deposits or hummocky till deposits described below. Organic terrain typically has flat to moderate slopes.

3.2.3.2 Thermokarst Lake Beds

Thermokarst lake beds occur where clay, silt and peat, and local sand have formed a thin veneer (generally less than 3 metres) in low flat areas previously occupied by tundra ponds.

These lake beds often have an associated peat cover in excess of 3 m thick and these areas tend to be wet and marshy with many shallow pools. Ice content is generally high with up to 60% excess ice in the fine-grained materials, but examples of low to medium ice content sands and gravels have been found. These areas often exhibit thermokarst subsidence with erosion along ice wedge cracks, and slumps on medium slopes triggered by permafrost regression in ice-rich fine- grained materials. Because of the lack of coarse granular material, these areas can not be considered for sources of barrow material. Pingos are commonly associated with this formation.

3.2.3.3 Gravel-Sand Hills, Ridges and Terrances

Materials in this depositional type are usually gravel and sands with some silty sands. Eskers, and other glaciafluvial deposits, river terraces, sand dunes, and moraines consisting of deformed gravelly-sandy strata are commonly formed in these areas. Rampton (1988) uses three broad descriptive categories.

- Morainal deposits, consisting of deformed and tilted sand silt and clay beds with minor gravel inclusions, often overlain with fine dune sand or stony clay. The topography is hilly, with relief up to 60 metres with the presence of cliff top dunes and blowouts.

- Hummocky areas, consisting of interbedded sands and gravels up to 10 metres thick exist at several locations along the route. Local relief varies from 15 to 50 metres and peat cover is negligible except in some depressions.

- Terrace areas, consisting of sands, interbedded sands and gravels and gravel up to 10 metres thick, often form flat benches along present or former rivers and estuaries. Thermokarst ponds and lakes are common to these terraces and dunes and blowouts are found on the Tuktoyaktuk Peninsula. Peat cover is usually found on larger flat areas and in abandoned river channels.

There is generally a low ice content in the near surface sand and gravels, while the stony clays and silt veneer may contain moderate amounts of ice. The ground surface tends to be dry except on larger flat areas or in channel traces where thaw ponds are common. These deposits are susceptible to ground ice regression and associated slumping and gullying, particularly on hillsides and sloping banks where the material consists of fine sand or silt.

These deposits represent a major source of useful borrow materials, consisting of gravels and mixed sands and gravels.

3.2.3.4 Till Plains

Generally till-type deposits exist as a ground moraine with low rolling relief and/or parallel drumlin ridges. Two local variations of this type of deposit are identified in the area of interest.

- Thin morainal deposits over shale, consisting of silty to clayey till are found at the southern end of the proposed road route. The topography here is typically sloping rolling plain with local relief, due to stream erosion and thermokarst subsidence, up to 30 metres.

- Thin morainal deposits over sand, consisting of silty to clayey pebbly till, are found in the Tuktoyaktuk Peninsula. The till veneer form 0 to 5 metres thick lie over 10 metres of fine to coarse marine and/or fluvial sands. The topography varies from hummocky to rolling with local relief up to 50 metres.

For both morainal deposits over shale and morainal deposits over sand, the ice content of the till tends to be moderate, but the ice content for the underlying sands may vary from low to high.

The morainal deposits over shale are only moderately susceptible to thermokarst, and gullying. The occasional ice slump and minor mudflow do occur on the steeper slopes.

The morainal deposits over sand can have major susceptibility to thermokarst where a thin veneer over-lays an ice rich sand.

Because gravel deposits are rare in these formations, the usefulness of any proposed borrow source is a function of the ice content of the material. The underlying shale is a source of low-ice borrow material, and the underlying sands are also a useful borrow source if the ice content is low enough.

3.2.3.5 Hummocky Till

Till deposits consist of clayey to gravelly-sandy till mixed in with local gravel deposits. The silty to clayey tills are often up to 10 metres thick and overlay sand and/or silt with minor clay and gravel inclusions. The topography varies from rolling to hilly moraine, with individual to coalescent hummocks, 15 to 50 metres high and 30 to 50 metres across. Slopes vary from flat to 20% with isolated instances of 30% slopes. Many of the hills in the Tuktoyaktuk area are "involuted" with a characteristic pattern of ridges and swales with 1 to 3 metres of relief.

The ice content of these deposits varies greatly and is usually dependent on topographic location. Crests of prominent ridges and hummocks are typically well-drained and ice free to depths of 2 to 5 metres. The till is often icy with reticulated ice lenses. Massive ice is common at the base of the till in involuted hills and in areas underlain by silts and marine sands. The deposits are moderately susceptible to thermokarst activity with some signs of subsidence and ground ice slumps and minor susceptibility to gullying. Where the till forms a thin veneer on sand or finer materials which normally contain excessive ground ice, the hazard of thermokarst activity taking place increases.

Local drainage patterns tend to be deranged with some centripetal drainage to local ponds. There is poor drainage in the swales of the involuted hills.

The potential of these deposits as borrow material is limited by the ice content. Minor sources of gravel and mixed and gravel are located in these features, but generally only the higher crests and hummocks will yield useful material.

3.2.3.6 Eroded and/or Eroding River Banks and Valley Walls

Rampton (1988) describes two distinct units where one unit consists of unconsolidated materials and the other consists of bedrock.

In the first unit, various unconsolidated materials form moderate to steep slopes, generally with a surface veneer of slope debris. The material on the upper part of the slopes is typically the same as the material covering adjacent terrain, with variations in material with depth. The slopes are generally less than 50 metres in length and the quantity of ground ice present varies with the particle size of the material and the presence or lack of good drainage. The surfaces of sand and gravelly materials are commonly dry, while other materials are wet with locally running water and active gullying. Borrow potential for these types of deposit is predicated by the presence and quantity of ground ice.

For the second unit, bedrock outcrops or bedrock is partly covered by rock detritus or unconsolidated materials. Steep faces, consisting of horizontally stratified shale or of shale partly covered by debris, are common. The shales are usually dark grey and friable, and contain gypsum crystals and layers with some coal. The ground ice content of the shale is very low, however the ice content in the overlying unconsolidated materials can vary from high to low.

As a borrow source, these features are important as a source of low strength shales with low-ice content. In some cases the overburden may be a worthwhile area to consider for borrow material.

3.2.3.7 Silt-Clay Plains

These marine and lake deposits generally consist of clay and silt, surfaced by sand or silty sand with a discontinuous organic cover, and principally form the plains bordering rivers and coastal areas. For the study area, lake deposits with depths exceeding 30 metres are typically found near the Husky Lakes. The topography is generally hilly because of thermokarst depressions and in poorly drained areas peat cover in excess of 4 metres may be found.

The sediments forming the silt-clay plains have a high ice content with up to 10% segregated ice typically occurring as thin seams in the upper 3 metres. At greater depth (greater than 3 metres) reticulated networks of ice, up to 40% by volume in the silts and clays, are also found as thick tabular bodies of ice at depth. This deposit is susceptible to thermokarst subsidence, with erosion along ice wedge cracks, ground ice slumps and some gullying on slopes.

3.2.4 Terrain Along Proposed Route

The following description uses the start of the roadway at kilometre zero at Inuvik. The descriptions are from the Energy mines and Resources Canada Map 1647a (Rampton, 1987), and from Public Works Canada (1975). Figure 3.2-1, reproduced from Public Works Canada (1975), describes the surficial geology of the 1977 PWC surveyed route in detail.

Kilometre 0 to Kilometre 11

The proposed road leaves Inuvik and ascends onto an elevated hummocky plain. Rampton shows this area to be fans with silt, clay, fine sands some coarse sand and gravel. The sediments are generally more than 10 metres thick. The road alignment borders on colluvial deposits that are generally comprised of coarser deposits.

Kilometre 11 to 16

The corridor traverses an area of morainal deposits comprised of till and associated gravel and sand deposits. The area is hummocky and rolling. The route crosses a series of poorly drained depressions lying to the west.

Kilometres 16 to 39

The corridor crosses a morainal blanket generally 4 to 12 metres thick. The area is rolling terrain consisting of clayey or silty clayey tills. The ground in this area is generally well drained.

Kilometre 39 to 55

The route crosses several small drainage courses in this section. There are signs of thermokarst and associated slumping (PWC, 1975). At approximately kilometre 47 to 55, the route crosses several deeper valleys. These show signs of erosion where ice rich soils have melted. This indicates local instability (PWC,1975).

Kilometre 55 to 80

The route enters a more complex surficial geological section of outwash plains, terraces and lacustrine deposits. From kilometre 55 to 69 the area is gently rolling hummocky till. At kilometre 62 the route crosses Hans Creek, a major drainage course. The route runs adjacent to the Husky Lakes along this section and to kilometre 107.

At kilometre 69, the route descends to flat, gently rolling low land, consisting of sandy glaciofluvial deposits with gravelly sand ridges and terraces inter-dispersed in the plain.

At kilometre 73, the route crosses Parsons Creek, the outlet to Parsons Lake and a major drainage course. This area is characterized by thermokarst lake beds with evidence of ground slumping (PWC, 1975).

Kilometre 80 to 115

This area passes primarily through gravel sand till. PWC (1975) reports that the road alignment parallels a series of thermokarst lake beds where there are several developing pingos. The route passes through areas that have small depressions and can be characterized as poorly drained. At kilometre 100, the route enters a better drained area of gravel-sand till and gently rolling terrain.

Kilometre 115 to 140

The final stretch to Tuktoyaktuk continues on a gravel-sand till with hills and ridges. This area has many thermokarst lakes, pingos and peat mound formations. At kilometre 125 the route follows a series of higher ridges. At kilometre 130 the route crosses onto a relatively flat plain with many small lake beds and consisting of silty clayey till.

3.2.5 Potential Borrow Sources

Investigations into the potential land-based granular sources in the area of interest were initiated in the early 1970's. Since that time an extensive number of regional investigations have been completed. Many of these investigations triggered more detailed site investigations of specific granular sources with the intent of developing these sources for use by the governments, industry, local communities and the land claims groups. The most recent work was completed by EBA Engineering Ltd. in 1987. For Indian and Northern Affairs Canada. This document forms part of the Inuvialuit Final Agreement

(IFA), and identifies the expected granular resources for Inuvialuit lands for the 20 year period after the date of the report. The identified granular requirements included the construction of the Inuvik to Tuktoyaktuk road (3,300,000 m^3).

Granular resources located near Inuvik that may not be part of the IFA, are referenced in Hardy BBT, 1988. Other granular resource studies carried out in the region are included in Reference Section 3.2-1 as a bibliography.

These documents, and others identify some 150 potential sites for granular resources along the proposed routing. The resources can be identified under one of five classifications. These classifications, developed by INAC in 1983 to describe resources found in pits and quarries, are as follows:

- Class 1 - Excellent quality material consisting of clean, well graded, structurally sound sands and gravels suitable for use as high quality surfacing materials or as asphalt or concrete aggregate with minimal processing.

- Class 2 - Good quality materials generally consisting of well graded sands and gravels with limited quantities of silt. This material will provide good quality base and surface course aggregates or structural support fill. Production of concrete aggregate may be possible with extensive processing, except where deleterious materials are present.

- Class 3 - Fair quality material consisting generally of poorly graded sands and gravels with or without substantial silt content. This material will provide fair quality general fill for roads, foundations and lay down yards.

- Class 4 - Poor quality material generally consisting of silty, poorly graded, fine grained sand with minor gravel. These deposits may also contain weak particles and deleterious materials. These materials are considered suitable for marginal general fill.

- Class 5 - Bedrock of fair to excellent quality, felsenmeer or talus. Potentially excellent sources of construction materials, ranging from general fill to concrete aggregate or building stone if quarried and processed. Also includes erosion control materials such as rip-rap or armour stone.

The potential granular resources are further described as either proven, probable, or prospective. Proven being one whose occurrence, distribution, thickness and quantity based on direct and indirect evidence, such as topography, landforms, air photo interpretation, *etc*. Prospective is one whose existence is supported on the basis of limited direct evidence.

The granular sources in the vicinity of the communities of Inuvik and Tuktoyaktuk have been ground truthed, and are Proven resources. The majority of the granular resources along the road routing are Probable, and in many cases of poor quality (Class 3, and Class 4). The use of these resources will need to be proved up through additional site investigation.

3.2.6 Data Gaps

In general the surficial geology of the 1977 PWC Surveyed Route is well documented and sufficient for the further planning of the proposed road. However, at the Tuktoyaktuk and Inuvik community public consultation and elder interview sessions held in January 1999 (chapters 6 and 7), some individuals expressed considerable concern over the proximity of the proposed road to Husky Lakes and requested that the alignment be relocated two to three kilometres inland in this area if possible.

Based on these concerns, the feasibility of relocating the alignment in the Husky Lakes area should be examined. In particular, a level of “ground truthing,” similar to that completed for the 1977 PWC Surveyed Route is recommended.

3.3 Hydrology and Water Quality

3.3.1 Hydrology

In the Canadian Arctic, the extreme climate and unique ground conditions influence the hydrological cycle. As indicated in Section 3.1 the climate is characterized by long, very cold winters and short summers. Snow and ice affect the temporal redistribution of liquid water occurrence at the earth’s surface, hence affecting the timing and character of flood runoff. Additionally, the extremely cold environment causes the ground to be perennially frozen, thus influencing the runoff regime by drastically altering infiltration properties of soils and changing runoff pathways. The watersheds which will be crossed by the proposed road are distributed along a latitudinal gradient (68º20’ to 69º25’N) that includes a strong vegetational gradient from boreal forests in the south to low Arctic tundra conditions in the north. The principal hydrological processes in this region are snow accumulation, snow-melt, surface runoff, streamflow, and lake hydrology.

3.3.1.1 Hydrological Processes in Arctic Basins

In the cold climate of the western Canadian Arctic, snow is accumulated over approximately eight months and subsequently released over several weeks during snow-melt. Annual precipitation totals rapidly decrease from Inuvik to the coast. Based on data from the 1990 to 1997 period (Section 3.1), annual precipitation averaged 275 mm for Inuvik and 53 mm for Tuktoyaktuk for the 1991 to 1997 period. Snow water equivalent contributes to total precipitation with approximately 55% and 56% for both sites, respectively. The snowpack usually attains its maximum water equivalent in early May. The windswept surface concentrates the light snow into drifts, and much of the snow surface blows free.

Snow-melt occurs from May to July when energy from direct solar radiation is added to a snowpack that is isothermal at 0 ºC. Usually, a strong diurnal rhythm dominates snow-melt. However, Robinson (1986) showed that early and sudden snow-melt can also be caused by warm air advected into a region. The shape of the diurnal melt hydrograph in a stream channel is not only controlled by the pattern of melt at the surface, but also by the passage of water through the snowpack and by the saturated flow at the base of the snow to an unimpeded channel. Inhomogenities in the snowpack, *e.g.* snow layers of different hydraulic properties or ice lenses, tend to diffuse the shock front of the melt wave by ponding at the interfaces and the development of ‘flow fingers’, thus reducing the peak flow (Marsh *et al.*, 1984). Once the snowpack is thoroughly wetted, some meltwater infiltrates into the soil, freezes, and effectively seals the soil pores with ice (Woo, 1993). The reservoirs at the base of the snow have to be filled, before flow will concentrate in pathways at the base of the snow.

In smaller drainage basins, streamflow hydrographs closely follow the diurnal flow pulses during snowmelt. In contrast, medium to large sized basins exhibit a seasonal nival flow peak in which the details of the hydrograph are dominated by synoptic weather periods. On the Anderson and Pleistocene Coastal Plain, peak freshet flows occur between late May and early July over a period of two to four weeks, depending on basin size and initial snowpack depth (Anderson, 1974; Appendix 3.3-1). The volume of the snowpack and the weather conditions, *i.e.* temperature curve, govern the magnitude of the flows. While the ground is frozen, it restricts infiltration of snow meltwater so that the bulk of spring runoff occurs as overland flow. Depending on the timing and duration of snowmelt, the spring snowmelt flood may comprise between 50 and 90% of annual runoff (Robinson, 1986). As the active layer begins to thaw, the ground's capacity to store and to transmit water increases. Therefore, freshet flows are followed by a rapid recession to base flow, interrupted occasionally by rainstorm-generated peaks.

Essentially, all subsurface flow during summer occurs in the shallow active layer that undergoes annual freezing and thawing cycles. Therefore, for areas underlain by continuous permafrost there is typically a large difference between seasonal maximum and minimum streamflow rates. In the project region, minimum flows during the openwater season are usually reached from early July to late September, before heavy rainfall produces a notable flow response (Appendix 3.3-2). In the project area, the freezing of streams usually starts between mid-September and mid-October (Appendix 3.3-3). On most waterways freeze-over is usually complete by November. Surface stream flows typically cease between early November and early February, because the suprapermafrost groundwater reservoir is too limited to maintain flow in winter (Woo, 1983; Appendix 3.3-4). However, streams that are fed by headwater lakes, will flow longer than those without (Hobbie, 1984). In other words, large lakes continue to release water from their outflow streams during early winter, when all inflows into the lakes have already ceased to flow. Consequently, lake levels continue to drop in early winter.

Spring runoff typically generates the highest flows each year. Only in years with low snowmelt peaks and intense summer rainstorms are summer floods generated that exceed spring freshet flows (Jasper *et al.*, 1992). The highest stages observed may also be due to channel blocking by ice, or in small basins by snow. Break-up ice jams affect large rivers and can produce large stage rises upstream and potentially destructive floods downstream.

Evapotranspiration is also an important component of the water balance of Arctic watersheds. According to Maxwell (1997), annual actual evapotranspiration across the mainland of Arctic Canada averages approximately 113 mm. Evapotranspiration in the Arctic tussock tundra is greatest during summer and is mainly controlled by the moisture level in the active layer (Kane *et al.*, 1988). Actual evapotranspiration is much lower than potential evapotranspiration, as non-vascular plants (such as mosses and lichens) in the vegetation mat transpire to a lower degree than vascular plants do (Anderson, 1974). During a five-year study in the Mackenzie Delta (1982-1986), evaporation from open water surfaces was usually greater than summer precipitation and in some areas even greater than annual precipitation (Marsh *et al.*, 1988). Annual evaporation varied between 200 and 387 mm per summer.

3.3.1.2 General Watershed Characteristics

The proposed road leads through the northern spurs of the Anderson plain, then skirts the eastern edge of the Caribou Hills, before entering an extensive coastal plain, which borders the eastern side of the Mackenzie Delta (Figure 3.3-1). The road initially passes through scrub taiga with an elevation approaching 200 m above sea level. The elevation of the land gradually decreases northward towards the coastal plains of the Tuktoyaktuk Peninsula which consist mainly of Pleistocene fluvial and deltaic deposits. Except for some of the pingos, most of the coastal plain lies below an altitude of 70 m with about 50% below 35 m (French *et al.*, 1983). Therefore, the topography of the area is low, usually being less than 5º where the terrain is unaffected by thermokarst processes. As described in Section 3.2, thermokarst results from thawing of ice-rich permafrost on the Tuktoyaktuk Peninsula and creates thermokarst topography, which is characterized by an irregular land surface and numerous small depressions and lakes (Bates *et al.*, 1984). Due to permafrost underlying the Arctic Coastal Plain, shallow ponds form inside ice-wedge polygons and subsequently may coalesce into larger ponds (Hobbie, 1984).

As a result, approximately 30 to 50% of the Tuktoyaktuk Peninsula is covered with lakes and ponds (Mackey, 1963). According to Percy *et al*. (1975), lakes on the Coastal Plain are relatively shallow and shorelines are irregular. Nine Lakes in the Freshwater and Mayogiak watersheds near Tuktoyaktuk had maximum depths of less than 4 m (Ramsey, 1985). The lakes surveyed by Pienitz *et al*. (1997) on the Arctic Coastal Plain, are shallow, with mean depths between 2.8 and 5.8 m. Lakes are usually of small to medium size. Husky Lakes are the biggest lakes with an approximate area of 880 km^2.

The complex surface hydrology of the project study area is due primarily to the low relief of the terrain, with a resulting diffuse drainage pattern. The lakes are typically connected by small streams following weak hydraulic gradients.

3.3.1.3 Major Streams Crossed by the Proposed Road

Upon leaving Inuvik, the proposed road would advance east and then north for 15 km among small lake and stream systems that drain into the Mackenzie River Delta. From here, the road would leave the Mackenzie River Delta drainage basin and enter the Husky Lakes drainage basin, which drains in a northeasterly direction reaching the Beaufort Sea through Liverpool Bay. The road subsequently crosses various sub-drainage basins of the Husky Lakes basin. While traversing the Stanley Creek watershed, it skirts the western shores of Noell and Jimmy lakes. The road would proceed north-northeast, passing east of East Hans and Parsons lakes and following the western shores of Husky Lakes. In this section, the road crosses Trail Valley Creek, Hans Creek, Zed Creek, and several unnamed streams, all discharging in an eastward direction into Husky Lakes. South-southeast of Tuktoyaktuk, the road would angle north, leaving the shores of Husky Lakes and crossing into the Kugmallit Bay drainage basin. Immediately, the road would pass between the two unnamed headwater lakes of the Reindeer Creek and Freshwater Creek systems, both of which drain via Tuktoyaktuk Harbor into Kugmallit Bay and the Beaufort Sea. Eight kilometres north, the road would cross over Reindeer Creek before joining the existing local road south of Tuktoyaktuk. In all, 9% of the road would be in the Mackenzie River Delta drainage, 14 % in the Kugmallit Bay drainage, and 77% in the Husky Lakes drainage.

Figure 3.3-1 Watersheds within the Project Area

3.3.1.4 Regional Water Survey of Canada Streamflow Data

Location of the WSC Watersheds

Daily discharge data were obtained from Environment Canada, Water Survey of Canada (WSC, 1998) for five regionally gauged hydrometric stations in order to asses the spatial variability of surface water flows on a regional basis (Table 3.3-1). The stations are located in the watersheds between Inuvik and Tuktoyaktuk. The Boot Creek watershed (10LC010) is located directly to the east of Inuvik. Boot Creek flows in a westerly direction and discharges into the Mackenzie River. Streamflow data from the Boot Creek watershed were obtained for the period 1981 to 1990. Approximately 45 km to the north of Inuvik, Trail Valley Creek (10ND002) drains the Caribou Hills. The period of record for Trail Valley Creek is 1977 to 1987. Trail Valley Creek flows into Husky Lake approximately 10 km to the south of Hans Creek (10ND001 and 10ND004). The hydrometric station at Hans Creek was moved in 1987. Therefore two periods of record were available, one from 1977 to 1987 and the other from 1988 to 1996. Of the streams monitored by the Water Survey of Canada, Freshwater Creek near Tuktoyaktuk (10ND005) is the one furthest to the north on the Tuktoyaktuk Peninsula. Freshwater Creek drains a portion of the Tuktoyaktuk Peninsula and enters the Arctic Ocean at Kugmallit Bay near the Hamlet of Tuktoyaktuk. A continuous discharge record was obtained for the 1990 to 1995 period. The size of the drainage areas of the streams analyzed ranges from 28.2 to 337 km^2.

Table 3.3-1 summarizes the streamflow data from the five watersheds gauged by the Water Survey of Canada. The analysis includes monthly flows, annual runoff, peak discharge, and low flows.

Table 3.3-1
Summary of WSC Station Locations

No.	Location	Drainage Area (km^2)	Period of Record	Latitude	Longitude
10LC010	Boot Creek near Inuvik	28.2	1981-90	68º21’40”	133º38’38”
10ND002	Trail Valley Creek near Inuvik	68.3	1977-96	68º44’18”	133º26’27”
10ND001	Hans Creek near Inuvik	337.0	1977-87	68º51’55”	133º29’54”
10ND004	Hans Creek above Husky Lakes	329.0	1988-96	68º52’14”	133º34’42”
10ND005	Freshwater Creek near Tuktoyaktuk	167.0	1990-95	69º26’08”	132º54’07”

Source: Environment Canada, WSC (1998)

Mean Monthly Flows and Mean Annual Flows

The flow characteristics of streams can be described by the flow regime. Regime types are classified by the timing and source of runoff. For this purpose, an analysis of the variation of mean monthly discharge data of the Water Survey of Canada streams was conducted (Figure 3.3-2). Mean monthly discharges for the streams analyzed are summarized in Appendix 3.3-5.

As a result of snowmelt, streams in the vicinity of Inuvik reach maximum monthly flows in June. Due to a more northerly location and the proximity to the Arctic Ocean, which effectively cools the ambient air temperature in spring, snowmelt and break-up are delayed at Freshwater Creek on the Tuktoyaktuk Peninsula (Anderson, 1984; Ramsey *et al.*, 1985). Therefore, maximum monthly flows at Freshwater Creek near Tuktoyaktuk are generally observed more typically in July. A secondary, rainfall-generated runoff peak is commonly recorded at the streams near Inuvik in September. As a result, the low flow period usually occurs on these streams in July or August. When plotting mean monthly discharge, the hydrograph of Freshwater Creek near Tuktoyaktuk does not show this pluvial component in fall. Instead, mean monthly flows decline steadily after the occurrence of spring freshet.

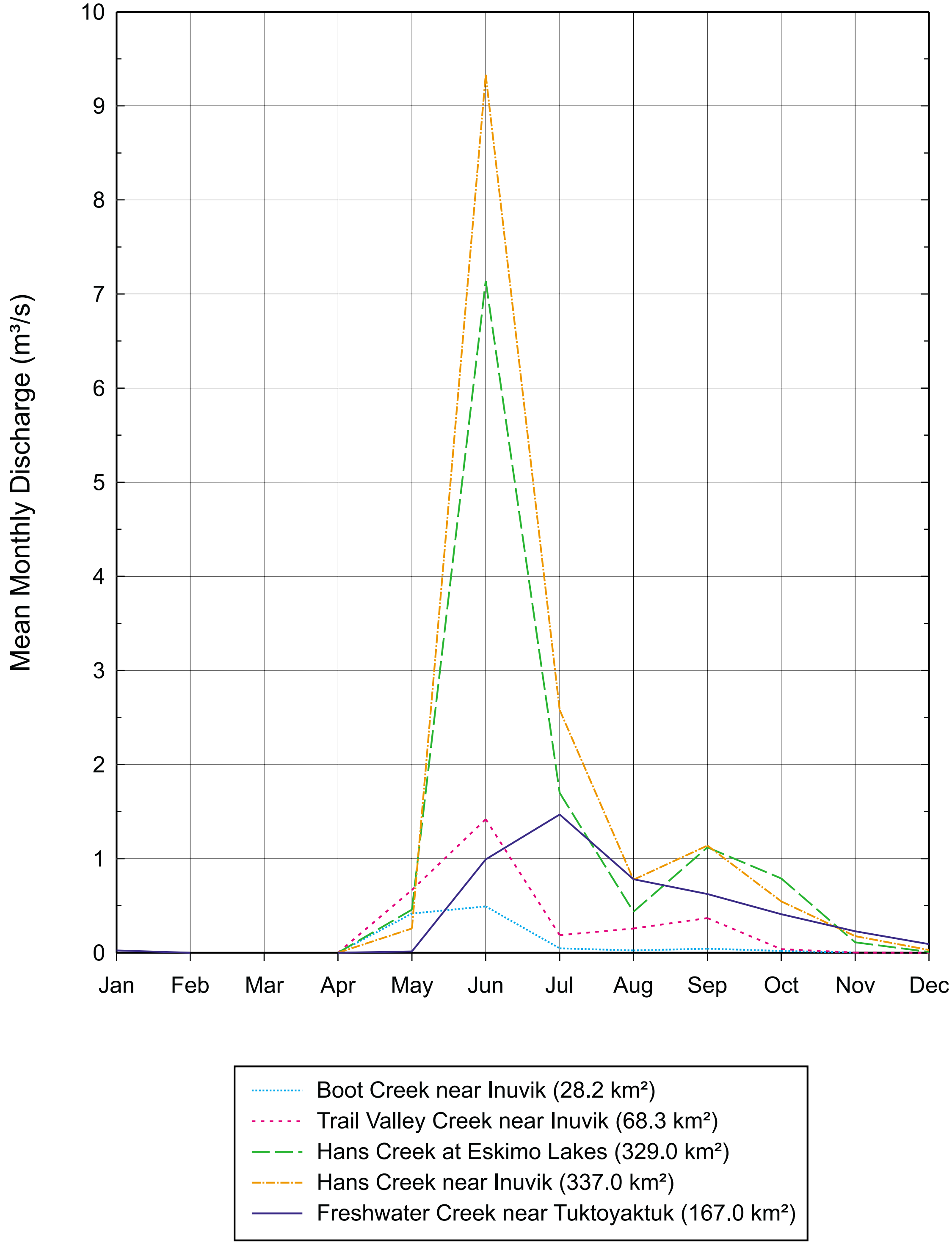
The characteristics described above, *i.e.* major flood period in spring, followed by rapid recession to base flow, interrupted occasionally by rainstorm generated peaks in late summer and absent winter flows, are typical for an Arctic-nival regime (Woo, 1993).

Table 3.3-2 summarizes mean annual discharge for the periods of record. Mean annual discharge ranges from 0.252 to 1.390 m^3/s for the streams analyzed.

Table 3.3-2
Mean Annual Discharge (m3/s)

Location	Drainage Area (km^2)	Period of Record	Mean Annual Discharge (m^3/s)
Boot Creek near Inuvik	28.2	1981-90	0.087
Trail Valley Creek near Inuvik	68.3	1977-96	0.252
Hans Creek above Husky Lakes	329.0	1988-96	0.985
Hans Creek near Inuvik	337.0	1977-87	1.390
Freshwater Creek near Tuktoyaktuk	167.0	1990-95	0.463

Source: Environment Canada, WSC (1998)



Northwest Territories

Mean Monthly Discharge at Water Survey of Canada Streams within the Project Area

FIGURE 3.3-2

Rescan

Source: Graph based on data from Environment Canada, WSC (1998)

Annual Runoff

Mean annual runoff was calculated for each of the streams analyzed for the periods of record (Table 3.3-3). Mean annual runoff ranged from 87 mm to 130 mm. Usually, annual runoff is expected to decrease with increasing basin size. The data indicate that no such correlation can be established for the site. Mean annual runoff is influenced to a varying degree by lake storage effects within the watersheds, and consequently by water losses through free-water evaporation. Runoff recorded at Freshwater Creek is significantly lower than that recorded at the stations located further inland due to precipitation totals which decrease from Inuvik towards the coast. In comparison, data compiled in the Hydrological Atlas of Canada (Canadian National Committee for the International Hydrological Decade, 1978) shows an annual runoff of approximately 137 and 119 mm for Inuvik and Tuktoyaktuk, respectively. Mean annual runoff, derived from an isoline map, which was developed by Church (1974), is in general agreement with the Water Survey of Canada data analyzed, and equals approximately 94 mm for the Tuktoyaktuk Peninsula.

Table 3.3-3
Mean Annual Runoff (mm)

Location	Drainage Area (km^2)	Period of Record	Runoff (mm)
Boot Creek near Inuvik	28.2	1981-90	97
Trail Valley Creek near Inuvik	68.3	1977-96	116
Hans Creek above Husky Lakes	329.0	1988-96	94
Hans Creek near Inuvik	337.0	1977-87	130
Freshwater Creek near Tuktoyaktuk	167.0	1990-95	87

Source: Environment Canada, WSC (1998)

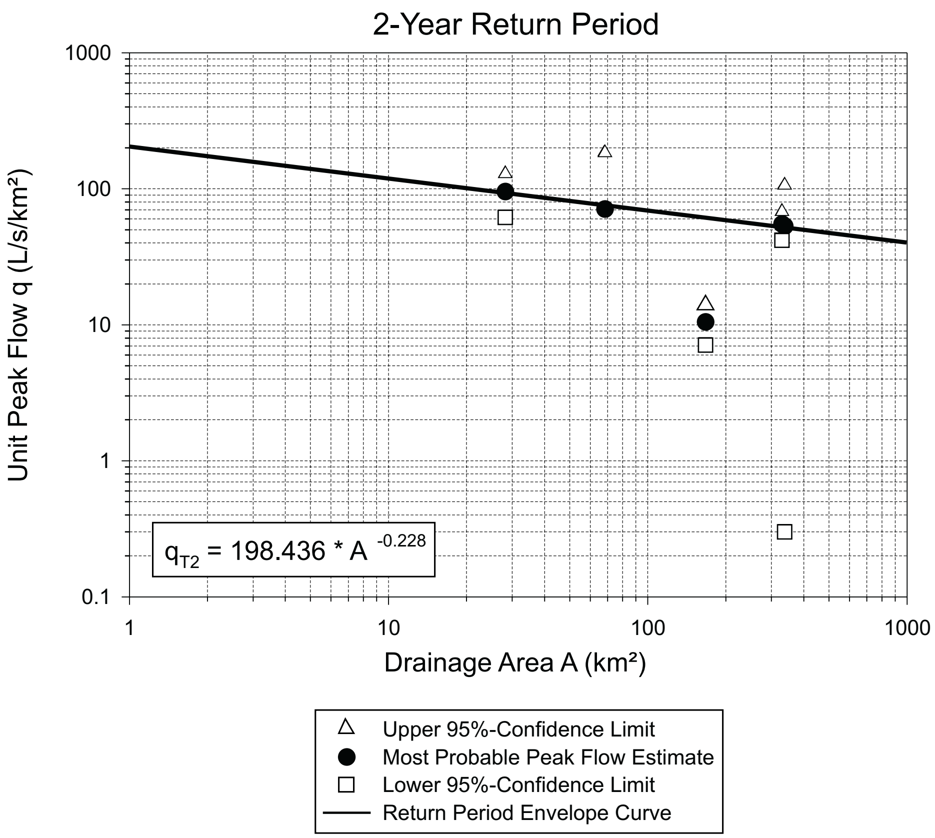
Peak Discharge and Design Flow Data

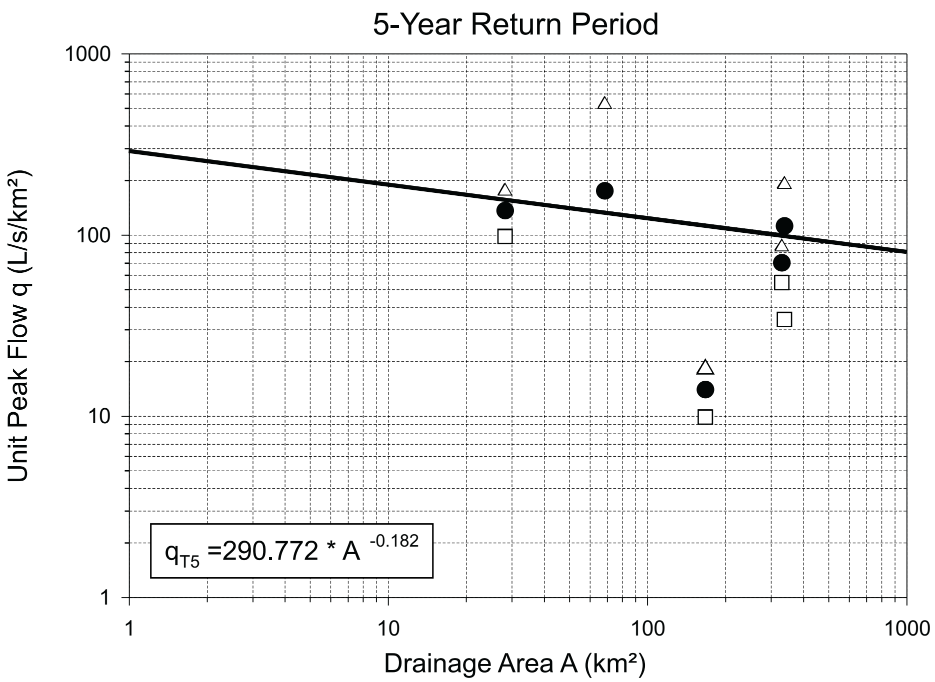
The data analysis of five streams within the project region shows that maximum flows are snowmelt-related (Appendix 3.3-1). In some years, freshet flows were several times larger than normal. These flood flows were assumed to be caused by ice jams during break-up. In the Boot Creek, Trail Valley Creek, and Hans Creek watersheds, maximum daily discharge is usually observed from late May to mid-June. At Freshwater Creek near Tuktoyaktuk, maximum daily flows are observed from late June to early July. The delay in snowmelt runoff processes is assumed to be a result of the cooling effect of the frozen Arctic Ocean.

Among the problems to be faced by highway design engineers in the north is that of culvert washouts. In the event of a culvert failure, the aquatic system, specifically andromous fish populations, can potentially be harmed. Therefore, a hydrologic investigation of design peak flows was carried out. A regional analysis of streamflow data permits the estimation of design floods for those areas where flow measurements were not available. Various methods can be employed for peak flow regionalization. These include the ‘simplified regional peak flow procedure’ (Coulson, 1991), the ‘preliminary design regional peak flow procedure’ (Coulson, 1991), the Index-Flood method (Kite, 1989), and multiple regression techniques (Kite, 1989). Relatively short periods of data records and short overlapping periods between the data sets, led to the decision to use the ‘preliminary design regional peak flow procedure’.

Flood frequency analyses were completed on the data sets of the WSC streams using the Kite software package (1989). This package computes flood flow estimates for various return periods. The 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year floods were obtained by fitting probability distributions (Appendix 3.3-6). Aitken *et al.* (1986) determined that the three-parameter lognormal distribution gave the best results for most Northwest Territories rivers. The parameters were selected by the method of the moments. Due to the lack of data, series of six years were also analyzed. Both high and low outliers were identified but not analyzed, as it is the accepted practice to ignore the mechanism of peak flow origin and to conduct a frequency analysis on a given record. The results of the frequency analyses are summarized in Table 3.3-4.

For the regionalization procedure, peak flow envelope curves, *i.e.* curves which correlate unit peak flow with drainage area, were plotted for various recurrence intervals (Figure 3.3-3, 3.3-4, and 3.3-5). These graphs can be used for estimating peak flows for ungauged watersheds by defining their drainage areas. The calculated 95% confidence limits show the uncertainties that arise from extrapolating runoff data to return





Note: Envelope Curves were calculated based on Boot Creek (10LC010), Trail Valley Creek (10ND002),and Hans Creek (10ND001, 10ND004).

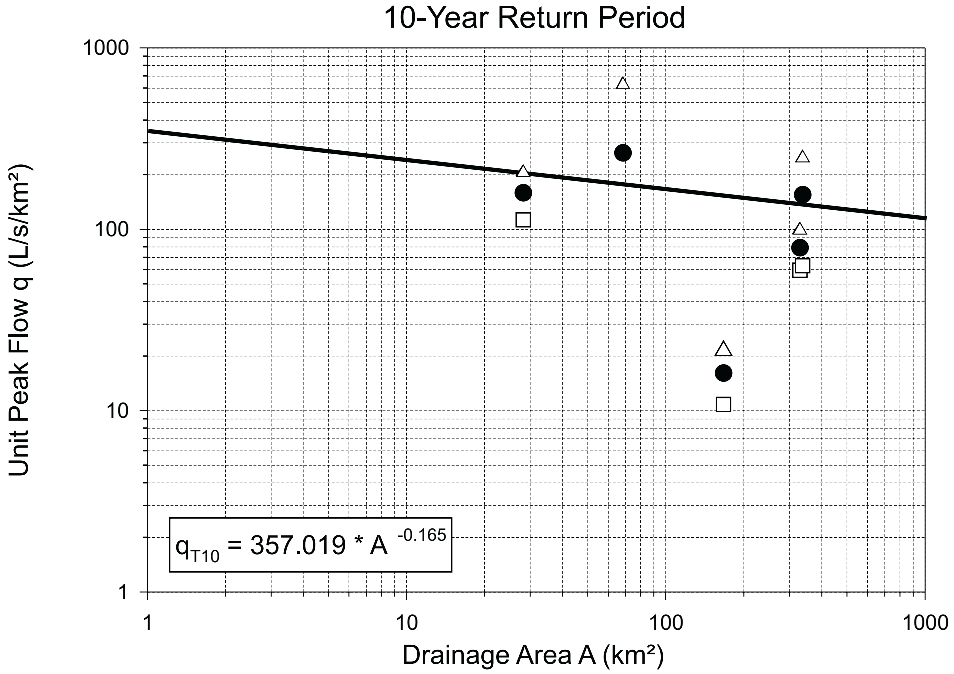
Northwest Territories

Envelope Curve of Daily Peak Unit Flow
2 and 5-Year Return Period

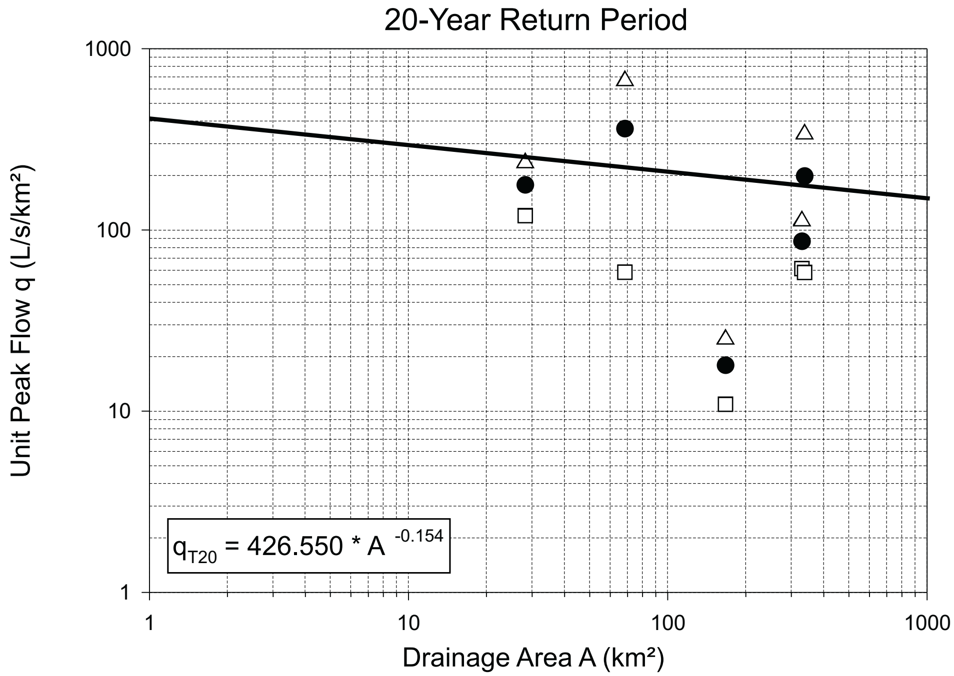
FIGURE 3.3-3

Rescan

Source: Calculation based on data from Environment Canada, WSC (1998)



Upper 95%-Confidence Limit
Most Probable Peak Flow Estimate
Lower 95%-Confidence Limit
Return Period Envelope Curve



Note: Envelope Curves were calculated based on Boot Creek (10LC010), Trail Valley Creek (10ND002),and Hans Creek (10ND001, 10ND004).

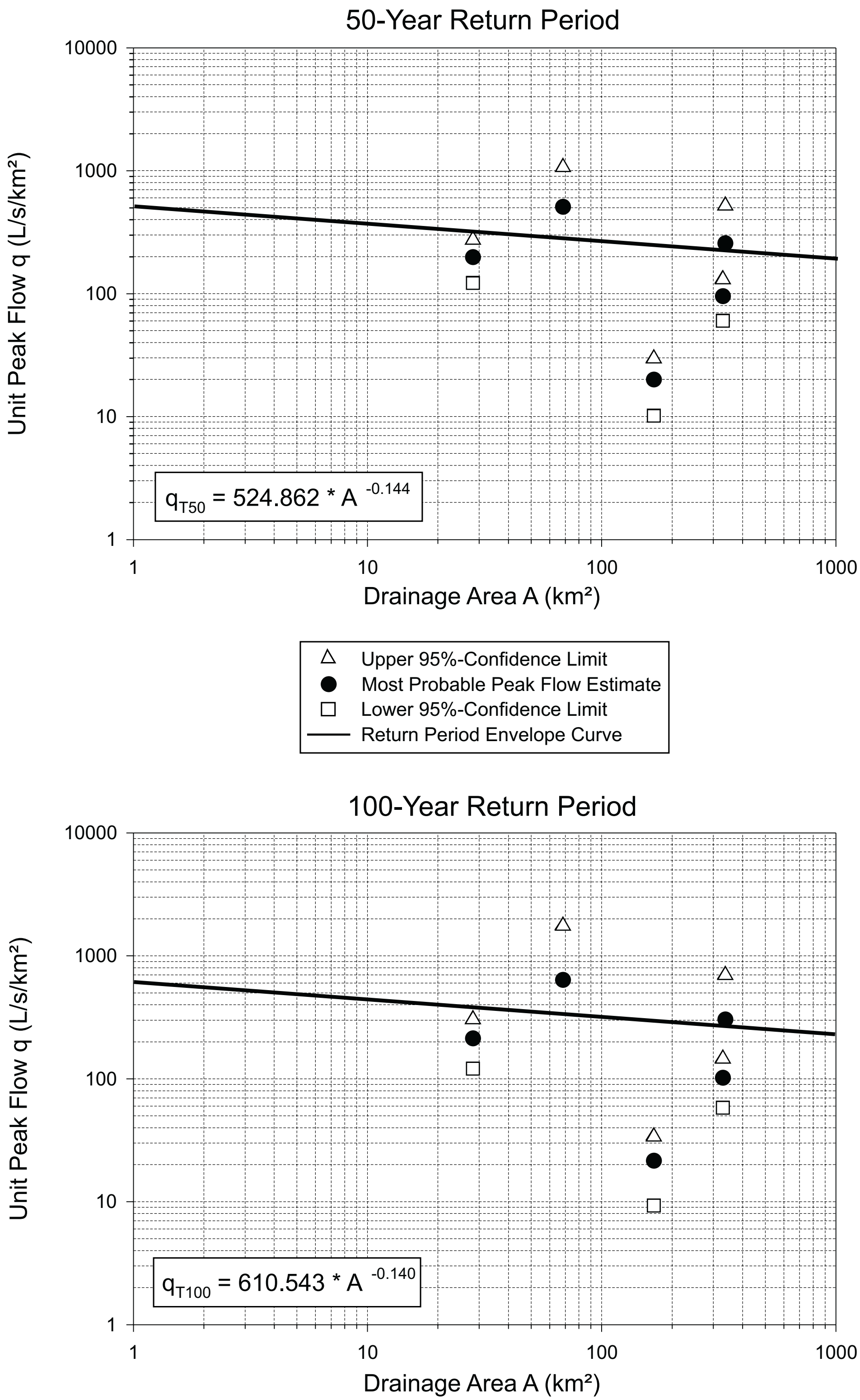
Northwest Territories

Envelope Curve of Daily Peak Unit Flow 10 and 20-Year Return Period

FIGURE 3.3-4

Rescan

Source: Calculation based on data from Environment Canada, WSC (1998)



Note: Envelope Curves were calculated based on Boot Creek (10LC010), Trail Valley Creek (10ND002),and Hans Creek (10ND001, 10ND004).

Northwest Territories

FIGURE 3.3-5

Envelope Curve of Daily Peak Unit Flow 50 and 100-Year Return Period

Rescan

Source: Calculation based on data from Environment Canada, WSC (1998)

Table 3.3-4
Summary of Return Period Peak Flows (m^3/s)

No.	Location	Drainage Area (km^2)	Daily Discharge (m^3/s) Return Period					
			2-Year	5-Year	10-Year	20-Year	50-Year	100-Year
10LC010	Boot Creek near Inuvik	28.2	2.688	3.845	4.469	4.994	5.597	6.005
10ND002	Trail Valley Creek near Inuvik	68.3	4.841	11.988	17.988	24.695	34.818	43.538
10ND004	Hans Creek above Eskimo Lakes	329.0	18.092	23.128	25.988	28.498	31.464	33.533
10ND001	Hans Creek near Inuvik	337.0	17.929	37.829	52.181	66.719	86.655	102.460
10ND005	Freshwater Creek near Tuktoyaktuk	167.0	1.758	2.346	2.686	2.985	3.343	3.595

Source: Calculation based on data from Environment Canada, WSC (1998)

period peak flows beyond the range of existing data. For all return period flows, unit peak flows decreased with drainage area according to the slope of the envelope curve, which plots as a straight line on log graph paper.

The peak flow analyses were based on maximum daily discharge values. Therefore, an effort was made to relate maximum instantaneous values to maximum daily values for different years (Appendix 3.3-7). The ratios of maximum instantaneous to maximum daily flows did not reveal any correlation with the size of the drainage areas. The average ratio equals 1.06, with the most conservative result being 1.10. Multiplying this ratio by the daily design peak flows yields estimates for the instantaneous discharge at any stream of interest within the project region.

It has to be considered though, that design peak flows with high recurrence intervals are calculated from extrapolations of distribution curves and may therefore be inaccurate. Theoretically, a frequency estimate for a 50-year return period flood should be based on a record length of 11 to 15 years, when employing the 'preliminary design' method (Coulson, 1991). However, the data sets available from the Water Survey of Canada range from 6 to 18 years, with 4 of 5 stations having shorter record lengths than recommended. Other physiographic factors affecting peak flows are natural storage, shape of the watershed, and channel and basin slope.

The 50-year design flood relationships for instantaneous flow were derived by Northwest Hydraulic Consultants (1972) and the Foundation of Canada Engineering Corporation Ltd. ('FENCO') (1974). The 'Northwest' curve was the design for drainage basins of intermediate and flat relief along the Mackenzie and Dempster Highways from Inuvik to the Yukon border. The 'FENCO' curve applied to basins crossed by the proposed Mackenzie Highway from Fort Good Hope to the Dempster junction. These two design curves were not intended for use north of Inuvik, and the design curve obtained from the analysis of data of streams located between Inuvik and Tuktoyaktuk was only included in Figure 3.3-6 for purposes of comparison. For small to intermediate sized watersheds, the 'Rescan' 50-year design curve, which is based on data of streams north of Inuvik, plots below the FENCO and Northwest Hydraulics curves. For larger basins the estimated 50-year return period flows correspond very well. The discrepancy between the design curves for streams north and those south of Inuvik is not surprising as estimation of the FENCO and Northwest Hydraulics design curves was based on data from large drainage basins (between 625 and 70,600 km^2). In contrast, the Rescan design curve is based on data of watersheds with a size ranging from 28.2 to 337 km^2. It is therefore assumed that the extrapolation of the FENCO and Northwest Hydraulics design curves to small watersheds is less accurate.

Low Flows

An understanding of the low flow characteristics of rivers and streams on the Anderson Plain and the Arctic Coastal Plain near Tuktoyaktuk is necessary to allow sufficient instream flows for the protection of fish and wildlife habitat and to evaluate the effects of added pollutants to a stream. Low flow or base flow is the portion of runoff that emerges where the streambed intercepts the suprapermafrost groundwater table or that emerges as seepage or springs.

In the area of interest, streams are winter dry, *i.e.* the watersheds freeze, so that flows cannot be maintained throughout the winter (Figure 3.3-2). In mid-September, icing begins to occur at the streams analyzed and flows subsequently approach zero between October and mid-January (Appendix 3.3-6). However, data from Freshwater Creek near Tuktoyaktuk show that some streams on the Tuktoyaktuk Peninsula may not cease to flow until as late as early February.

In spring, Boot Creek near Inuvik usually breaks up by May (Appendix 3.3-7). Discharges at Trail Valley Creek and Hans Creek, which are located further to the north from Boot Creek, increase in May to early June, whereas Freshwater Creek near Tuktoyaktuk may break up as late as mid-June. As discussed earlier, the high heat storage capacity of the Arctic Ocean causes freeze-up and break-up processes on the Tuktoyaktuk Peninsula to occur later than near Inuvik.

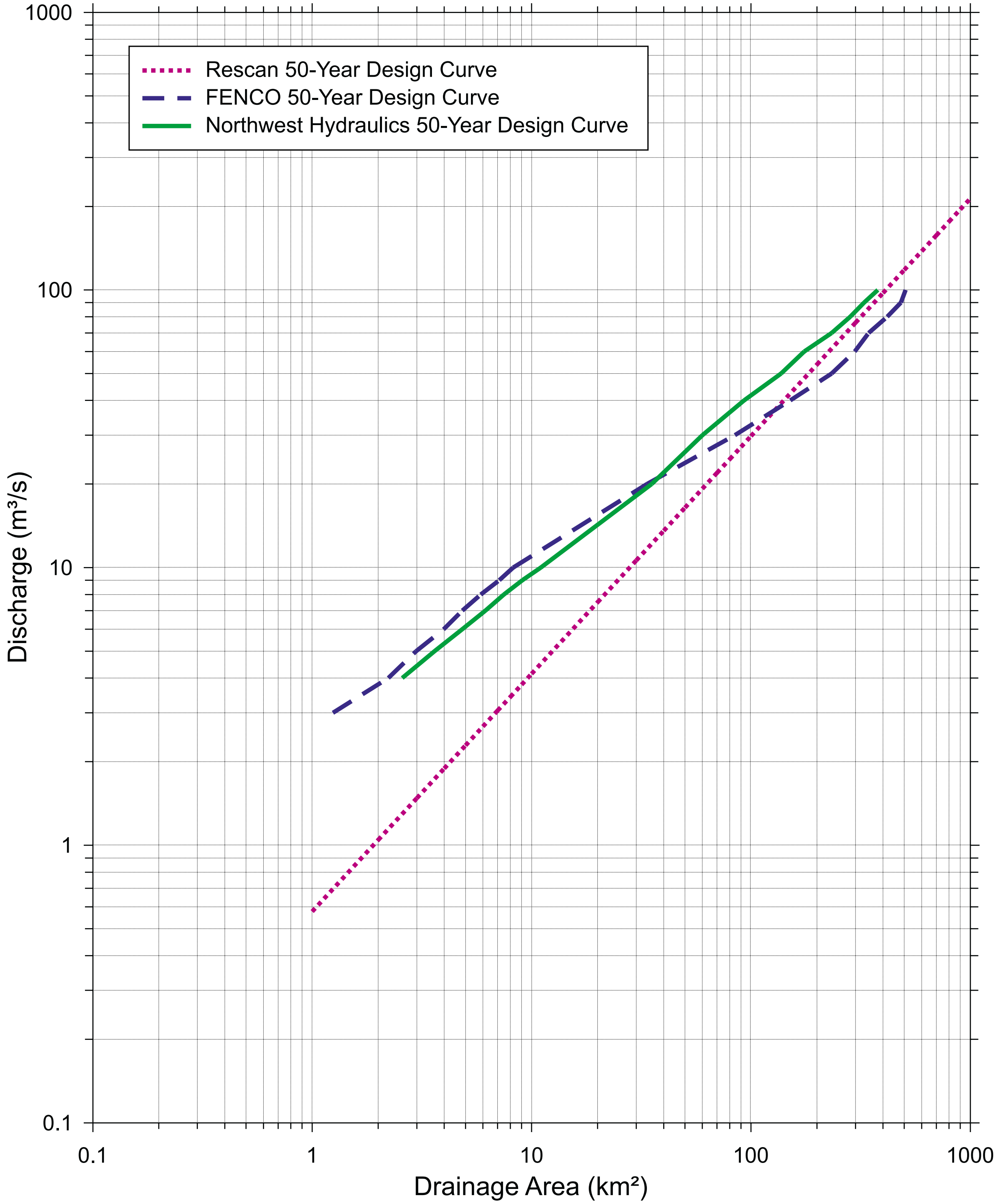
To describe the ability of a watershed to generate and sustain low flows and to compare one watershed with another, low flow characteristics are calculated. Usually, the seven-day average low flow, *i.e.* the lowest mean discharge in seven consecutive days within a year, is the parameter used (Coulson, 1991). In general, low flows occur every year in the annual cycle of arctic streams, *i.e.* after spring freshet flows and before the occurrence of the rainfall induced peak flows in September. At the streams near Inuvik the minimum seven-day average low flow is generally recorded between early July and late August, but can also occur in mid-September. Freshwater Creek near Tuktoyaktuk reaches minimum seven-day average low flows between mid-August and late September. However, in some years flows decrease steadily after spring freshet, as rainfall fails to increase flows in late summer.

A frequency analysis was performed on the seven-day average low flow data sets for Boot Creek, Trail Valley Creek, Hans Creek near Inuvik, and Hans Creek above Husky Lakes. The data set for Freshwater Creek near Tuktoyaktuk consisted of three data points and was regarded to be too small for a frequency analysis. The two parameter lognormal and the three parameter lognormal distributions create the lowest standard error when fitting various frequency distributions to the measured data points and were therefore used for the analysis. The results of the frequency analysis are summarized in Table 3.3-5. As the distribution fitting procedure at Boot Creek did not produce any results for 10-year and higher return periods, it was decided not to calculate envelope curves for seven-day average low flows in the development region.

3.3.1.5 Summary

The proposed road from Inuvik to Tuktoyaktuk extends some 140 km over the Anderson and the Pleistocene Coastal Plain. A low relief of the terrain and

Note: The Rescan 50-Year design curve is calculated using a conservative maximum instantaneous to maximum daily flow ratio of 1.1 .



Sources: Northwest Hydraulic Consultants (1972)
Foundation of Canada Engineering Corporation (1974)
Calculation based on data from Environment Canada, WSC (1998)

Northwest Territories

Instantaneous Peak Discharge vs. Drainage Area, with Recommended Design Curves

FIGURE 3.3-6

Rescan

Table 3.3-5
Summary of Return Period 7-Day Average Low Flows (m^3/s)

No.	Location	Drainage Area (km^2)	Daily Discharge (m^3/s) Return Period					
			2-Year	5-Year	10-Year	20-Year	50-Year	100-Year
10LC010	Boot Creek near Inuvik	28.2	0.014	0.002	0.000	0.000	0.000	0.000
10ND002	Trail Valley Creek near Inuvik	68.3	0.018	0.005	0.003	0.002	0.001	0.001
10ND004	Hans Creek above Husky Lakes	329.0	0.338	0.139	0.088	0.060	0.039	0.029
10ND001	Hans Creek near Inuvik	337.0	0.425	0.242	0.181	0.142	0.108	0.090

Source: Calculation based on data from Environment Canada, WSC (1998)

thermokarst topography are characteristic and create a diffuse drainage pattern and numerous shallow lakes. Upon leaving Inuvik, the proposed road would cross stream systems that drain into the Mackenzie River, before entering the Husky Lakes basin. South of Tuktoyaktuk the road would pass through portions of the Kugmallit Bay drainage basin.

Streamflow data of five regionally gauged Water Survey of Canada streams were analyzed to assess the spatial variability of flows. The cold climate and continuous permafrost restrict the hydrological processes to snow accumulation from October to May and an open-water season between May to mid-June and mid-September to mid-October. Snowmelt runoff in late May to early-July usually produces the highest flows during the year. However, rainfall in September may produce a notable flow response. The summer low flow period is recorded between the snowmelt and rainfall induced peak flows, *i.e.* from early July to late September. In winter, the watersheds freeze, because the suprapermafrost groundwater reservoir is too limited to maintain flows.

Mean annual runoff increases from the coast towards the south. It ranges from 87 mm at Freshwater Creek near Tuktoyaktuk to 130 mm at Hans Creek near Inuvik. The large heat storage capacity of the Arctic Ocean contributes to later break-up, freeze-up, and later spring freshet flows in watersheds close to the Arctic Ocean when compared with watersheds near Inuvik.

The proposed road route from Inuvik to Tuktoyaktuk will probably cause some unavoidable disruption of drainage patterns due to the low relief of the Tuktoyaktuk Peninsula. According to Percy *et al.* (1975) even minimal terrain disturbance could potentially result in a number of the smaller lakes completely drying up. Additionally, the construction of a road could block natural flow paths and thus cause ponding.

3.3.2 Water Quality

Water quality is an important consideration for the aquatic environment of the development area as the lake and stream waters of the watersheds crossed by the proposed road provide fish habitat and are sources of freshwater. Along the corridor of the proposed road from Inuvik to Tuktoyaktuk three water quality related studies have been conducted. Percy *et al.* (1975) surveyed the fish resources along the Inuvik Tuktoyaktuk portion of the Mackenzie Highway and at the same time collected water quality data for ten streams and eight lakes. Anema *et al.* (1990a, 1990b) through the NOGAP program (Northern Oil and Gas Action Program) sampled lakes in the Mackenzie Delta, Noell Lake, and lakes in the Kukjuktuk Bay area, northeast of Tuktoyaktuk. The most recent study, published by Pienitz *et al.* (1997), provides a detailed description of water quality and other limnological data gathered for 59 lakes in the Yukon and adjacent Northwest Territories. This information has been used collectively to establish a baseline for predicting future potential impacts of the proposed Inuvik-Tuktoyaktuk road on water quality in the area.

3.3.2.1 Limnological Characteristics of Arctic Lakes and Streams

The watersheds which are potentially affected by the construction of the road are located within the Mackenzie River Delta, Husky Lakes, and Kugmallit Bay drainage basins. A steep climatic gradient along the transect from Inuvik to Tuktoyaktuk causes temperature and precipitation to decrease in a northerly direction. On the basis of vegetational zones, Pienitz *et al.* (1997) distinguishes between arctic tundra lakes on the Tuktoyaktuk Peninsula and forest-tundra lakes near Inuvik, which are located within the transition zone from boreal forests to arctic tundra. The transition from forested to treeless regions marks a drastic physiographic change, thus accounting for changes in surface albedo. As a result of the more northerly location and the proximity to the Arctic Ocean (Chapter 3.3.1.4), spring breakup at small lakes near Tuktoyaktuk is typically more than a month later than at lakes near Inuvik. In the northern forest zone, small lakes are ice free by mid-June and freeze over by mid-October, whereas large lakes become ice free roughly two weeks later than the smaller ones. Lakes with water depths below 2 m may freeze to the bottom during winter, since ice covers ranging in thickness from 1.1 to 2 m have been observed to occur on the Tuktoyaktuk Peninsula (Pienitz *et al.* 1997). The following description of water quality parameters closely follows the grouping of lakes into forest-tundra and arctic tundra lakes, used by Pienitz *et al.* (1997).

The hydrological regime of the arctic lakes near Inuvik and on the Tuktoyaktuk Peninsula is largely controlled by low precipitation and permafrost, with snowmelt runoff in spring being the dominant hydrological event. In summer, evaporation from open water surfaces is generally greater than precipitation. During snowmelt, the concentration of inorganic ions in stream water resembles that of precipitation, which is extremely dilute in the Arctic (Hobbie, 1984). Meltwater entering the lakes in spring causes a concentration minimum of inorganic ions immediately beneath the ice, but much of this water flows through the lakes in a layer and does not mix with the underlying layers. In general, turbidity levels and concentrations of metals, TP (total phosphorus), and most suspended variables increase during spring freshet in tundra streams and lakes.

After snowmelt, the active layer begins to thaw and the concentration of ions in stream waters increase. Higher concentrations of ions are caused by a higher portion of subsurface flows entering the streams and lakes. Subsurface waters are characterized by relatively long residence times within the active layer, which enables the water to take up solute inorganic and organic compounds. For the same reason, ion concentrations vary with flow rates, as the proportion of surface and subsurface runoff changes.

Due to high evaporation rates in summer, ionic concentrations in small tundra ponds tend to increase. However, Anema *et al.* (1990 b) recorded only little variation in the water chemistry of Noell Lake and the Kukjuktuk Lakes during the open water season. In summer, when surface runoff ceases to flow, concentrations of water quality parameters in streams closely reflect those of lake water. Depending on the magnitude of precipitation in fall, turbidity levels, and concentrations of TP and suspended variables may show a secondary maximum, which is usually not as high as the one observed in spring. Conversely, TP levels may remain low owing to the uptake by plants. Exclusion from ice and/or near the lake bottom (due to return from sediments) during freeze-up may again increase ionic concentrations. The processes mentioned above can cause considerable fluctuations in the chemical concentrations of major ions in arctic lakes (Pienitz *et al.*, 1997).

Ionic concentrations in lakes and streams also depend upon the soil characteristics and, ultimately, upon the parent bedrock of the drainage basin. Sandstones and shales of Tertiary or Quarternary origin underlie most of the Coastal Plain, including the Tuktoyaktuk Peninsula. On the surface of the Tuktoyaktuk Peninsula, deltaic sediments and deposits of glacial origin from the early Wisconsin glaciation, such as moraines, glaciofluvial outwash sediments, eskers, kames, and glaciolacustrine sediments occur. In the Caribou Hills, only thin glacial and glaciofluvial deposits cover poorly consolidated Tertiary bedrocks, *e.g.* sands and gravels, and upper Cretaceous shales.

The results of the studies conducted by Percy *et al.* (1975), Anema *et al.* (1990a, 1990b), and Pienitz *et al.* (1997) are presented below. The water chemistry data collected by Percy *et al.* (1975) and Pienitz *et al.* (1997) are summarized in Appendix 3.3-8 and 3.3-9, respectively.

3.3.2.2 Lakes

Physical and Geographic-Environmental Variables

The extended duration of the ice cover means that ponds and lakes become ice-free after the insolation peak. This, combined with the low sun angle and the generally cool air, keeps available insolation low in summers and limits the heating of surface waters. Along with air temperature, lake surface temperature consistently decreases along a longitudinal transect from south to north. Pienitz *et al.* (1997) recorded an average mid-summer temperature of 18.6 and 17.1 ºC for forest-tundra and Arctic lakes, respectively. These temperatures were high, when compared with temperature data compiled by Anema *et al.* (1990a) for lakes on the Tuktoyaktuk Peninsula, probably owing to different sampling dates. Anema *et al.* (1990a) measured surface water temperatures from 6.8 to 11.7 ºC.

Polar lakes are usually cold-monomictic, *i.e.* they almost never stratify once they become ice-free in summer (Schwoerbel, 1993; Hobbie, 1984). Because of low temperatures density differences are low, and winds readily mix entire lakes. Although it is usually assumed that the ice cover in winter isolates lakes from wind and thus prevents circulation, it has been proven, that water beneath the ice receives radiation and that stored heat returns from the sediments to warm adjacent water (Welch *et al.*, 1985). As a result, density currents may cause the water in some lakes to circulate slowly even in mid-winter. With the exception of a weak stratification in two forest-tundra lakes near Inuvik, Pienitz *et al.* (1997) recorded isothermal conditions in all of the forest-tundra and arctic tundra lakes investigated.

Light transmission depends on the amount of suspended inorganic and organic material as well as dissolved organic material. Those, in turn, are correlated with decaying vegetation and leaching organic soils in the catchment. Water color is also affected by mineral components such as Fe and Mn. Water transparency is commonly measured by Secchi disc readings and is an indicator of the trophic state of a lake. Secchi depths in forest-tundra lakes are relatively low, due to the brown colored waters of the lakes that are surrounded by muskeg and in areas below the tree-line, by open spruce woodland. Pienitz *et al.* (1997) recorded a mean Secchi depth of 1.7 m in forest-tundra lakes, as opposed to the 1.0 to 7.0 m recorded in arctic tundra lakes.

During the open water season shallow arctic tundra lakes are usually completely saturated with oxygen. Even in winter, the exclusion of oxygen during freezing and photosynthesis immediately beneath the ice keeps saturation levels usually close to 100% saturation. However, saturation levels may drop in fall when water temperatures decrease faster than the water can take up oxygen from the air and in winter due to benthic respiration under the ice-cover. In particular, severe deoxygenation in the waters of shallow lakes can occur, when deep snow covers the ice, thus preventing spring algal blooms (Tash *et al.*, 1967). Photosynthesis below the lake ice usually starts with snowmelt, so that oxygen production greatly exceeds oxygen consumption and may result in oversaturation of the top water layers. In a study conducted by Percy *et al.* (1975) in the fall of 1997, dissolved oxygen levels of 10.9 mg/L were recorded for eight lakes located between Inuvik and Tuktoyaktuk.

If not specifically indicated, the following summary of chemical parameters of lakes in the forest-tundra and arctic tundra region is based on the study conducted by Pienitz *et al.* (1997) during the month of July 1990.

pH

Lakes on the transect between Inuvik and Tuktoyaktuk are slightly acidic to alkaline. Lowest pH values are reported from forest-tundra lakes near Inuvik due to the widespread occurrence of muskeg. For the forest-tundra lakes, recorded pH values range from 6.6 to

8.6 with a mean pH of 7.6. In contrast, a mean pH of 7.9 was reported for arctic tundra lakes with minimum and maximum pH values of 6.9 and 8.4, respectively (Pienitz *et al.*, 1997). The average pH value of 7.8 calculated from data collected by Percy *et al.* (1975) agrees very well with the data compiled by Pienitz *et al.* (1997).

Conductivity and Major Ions

Patterns in conductivity closely follow the concentration of major ions, *e.g.* sodium, chloride, potassium, calcium, and sulfate.

A strong correlation exists between sodium and chloride concentrations and distance from the Arctic Ocean, with highest concentrations observed on the coastal plain near Tuktoyaktuk. Most of the arctic tundra lakes investigated by Pienitz *et al.* (1997) have high sodium and chloride concentrations of 7.0 and 12.2 mg/L, respectively. By comparison, sodium and chloride concentrations of forest-tundra lakes near Inuvik were closer to 3.8 and 3.0 mg/L respectively. According to Pienitz *et al.* (1997), the most likely source of chloride in lakes of maritime arctic regions is sea salt in precipitation. However, it is also possible that the chloride originates from sea water once covering the Arctic Coastal Plain during postglacial times, *i.e.* before the Tuktoyaktuk Peninsula emerged from the ocean owing to isostatic rebound of the earth's crust. In addition, some shallow lakes in the immediate coastal zone may have been subjected to seawater intrusions due to historic storm surges which have been recorded in the area.

Potassium concentrations are low in lake waters between Inuvik and Tuktoyaktuk. In forest-tundra and arctic tundra lakes mean potassium concentrations of 1.1 to 1.3 mg/L were measured (Pienitz *et al.*, 1997).

Calcium levels increase from Inuvik towards the Tuktoyaktuk Peninsula, averaging 16.2 and 19.9 mg/L in forest-tundra and in arctic tundra lakes, respectively (Pienitz *et al.*, 1997). As calcium concentrations are correlated with pH, it is not surprising that forest-tundra lakes are generally more acidic than arctic tundra lakes. With an average concentration of 73.4 mg $CaCO_3$/L, hardness in lake waters between Inuvik and Tuktoyaktuk can be classified as medium (Percy *et al.*, 1975).

High sulphate concentrations are generally due to the weathering of sedimentary bedrock. Therefore, the lakes near Inuvik, that are located on bedrock comprised of Tertiary sandstones and Cretaceous shales, have a relatively high mean sulphate level of 21.2

mg/L. In contrast, sulphate concentrations of lakes on the Tuktoyaktuk Peninsula average 6.8 mg/L (Pienitz *et al.*, 1997).

As a result of relatively high chloride, sodium, and calcium concentrations in lake waters near the Arctic Ocean, specific conductivities in the area increase in a northerly direction. The conductivity of forest-tundra lakes averages 99.1 μS/cm as compared to the 131.0 μS/cm recorded in the arctic tundra lakes (Pienitz *et al.*, 1997).

Nutrients and Carbon

Silica is most likely leached from sedimentary and volcanic rocks. Concentrations of silica are low in all lakes and range from 0.1 to 3.3 mg/L, with a mean of 1.2 mg/L. Average concentrations calculated for forest-tundra and arctic tundra lakes show a latitudinal gradient, with values decreasing towards the north from 1.6 to 0.7 mg/L (Pienitz *et al.*, 1997).

Dissolved organic carbon levels increase due to organic inputs from bog vegetation and Sphagnum mosses in the watersheds. Production of organic acids from these sources describes the differences in dissolved organic carbon levels observed in forested and unforested watersheds. Dissolved organic carbon concentrations in forest-tundra lakes are higher than in arctic tundra lakes with mean concentrations of 16.5 and 9.4 mg/L, respectively (Pienitz *et al.*, 1997).

Total nitrogen is the sum of particulate nitrogen, total Kjeldahl nitrogen, nitrate, and nitrite. Total nitrogen levels are substantially lower in arctic tundra lakes (435.3 μg/L) than in forest-tundra lakes (748.5 μg/L). The concentrations of the inorganic nitrogen components (nitrite, nitrate, and ammonia) are very low or below the detection limit (Pienitz *et al.*, 1997).

Similarly, soluble reactive phosphate-phosphorus concentrations in all lakes are low or below the detection limit. This is largely because of the restricted availability of sources of soluble reactive phosphate-phosphorus, *i.e.* surficial and wind-suspended particulate matter, interstitial water, leaching of litter, and plant excretion into the water column (Hobbie, 1984). The average soluble reactive phosphate-phosphorus level is 2.3 μg/L for forest-tundra lakes and 0.6 μg/L for arctic tundra lakes. However, total unfiltered phosphorous levels show a latitudinal gradient with more than double the total unfiltered phosphorus concentration recorded in lakes near Inuvik (28.4 μg/L) than on the Tuktoyaktuk Peninsula (11.6 μg/L) (Pienitz *et al.*, 1997).

Total nitrogen to total phosphorus ratios are relatively low for the lakes analyzed with average ratios of 34:1 and 42:1 for forest-tundra and arctic tundra lakes, respectively (Pienitz *et al.*, 1997). Typically, the release of available nutrients is slow in polar soils and there is little streamflow and groundwater to transport the nutrients to the lakes. According to Ramsey *et al.* (1985) lakes on the Tuktoyaktuk Peninsula are phosphorus limited.

Iron and Manganese

Iron and manganese concentrations are usually high, when bogs and peatlands occur in the catchments of lakes. Iron and manganese form chelates with humic and fulvic acids of organic soils and become mobilized as organometallic complexes. Therefore, it is surprising that average manganese concentrations are lower in forest-tundra lakes than in arctic tundra lakes. Values are 21.9 μg/L and 34.8 μg/L, respectively. Iron concentrations are particularly high in lakes near Inuvik. They average 560.7 μg/L, but reach values as high as 1660.0 μg/L. In contrast, iron concentrations in arctic tundra lakes average 156.7 μg/L (Pienitz *et al.*, 1997).

3.3.2.3 Streams

Water quality data for streams in the project are scarce. The only data available were collected by Percy *et al.* (1975) in the fall of 1975 from ten streams along the proposed corridor of the road from Inuvik to Tuktoyaktuk. The parameters measured were temperature, pH, hardness, dissolved oxygen, and alkalinity. When sampled in the fall of 1975, stream temperatures averaged 11.2 ºC. Mean pH values and mean dissolved oxygen levels equaled 7.3 and 10.4 mg/L, respectively.

Table 3.3-6
Average Concentrations of each Parameter in Forest-Tundra and Arctic Tundra Lakes

		Forest-Tundra Lakes	Arctic Tundra Lakes
Conductivity[1]	µS/cm	99.1	131.0
Hardness[2]	mg $CaCO_3$/L	73.4[3]	73.4[3]
pH[1]		7.6	7.9
Alkalinity[2]	mg $CaCO_3$/L	68.5	47.6
Chloride[1]	mg/L	3.0	12.2
Sulphate[1]	mg/L	21.2	6.8
Silica[1]	mg/L	1.6	0.7
Total Nitrogen (TN)[1]	µg N/L	748.5	435.3
Total Phosphorus (TP)[1]	µg P/L	28.4	11.6
TN:TP[1]		34:1	42:1
Calcium[1]	mg/L	16.2	19.9
Iron[1]	µg/L	21.9	34.8
Manganese[1]	µg/L	560.7	156.7
Potassium[1]	mg/L	1.1	1.3
Sodium[1]	mg/L	3.8	7.0

Note: 1. Source: Pienitz *et al.* (1997).
2. Source: Percy *et al.* (1975).
3. Average for lakes between Inuvik and Tuktoyaktuk.

Calcium concentrations averaged 66.6 mg $CaCO_3$/L, typical of waters with a medium level of hardness.

3.3.2.4 Summary

Most chemical parameters in the surface waters between Inuvik and Tuktoyaktuk reflect the steep climatic and vegetational gradient, but also the geology of the study area. Levels of major electrolytes indicate that rivers and lakes near Inuvik are dilute Ca-HCO_3 waters (mean conductivity 99.1 µS/cm). In lakes on the Tuktoyaktuk Peninsula within 25 to 50 km of the Arctic Ocean, the chloride content increases and thus waters have characteristics of dilute Ca-Cl-Na waters (mean conductivity 131.0 µS/cm) (Kalff, 1968; Pienitz *et al.*, 1997).

On average, most waters are alkaline. Due to the increasing occurrence of muskeg north of Inuvik, pH values slightly increase from south to north. High levels of chloride and sodium in lakes near Tuktoyaktuk probably originate from marine aerosols and/or the former coverage of the Tuktoyaktuk Peninsula with sea water. Therefore, concentrations in chloride and sodium decrease rapidly with increasing distance from the Arctic Ocean. In contrast, sulphate levels increase from north to south, due to differences in bedrock geology. Overall, conductivity increases from forest-tundra lakes to arctic tundra lakes. Nutrient levels, *i.e.* concentrations of silica, dissolved organic carbon, total nitrogen, soluble reactive phosphorus, and total phosphorus, approximately double from north to south. Due to the widespread occurrence of peat, iron levels were very high in forest-tundra lakes.

Total nitrogen and total phosphorus concentrations in the lakes investigated by Pienitz *et al.* (1997) indicate, that forest-tundra and arctic tundra lakes have different trophic states. When using total phosphorus as a variable, forest-tundra and arctic tundra lakes can be classified as meso-oligotrophic and oligo-mesotrophic, respectively (Wetzel, 1975). According to trophic limits, determined by Nuernberg (1996) using total nitrogen as a variable, forest-tundra lakes are in an eutrophic state and arctic tundra lakes are in a mesotrophic state.

Concentrations of water quality parameters in streams closely reflect those of lake water. However, data recorded by Percy *et al.* (1975) indicate that temperature, pH, hardness, and dissolved oxygen levels were slightly higher in lakes than in streams.

3.3.3 Data Gaps

The regional hydrological characteristics of the Tuktoyaktuk Peninsula were analyzed in some depth in the Environmental Scoping Report. For final road alignment and design purposes, flood flows determined by using the regional frequency curves will need to be confirmed by calibrating precipitation – runoff models for the major stream crossings.

In addition, an important phenomenon that was not addressed is that of culvert icings and river ice jams. If culverts are subject to icing, the magnitude and frequency of the icings must also be taken into account and allowances made during the design phase. No estimates have yet been made for the effects of river ice jams on the magnitude of floods in the corridor area.

Once the detailed alignment of the proposed Inuvik-Tuktoyaktuk road has been established, all watercourses that will be crossed by the road will have been identified. Due to the low relief of the Tuktoyaktuk Peninsula, even minimal terrain disturbance could potentially result in lakes drying up and ponding as a result of blockage of the natural flow paths. Should minor flow paths be disrupted, an assessment of the potentially drained and flooded areas would be required.

3.4 Aquatic Biota

3.4.1 General

The proposed road would leave the northeastern limits of Inuvik and pass through several lake and stream drainage systems before connecting with the existing local road south of Tuktoyaktuk (Figure 3.4-1). Upon leaving Inuvik, the proposed road would advance east and then north for 15 km among small lake and stream systems that drain into the Mackenzie Delta. From there, the road would leave the Mackenzie Delta drainage basin and enter the Husky Lakes drainage basin, skirting the western shores of Noell and Jimmy lakes. The proposed road would proceed north northeast, passing east of East Hans and Parsons lakes and following the western shores of Husky Lakes. South southeast of Tuktoyaktuk, the road would angle north, leaving the shores of Husky Lakes, crossing into the Kugmallit Bay drainage basin. At this point, the road would pass between two unnamed headwater lakes of the Reindeer Creek and Freshwater Creek systems, both of which drain in to Tuktoyaktuk Harbor. Eight kilometres north, the road would cross over Reindeer Creek before joining the existing local road south of Tuktoyaktuk. In all, nine percent of the road would be located in the Mackenzie Delta drainage, 14 % in the Kugmallit Bay drainage, and 77 % in the Husky Lakes drainage.

For the most part, all the lake and stream systems approached or crossed by the proposed road are relatively similar in origin and make-up and can be classified as peninsula lakes and streams. The lakes are biophysically different than the Delta lakes found to the west as discussed in Section 3.3 of this report and Ramsey and Ramlal (1985).