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CAPITAL BUDGETING PROGRAM

for the

Town of Inuvik N.W.T.

September, 1973

MAKALE, HOLLOWAY & ASSOCIATES LTD.
Town and Regional Planning Consultants

AESL
Consulting Engineers

ASSOCIATED ENGINEERING SERVICES LTD.

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September 28, 1973

Mayor and Council
Town of Inuvik
P. O. Box 1160
Inuvik, N. W. T.

Your Worship, Ladies and Gentlemen:

I have the pleasure to submit the report on capital budgeting program, from 1973 to approximately 1980-1981, for your Town.

As the development circumstances are unusual, and the growth rate of your Town is very rapid, the expenditures which are required to upgrade the existing community and to cater to the new growth are quite large. In order to place the ability of the Town to carry out this task in the proper prospective, we investigated the conditions under which the municipality is handling the growth, the resources of the municipality to meet the costs of this growth and the ability of residents to meet the increased taxation.

Although presented as a separate document, this report will ultimately form a part of the expanded General Plan document.

Respectfully submitted,

D. L. Makale, MTPIC
President
Makale, Holloway & Associates Ltd.

/kp

D. L. MAKALE M.T.P.I.C.
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October 1, 1973
File: 3587-A914

Town of Inuvik
P.O. Box 1160
Inuvik, N.W.T.

Attention: Mayor and Council

Your Worship and Members of Council:

Re: Capital Budgeting Program

Associated Engineering Services Ltd. in conjunction with Makale Holloway and Associates Ltd., we are pleased to present this report on capital budgeting for the Town of Inuvik.

The most important aspect of this report is the magnitude of the expenditures required to meet the anticipated demand for municipal and community services, as summarized in Chapter III. Examination of the financial resources available to the Town (Chapter IV) reveals a substantial gap between the requirements and the fiscal ability to satisfy these requirements. Comparisons presented in Chapter II rule out increased property taxation as an open source of additional funds. Therefore, provision of additional funds requires consideration of the senior governments.

It is significant to note that substantial amounts of funds are required to upgrade existing utility systems to acceptable standards before any orderly expansion can be started. The details of utility system upgrading have been discussed in our recent reports on water supply and sewerage, to which we made reference.

The land which is considered for the townsite expansion almost entirely lies within ice-rich fine grained soils, which will require special engineering and construction techniques for development. The environmental and ecological considerations of the new site development will have a very significant influence on the costs, and for this reason we devoted an entire section (Chapter VI) to discussing the background which led to our conclusion.

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October 1, 1973
File: 3587-A914

Town of Inuvik

In order to sustain the present rate development and to allow for possible acceleration in capital works a clear definition of responsibilities is imperative as recommended in Chapter V. Definition of responsibilities involving the Federal Government, Northwest Territories Government, Northern Canada Power Commission and the Town of Inuvik, should be considered as the first step in the solution of the administrative and technical problems facing the present administration.

The planning of orderly development of the community is a challenge which we feel can be best met by implementation of the recommendations contained in this report.

Yours truly,

ASSOCIATED ENGINEERING SERVICES LTD.

N.A. Lawrence, P.Eng.

P. Lukomskyj, P.Eng.

PROFESSIONAL ENGINEER ALBERTA
N. A. LAWRENCE

PROFESSIONAL ENGINEER ALBERTA

TABLE OF CONTENTS

LIST OF APPENDICIES

LIST OF PLANS

I. INUVIK AS A COMMUNITY

HISTORICAL OVERVIEW

The Town of Inuvik is relatively a new community created by the Federal Government in order to provide a base for the administration and schooling system for the Mackenzie Delta area, as well as the hospital and social service facilities.

The original population visualized for the community was established at a maximum figure of 1300 while the original Town plan to be served by a utilidor for heat, water and sewer, had a capacity for 2000 persons. The provision of all the governmental services plus the most contemporary community in the region, in terms of physical layout and utilities, attracted considerable migration from the Delta area, in addition to persons from the south involved in activities other than those of Government. Very soon the original utility system was outgrown and the new, and not anticipated population located mainly in the west portion of the Town. This situation resulted in inequities in terms of urban facilities, amenities and services. In addition to differences in standards it has even produced considerable social and economic divisions within the community, and considerable strain on the newly emerging municipality of Inuvik attempting to place all of its residents under an equal standard of services.

RECENT EVENTS

By 1970 large programs of the servicing of the west end were undertaken and the differential between the two parts of the Town was reduced to a considerable extent. Even at that point in the development of the Town the population increased faster than it was originally anticipated and faster than the migration only would have justified. By the year 1970, Inuvik's population stood at 3078 persons. The exploration for oil and gas in the Mackenzie River Delta and the Arctic Islands was by necessity based on the Town of Inuvik. With its airport, which could take a large share of the air transport for northern Canada and being a terminal of river transportation via Mackenzie River, Inuvik was a logical distributing point for people and cargo. This fact of logistics increased rapidly both the transient and permanent segment of the community and by 1973 the permanent and transient population of Inuvik reached the level of over 4000 persons.

The activities in the area of oil and gas exploration created the need for auxiliary services based in Inuvik. With rapid increase in the regional air traffic based in Inuvik, both in terms of fixed wing planes and helicopters and with a sizable increase in trucking, construction, expediting and catering services, growth of activity in the private sector of economy caused an equivalent expansion of Governmental services with the resulting heavy demand on accommodation. In addition to the Government and oil industry generated employment, the Canadian Armed Forces expanded their personnel based in Inuvik. At this particular point, the housing, which was always a major problem due in part to its substandard quality - overcrowding and lack of services, became even more acute.

DEVELOPMENT PROBLEMS

While the Governmental agencies and the major industrial corporations engaged in various aspects of oil and gas exploration were able to meet the high cost of housing and subsidize the same for their own employees, the native population and the migrants from the south did not have the same financial resources or backing. Consequently, the housing problem became not only an issue of opening new areas and providing the services but also a very serious social and economic problem which still creates inequities and frustrates the normal development of the community. The general problems of provision of services and provision of housing, have fallen on the shoulders of the Municipality of Inuvik which is of a very recent origin with limited municipal experience and faced with major financial constraints in fulfilling it's function.

The updating of the general plan deals mainly with provision of land for major land uses, with relationship of various land uses to the entire community and with a functional provision of road network, services and amenities. As such, it is a basically utilitarian approach which provides for the necessities of life, but does very little for the quality of life in the community, which might well be beyond the scope of a technical solution but should not be disregarded as it is a main goal of human endeavor.

The community which is planned and for which a capital budgeting program is outlined in the following pages will result, if this is all that is accomplished, in an efficient work camp where the life supporting system will function and basic amenities will be present.

The community spirit and participation, of course, could not be legislated, neither could it be designed and preplanned, but the physical and economic environment could greatly influence and assist the way of life.

Urbanizing an Arctic landscape is never an easy task as every human activity which creates the change also creates a destruction of the very fragile ecological system. Just the matter of insulating the permafrost to be able to place various structures, means in practice, covering all vegetation with gravel and thus, effectively destroying it. Filling around the larger trees means raising the permafrost zone above the root level and killing the trees. By having the trees in a hollow means creating a swamp around the root system and killing it eventually as well. Providing only pads underneath the building, as the practice was up to now, creates surface drainage problems, providing a breeding ground for mosquitos and again a swampy condition interspersed throughout the urban area.

This is an area which requires a planned action, as it could be resolved by recreation of the landscape, which could be a costly and a slow process. Yet there is no precedent for the restoration of nature on such a large scale and at anticipated large cost, which is beyond the individual or municipal capabilities.

On the other hand, there is no precedent for a large urban unit in the Canadian Arctic, and it is obvious that a high level realization should be arrived at "that urbanizing the arctic is a unique challenge and experience, and that the orthodox municipal approaches in terms of planning, finance, and implementation could not be applied."

Even our relatively short experience could teach us that the change in approach is essential.

As Inuvik expands nature is pushed further away and the dreariness of urban scape increases proportionately. With the exception of a few scruffy trees, gravel and mud dominate the roads, boulevards, and yards of buildings. Similar dreariness pervades the social life, especially in its cultural aspects, and especially when related to geographical conditions and rigors of climate. Nowhere in Canada is there such a need for live theater, ethnological museums, botanical gardens, and yet even the schools lack a patch of decent grass.

The proposed capital budget program does not talk about the community. It talks about the basics required for its functioning on a municipal, physical level.

Inuvik was a new Town, it still is a new Town, and it will continue to be that for a considerable time to come. All industrial new towns in Canada had by far greater support in their development from governments or private corporations, with far greater ability to marshal their own resources and undertake some limited municipal responsibilities. Their population was guaranteed high levels of incomes and decent homes, which is not the case in Inuvik.

Inuvik is being used by some of the most powerful industrial corporations in Canada, as a new Town which provides a base for field operators and homes for their labour force. Those corporations place a strain on the municipality with their needs for serviced land and accommodation and do not contribute anything beyond what an average ratepayer does. The governments, while contributing to some of the municipal needs are not doing it to the extent that other new towns in Canada are assisted, despite the fact that the original system of utilities was inadequate and partially obsolete even prior to the oil and gas activities.

The capital budgeting program will indicate the extent of needs in terms of upgrading and in terms of expanding the community. It will attempt to illustrate the scale of the needs as related to the ability of the municipality to finance the same. It will be an important document, which must be a base for establishing or for reevaluating the policies as applicable to the development and functioning of Inuvik.

Prior to considering our overall budgeting program and the anticipated capital expenditures, it would be essential to establish the ability of a citizen and municipality to pay for the same. A basic source of municipal income relates to assessment and resulting taxes and the main provider for that income is the citizen, property owner. Neither the assessment nor mill rate as expressed in taxes could be treated in isolation from the ability of property owner to pay and the main type of property owner who deserves consideration is the individual home owner. In order to determine his ability to pay a taxation comparison was undertaken.

II. TAXATION COMPARISON

Property taxes are an important source of revenue for a municipality. An increase in the mill rate may be one possible method anticipated of increasing the revenue, through helping to meet the costs of the capital expenditures. The mill rate in Inuvik of 42 mills may seem low in comparison with some towns in Alberta. However before suggesting that the mill rate could be increased, the existing circumstances should be examined to see if the community could bear the increased burden. If the people of the community are already heavily burdened, an increase in the mill rate may result in high taxes in arrears, and it may discourage potential residents. This analysis will examine the portion of income that Inuvik families spend on taxes compared to a family in a central Alberta community. The costs of other expenditures will also be considered.

In order to analyze the existing burden of the home owner we will compare conditions in Inuvik to those in Sherwood Park. These two communities are both experiencing growth, but they differ in the rate of taxation. The mill rate in Sherwood Park is 70 mills. For purposes of comparison three types of families from each community have been selected, i.e. a below average income family, an average income family and thirdly an above average income family. Each type of family lives in a corresponding type of house. The following table describes the residential properties that have been chosen for the comparison.

TABLE I

		Assessed Value		Market Value		
Type	Size of House	Land	House	Land	House	Taxes
Inuvik						
Economy	512	2,000	2,660	2,000	15,000	195.72
Average	1,050	3,000	5,330	3,000	29,850	349.80
Modern	1,200+	4,000	8,000	4,000	44,500	504.00
Sherwood Park						
Economy	970	840	4,330	8,000	21,000	361.90
Average	1,070	840	4,520	8,000	24,000	375.20
Modern	1,286	860	6,000	8,500	31,000	480.20

In Sherwood Park it is hard to find a house as small as the economy size in Inuvik. The economy house in Sherwood Park is considerably larger than the one in Inuvik and correspondingly the market value is higher. Considering the other two types of houses the market values are higher in Inuvik. However this does not mean that the average house in Inuvik is a better house than the average house in Sherwood Park. As we will discuss later, the difference is due to construction costs.

Table II shows a comparison of expenditures between the two communities. The expenditures are also expressed as a percentage of the total income of the family. The average family in Inuvik is estimated to have a monthly income of $1000. This is higher than the income of the average family in central Alberta. The difference exists in order to attract labour and compensate for the higher cost of living.

The monthly property taxes for the average family in Inuvik amounts to $29.15. The average family in Sherwood Park pays a monthly property tax of $31.26. Although the mill rate in Inuvik is substantially lower, there are two reasons why the property taxes are not substantially lower. First the construction costs in Inuvik are higher and thus the market value is higher; this causes a higher assessment value. Secondly, the land in Inuvik is assessed at its fair value, whereas in Sherwood Park the land is assessed at approximately 10% of its fair value. The property taxes in Inuvik constitute a smaller percentage of the average family's income since incomes are higher in the North. Property taxes require 2.9% of the average family's income in Inuvik, whereas in Sherwood Park taxes require 4.2% of the income. However, the advantage of paying a lower percentage of income in taxes soon disappears when the cost of utilities and food are considered. The average family in Inuvik spends 5.9% of its income on heating fuel, whereas the average family in Sherwood Park spends only 1.2% of its income on fuel. Very high costs are also experienced for electricity, water and sewer services in Inuvik. In Inuvik property taxes, utilities and food require 42.6% of the average family's income, but in Sherwood Park the same expenditures require only 31% of the income. After meeting all the listed expenditures the family in Inuvik has $183.74 left and the family in Sherwood Park has $246.74 left. Thus, although the family in Inuvik has a higher income and a lower mill rate, it is at a financial disadvantage compared to the family in Sherwood Park.

Considering the above average income group, the property taxes of the Inuvik family amount to $42 compared to $40 for the family in Sherwood Park. The advantage of the lower mill rate is completely counter balanced by the higher construction costs and the fact that land in Inuvik is assessed at full value. In addition, the family in Inuvik has the burden of paying 6.0% of its income for electricity, water and sewer compared to the 2.4% that the family in Sherwood Park pays.

So far we have compared the average family in Sherwood Park with the average family in Inuvik. In addition, we should compare tax rates on comparable structures. Construction companies estimate that the cost of a home in Inuvik is almost double the cost of constructing a similar home in the Edmonton area. There are two main factors contributing to this difference. There is the problem of permafrost and secondly, there is the transportation of materials. An example of the cost difference is a bag of cement costing $2 in Edmonton costs approximately $6 in Inuvik. Thus, if there are similar houses in each community, the market value of the house in Inuvik is much greater and thus the assessment will be greater. Assuming a house in Sherwood Park costing $25,000, the yearly property taxes would be approximately $395. Assuming a cost variation of 80%, the property taxes for a similar structure in Inuvik would be approximately $485. Thus, it is seen that if a family enjoys a similar type of structure as a family in central Alberta their taxes may in fact be higher.

The analysis reveals that although the below average and average income groups in Inuvik spend a smaller portion of income on property taxes, due to the high cost of other services they cannot afford the cost of an increased mill rate.

The above average income family in Inuvik actually spends more on property taxes than the family in Sherwood Park. If a family in Inuvik enjoys a comparable living structure to one in central Alberta, their property taxes are not any lower, moreover they have the burden of higher costs for other services. An increase in the mill rate would only place the people in Inuvik at a greater financial disadvantage.

TABLE II

Below Average Income Family

	Inuvik		Sherwood Park	
Income:	$526.00		$500.00	
Expenditures:	Amount	%	Amount	%
Income Tax, CPP UIC Deductions	81.63	15.4	69.50	13.9
Property Tax	16.31	3.0	30.15	6.1
Heating Fuel	35.00	6.6	10.00	2.0
Electricity, Water and Sewer	54.00	9.9	15.00	3.0
Food	180.00	34.2	113.50	22.7
House Payments	60.00	11.4	120.00	24.0
TOTAL	426.94	80.5	358.15	71.7

Average Income Family

	Inuvik		Sherwood Park	
Income:	$ 1000		$750.00	
Expenditures:	Amount	%	Amount	%
Income Tax, CPP, UIC Deductions	200.11	20.0	131.00	17.5
Property Tax	29.15	2.9	31.26	4.2
Heating Fuel	59.00	5.9	12.00	1.6
Electricity, Water and Sewer	68.00	6.8	19.00	2.5
Food	280.00	28.0	170.00	22.7
House Payments	180.00	18.0	140.00	18.6
TOTAL	816.26	81.6	503.26	67.1

Above Average Income

	Inuvik		Sherwood Park	
Income:	$1167		$1000	
Expenditures:	Amount	%	Amount	%
Income Tax, CPP, UIC Deductions	253.61	21.7	220.00	22.0
Property Tax	42.00	3.6	40.00	4.0
Heating Fuel	59.00	5.6	15.00	1.5
Electricity, Water and Sewer	70.00	6.0	24.00	2.4
Food	280.00	24.0	227.00	22.7
House Payments	249.00	21.3	215.00	21.5
TOTAL	953.61	82.2	741.00	74.1

The preceding analysis is very pertinent since it will discourage a simplistic comparison of the assessments and the mill rates between Inuvik and southern Canadian communities.

It also shows that the assessment formula based on a fair market value penalizes the property owner in Inuvik, as it does not compare with the actual value to owner than the southern Canadians receive. The property owner in Inuvik pays high transportation and building costs and it is subsequently taxed on those. In terms of the actual income the resident of Inuvik, even on lesser mill rate, pays by far more on the total cost of accommodation and with other high expences has less disposable income than his southern counterpart.

The preceding analysis considered only those who have a tidy income and the corresponding earning potential. There is a considerable segment of Inuvik's population which has very low or no income at all, but depends on various types of social assistance to get by. That particular socio-economic problem is not even approached by the above analysis.

The conclusion is that the tax base of Inuvik is exploited to the utmost in terms of the citizen's ability to pay, and this should be a guiding yardstick for municipal taxation policy. Any increment in revenues could only come from an expanding assessment base. The question is whether this expansion could come soon enough to generate the revenues for reasonable administrative performance of Municipal Government, and whether it will generate enough borrowing power for some of the anticipated major capital expenditures. The pertinent question is, as well, whether with the increased debt burden the mill rate could remain the same without reducing the level of necessary municipal services.

To illustrate the growing demand for municipal services as indicated by the staff requirements the existing and the future municipal employment should be compared. The projected future employment in municipal administration is [illegible] for a population of 7800, as a matter of fact, most of the projected municipal staff will be required almost immediately to fill the existing gaps.

TABLE III

Projected Staff Requirements

Position	Present	Salary ($)	Projected	Estimated Salary ($) (1)
General Administration				
Secretary/Manager	1	18,000	1	18,000
Assistant Secretary/Manager	1	15,000	1	15,000
Bookkeeper	1	8,900	1	8,900
Counter Clerk	1	6,500	2	13,000

Position	Present	Salary ($)	Projected	Estimated[1] Salary ($)
Secretary/Typist	Nil	-	2	15,600
File Clerk	Nil	-	1	6,000
General Clerk	Nil	-	3	21,000
Engineer	Nil	-	1	18,000
TOTAL	4	48,400	12	115,500
Public Works (Including Water and Sewer Service)				
Works Superintendent	Nil	-	1	15,000
Labour Foreman	1	12,000	3	184,000
Labourers	12	96,000	23	33,000
Equipment Operator	1	11,000	3	33,000
Building Inspector	Nil	-	1	12,000
Draftsman	Nil	-	1	10,000
TOTAL	14	119,000	32	290,000
Protection to Persons and Property (Fire and Police)				
Fire Chief	1	15,000	1	15,000
Assistant Fire Chief	Nil	-	1	12,000
Fireman (full-time)	Nil	-	6	60,000
Bylaw Inspection Officer	1	12,000	4	48,000
TOTAL	2	27,000	12	135,000
Recreation Department				
Director	1	15,000	1	15,000
Assistant Director	Nil	-	1	12,000
Swimming Pool Instructor	Nil	-	1	10,000
Life Guards and Supervisors	Nil	-	3	24,000
Playground Staff	Nil	-	3	21,000
Arena Manager	1	10,000	1	10,000
Ice Maker	1	8,000	1	8,000

Position	Present	Salary ($)	Projected	Estimated Salary ($) (1)
Caretaker	1	7,000	1	7,000
Maintenance Man	1	8,500	1	8,500
TOTAL	5	48,500	13	115,500
GRAND TOTAL	25	242,900	69	656,000

(1) All above estimates in constant 1973 dollars.

Within the next three to five years (broadly estimating) the upgrading of present administrative organization and meeting of foreseeable needs will require in 1973 dollars, an additional $413,100 of municipal payroll. What this figure will represent in 1978 dollars, at the present rate of inflation is very difficult to predict excepting that it will be much higher. In addition, there will be 44 persons more on the staff and if the present conditions continue, the Town will have to provide and subsidize their accommodation.

III. CAPITAL COST REQUIREMENTS

BUILDINGS AND EQUIPMENT

The expansion of the Town will require the expansion of municipal facilities, which are at the present totally inadequate and overcrowded. The Town Hall consists of one medium size general office, which with three persons is overcrowded, and one small room for the secretary-manager. The fire hall portion is a large size double garage attached to and forming part of Town Hall. Council meetings are held in the research centre, which is in a separate building - consequently, the access to files or to staff during the meeting is impossible. While the combination of the garage and workshop is new, it is of a small size and inadequate to provide adequate storage and working space for the existing equipment.

The estimate was prepared to determine the capital cost of buildings and equipment required for a population level of 7000. There is however, an immediate need for a major part of this expenditure in order to upgrade the existing deficiencies.

TABLE IV

Municipal Capital Requirements

Facility	Estimated Cost (1)
General Administration	$
New Town Hall	300,000
Office and Building Equipment	28,000
TOTAL	328,000
Public Works	
Expansion to Garage and Workshop	75,000
Additional Machinery and Equipment	
Grader	40,000
Loader	25,000
3 Trucks	45,000
Caterpillar	50,000
Pavement, Street Cleaning Equipment	60,000
Regulation Sanitation Truck	33,000
TOTAL	328,000

Facility	Estimated Costs (1)
Persons and Property Protection - (Police and Fire)	
Provision of Two Fire Stations	90,000
Two Pumper Fire Trucks	77,000
Two Police Cruiser Cars	10,000
Police Department Equipment	5,000
TOTAL	182,000
Recreational Facilities (2)	
Indoor Swimming Pool	300,000
Outdoor Recreational Facilities (three playgrounds, development of two playfields, three small shelters)	100,000
TOTAL	400,000
GRAND TOTAL	1,238,000

(1) Estimates based on 1973 costs.
(2) Excludes general landscaping or development programme.

All the figures based on the estimates prepared by the Town.

UTILITIES AND ROADS

In addition to upgrading the municipal buildings and equipment there is the need to provide adequate utility systems and roads. This will be the major core of the Town's expansion, and it is necessary to estimate the capital costs and maintenance costs of these expanded facilities.

Upgrading the Existing Water and Sewerage System

The object of the proposed expenditures on the existing water and sewerage system in Inuvik is to upgrade the piping network to the standards established by good engineering practice and the requirements of governing agencies. The Town of Inuvik has grown rapidly and is faced with a continuing problem of upgrading its utility systems to meet the demands of a steadily increasing population. The expansion of service is hindered, in part, by the inadequacy of the existing physical plant which was originally designed to serve an ultimate population of only 2000. The details of the work (and costs) required to upgrade the existing system are given in detail in a report by Associated Engineering Services Ltd. to the Northern Canada Power Commission dated

January 1973 and entitled: "Water and Sewage System Analysis, Town of Inuvik, Northwest Territories." This section simply paraphrases parts of the recommendations of that report.

It must be noted that all costs are projected from historical construction records in Inuvik and no account has been taken of possible technological improvements.

The water source (Hidden Lake) and the treated water storage facilities are barely adequate to satisfy the requirements of the existing population. An 8-inch pipeline from the East Channel of the Mackenzie River is deemed vital to the continued safe operation of the system. Also, additional treated water storage is recommended to handle fire flow demands and raw water supply down time.

Some parts of the existing water distribution piping are also inadequate to satisfy the present requirements. Small portions of the 6-inch main will have to be replaced with 8-inch and all the existing 4-inch piping will have to be replaced with 6-inch.

The existing sewerage piping requires upgrading in specific areas. Two short lengths need to be increased in size to handle the additional flows that have resulted from the present development in the west end of Town. Perhaps most urgent of all is the upgrading of the sewerage outfall main from an 8-inch to a 14-inch diameter pipe. The present outfall main is seriously overloaded.

The past piecemeal approach to utility upgrading (and expansion) must not continue. Only by a well planned, well financed, and conscientious approach can the development constraints imposed by the existing utility key to the successful future development of the Town and elimination of these constraints must be attended to immediately.

<u>Upgrading of Existing Roads</u>

The intention of the proposed work on the existing roads is to improve traffic flow through the downtown area and to improve the standard of all residential and arterial streets. This program in its ultimate extent entails paving approximately 1.5 miles of the Mackenzie Road, upgrading and regravelling all streets, upgrading the surface drainage system, provision of sidewalks along all residential streets and development of an alternate arterial road parallel to the Mackenzie Road.

Paving of the Mackenzie Road will greatly improve traffic flow through the main business district of the Town. On the other hand paved main road will impose restrictions on some types of traffic which can cause damage to the roadway. Therefore it is recommended that before the Mackenzie Road is paved the alternate east-west arterial road should be constructed. Construction of this road mostly requires improvement of existing streets and building of about 1700 feet of new roadway.

Within the existing townsite there are many areas where surface drainage problems are evident, particularly during spring breakup. As development proceeds and the density of buildings increases these problems will increase unless positive steps are taken to establish and to control the overall surface drainage system. In the budgetary estimates an allowance for this work has been made which includes structures, ditching and filling.

Within the next three years it is proposed to improve the standard of all the existing residential streets. The existing street embankments are generally in a stable condition, but the surfacing on them has deteriorated considerably, and an overall upgrading and resurfacing program is recommended. At the same time it is suggested that installation of sidewalks should be considered. In the estimates an allowance has been included for a wooden sidewalk on one side of the street. The sidewalk along the Mackenzie Road would be paved provided [illegible] implemented.

Cost of paving the Mackenzie Road is relatively high compared to costs for similar work in southern Canada. Although eventually different methods of construction might be investigated, for estimating purposes an insulated roadbed design was used. Costs of the various components of the road were either obtained from available costs in Inuvik or were derived by adjusting costs from projects elsewhere. The cost which comes to about $2,000,000 per [illegible] provide for a 40 foot top roadway, curbs, and one sidewalk. Eventually [illegible] adjustments in this design may be made, such as providing a narrower roadway and adding another sidewalk.

Methods of construction on existing road improvements do not present any exceptional problems. Materials used for improvements would be the same as those discussed in the section of new road construction. In the estimates prices of materials used for road improvements were the same as those used for new roads. It should be noted that as in other estimates it has been assumed that road materials will come from the Ministry of Transport quarry near the airport.

New Roads and Drainage

Construction of new roads and drainage facilities covers road construction in the Mobile Homes Subdivision and all roads in Stages II and III. Estimates are based on the layout of the Mobile Homes Subdivision as it is being presently surveyed. Stage II estimates are based on a tentative layout which is governed mostly by design of the utilidor system and by topographical features. Stage III estimates are not related to any specific area or any definite layout. Estimates for this stage are an extrapolation of quantities calculated for Stage II.

Discussion of the environmental impact of development clearly indicates that only controlled and orderly methods can assure any reasonable success in development of the undeveloped area, most of which falls within Stages II and III. Experience gained on highway projects has demonstrated that roads constructed on fine grained high ice content soils caused very pronounced settlements during the initial years of service. This problem cannot be avoided unless the fill, using stable materials is built to a height of five to eight feet. A height of fill of this magnitude is not considered practical on most streets within the Town. A practical approach, therefore, has to consider staged methods of road construction and predevelopment of roads and building sites several years ahead of utility construction and occupancy of the land.

Staged construction entails placing of fill to a depth which will cause some thawing under it and will result in settlement. This method results in replacement of ice (which melts) in the top 12 to 24 inches of the original soil by fill material. In the process also the thawed soil below the fill becomes compressed. After this stage the settlements are extremely pronounced. During the next year additional materials should be placed and the road may now be surfaced with gravel. During subsequent years the road will be subject to settlements which will decrease with time. Three to four years after initial construction stable roadbed can be expected. It should be noted that these progressively improving conditions can only occur as long as road construction and other work in the vicinity do not disrupt surface drainage, since such disruption can cause very adverse conditions effecting the road.

In cases where timing of development does not allow staged construction the difficulties of settlement cannot be avoided and will have to be solved while building construction and other development is underway. If at all possible this approach, of starting all construction activities simultaneously should be avoided. The recommended method is to develop roads and building pads two or preferably three years in advance of utility and building construction.

The sources of fill materials for roads, utilidor fills, and development of lots are limited in the Inuvik area. The pit near Town in 1972 was estimated to contain 250,000 cubic yards of material which is deteriorating in quality, as this source is being exhausted. The most economical source of material which can satisfy the projected requirements is the Ministry of Transport quarry near the airport. This source has been estimated to contain 6,000,000 cubic yards and should be adequate to supply the needs of the Town which are estimated at 3,000,000 cubic yards up to and including Stage III. Estimates for individual stages indicate the following requirements:

Stage I	- 400,000 cubic yards
Stage II	- 1,250,000 cubic yards
Stage III	- 1,350,000 cubic yards

It should be noted that the above estimate of requirements considers only townsite development and does not include any material required for industrial development. Industrial demand is impossible to estimate with any degree of accuracy but it could approach the amounts required by the Town or even exceed them. These considerations imply that by the time the Town is developed to accommodate a population of 10,000 the quarry near the airport is likely to be exhausted, and then materials from other sources along the Mackenzie Highway would have to be used.

Obviously the proven material sources are adequate for proposed Town expansion but they are limited and, therefore, to assure adequate and constant supply at economic prices, firm control and management of the sources is required. It is recommended that the Town should obtain control of the quarry near the airport, or reserve at least 3,000,000 cubic yards from this source strictly for its own use.

Since the material from the pit near Town is poor in quality and limited in quantity, this source should be phased out. Consideration should be given to reclaiming this area, which covers about 70 acres, for industrial use. By developing an area which already contains some gravel, additional gravel requirements for site development can be reduced. Some portions of this pit can remain as sources of silty material for landscaping.

The design of the road embankment as proposed, requires placing of a fill over the entire width of the road. The recommended method of construction is to place a fill two feet deep over the entire right-of-way and then to build the road embankment on top of this fill. The initial low portion of the fill would eventually form the ditch after the higher fill is placed on the adjacent lots. It is recommended that the fill on the lots be placed at the time the roads are built.

When making estimates an allowance was made, to some extent, for poor terrain conditions in the proposed Mobile Homes Subdivision. In this area higher than average fills will have to be placed due to a very high ice content in the soil. Area covered by Stage II has terrain variation within its limits which might effect road construction, however for estimating purposes it was assumed to be uniform. The initial depth of fill for this area has been estimated at 4.5 feet. Of this total fill about 1/3 or more can be expected to sink into the existing ground as permafrost is disturbed by construction activities.

New Sanitary System

Utilidors serving the presently undeveloped area will function as essentially an independent system although there will be several connections from the new area to the present system. The utilidor system serving Stage II and the Mobile Homes Subdivision in Stage I will have a trunk main water supply line and a trunk sewer outfall line. It is proposed to locate these two main lines in the same utilidor running generally from east to west. The trunk water main would be of large diameter near the east end and progressively decreasing going westward. The opposite sizing applies to the sewer, with the largest diameter occurring at the west end of the system.

Consideration has been given to provide the trunk main utilidor with heat to prevent freezing of water mains. Tracing this utilidor with hot water lines might prove to be the most economical way of providing heat. If this method proves impossible then heating may be provided at a higher cost by installation of boilers, heat exchanges, circulation pumps, return lines, and other related equipment.

Aside from the main trunk utilidor the remainder of the water system is to be heated by constant circulation during cold weather months. Up to the end of

Stage II the proposed design allows controlled circulation in six separate and independent portions of the system which form separate neighborhoods. Breaking up the system into independently serviceable neighborhoods makes economical expansion possible. In most instances it will even be possible to construct only partial extensions in any single neighborhood. It should also be noted that it will be possible initially to operate with only portions of the main utilidor constructed. This means that this main utilidor does not have to be built all at once, but can be phased into up to three sections. Phasing however will present a few problems particularly in the Mobile Homes area where some temporary heating and pumping facilities will have to be provided.

For the main trunk utilidor the standard metal type of design will be most suitable particularly if hot water lines are used to distribute heat. Estimates of costs for this trunk line have been calculated on the basis of current costs for this type of utilidor. For lateral utilidors prices are based on actual costs paid for wood box type utilidor currently being built by the Town. This fact does not necessarily imply that the wood box type utilidors, which are being built now, will be most suitable in the future.

In the undeveloped area, where soil conditions are considered poor particular attention will have to be paid to the utilidor foundations. Placing of fills along the utilidor lines two or three years ahead of utilidor construction is desirable. This work should be done in conjunction with filling of lots and by the time construction starts the sites should be firm enough to carry equipment, and they should be accessible by reasonably stable roads. As a precaution against uncontrolled thawing of the ground near the utilidor, the piles should be installed a few feet deeper than in the existing part of the Town.
As in the case of roads the costs for the utilidor system in Stage III are simply extrapolations of costs calculated for Stage II. To arrive at Stage III costs more precisely is not possible at this time since very little is known about the terrain conditions in the area where Stage III is being projected. Some experience in Stage II area will be required before accurate estimates for additional expansions can be made. At this time there are even doubts about suitability of some areas within Stage II limits. If these doubts prove to be correct then more or less fundamental revisions will be required in the whole projected layout which will have very pronounced influence on the costs.

Water treatment and storage facilities must be increased to handle the requirements imposed as the population of Inuvik increases. When the population reaches 7000, the treated water storage facilities will have to be increased by 0.5 million gallons. This increase in storage would be adequate to satisfy the needs of the ultimate population of 10,000. As the population grows past 7000 however, the water treatment plant will have to be upgraded and a permanent raw water intake installed in the East Channel of the Mackenzie River. The details of this work are discussed in Associated Engineering Services Ltd. report to Northern Canada Power Commission "Water and Sewage System Analysis, Town of Inuvik, NWT" January 1973.

The sewage treatment and disposal requirements for the Town of Inuvik as it grows to 10,000 people are outlined in detail in a report by Associated

Engineering Services Ltd. for Environment Canada entitled "Field Survey and Report on Sewerage, Inuvik, NWT" dated January 1973. After assessing several treatment and disposal techniques, the report recommends the construction of a new sewage lagoon on the east side of the Mackenzie River. The costs associated with this construction are included in the present estimates. However, effluent regulations for communities in the Northwest Territories have not been clearly defined by Environment Canada at the time of writing of this report. If the pending regulations set standards greater than the capability of a lagoon, then a sewage treatment plant will be required and a substantial increase in the capital, operation and maintenance cost can be expected. The magnitude of this increase in clearly outlined in AESL's report.

Regulations governing the disposal of garbage in the Northwest Territories have not yet been defined by Environment Canada although such regulations are expected in the immediate future. The cost of garbage disposal in Inuvik is based on the probable cost of building and operating an incinerator. This type of disposal and its cost were based on the report by Associated Engineering Services Ltd. to the Department of the Environment entitled "Solid Waste Management in the Canadian North. The Problems and Some Recommendations for a Program of Investigation and Improvement" dated March 1973.

New Building Site Development

The condition of the terrain in the area proposed for expansion govern the proposed construction methods. The soils in this area which are fine grained and ice-rich cannot support any traffic, be it equipment or pedestrian, upon thawing. Furthermore, to make construction in this area possible the stable permafrost condition has to be preserved. Therefore, the only practical solution to development of this area is to cover it entirely and thereby provide a protective mat for the permafrost and a working surface for construction activities.

Costs shown for development of the lots make provision for total coverage of all residential lots and of other areas to be developed for building sites, recreational areas, school yards, etc. The best approach would be to place these fills in stages, as in the case of road construction, and to commence this work two or three years in advance of building construction. This sequence of development will allow overall control of construction in the area and development of an adequate surface drainage system. Entrusting development of the lots to individual owners is likely to produce serious problems such as disrupted drainage, ponding, heaving of foundations and deterioration of permafrost which might render some areas totally useless for any type of development.

Utility Maintenance and Operating Costs

The intent of the estimate for water and sewerage maintenance and operating costs is to show the general magnitude of the expenditure that the Town of Inuvik can expect when they assume responsibility from the Northern Canada Power Commission (NCPC). Unfortunately, historical operation and maintenance costs are not available from NCPC. Therefore, the estimated costs were based on the figure of two to three percent of the capital replacement value of the system which is used by the Territorial Government. Confirmation of this approach was obtained by reference to the report "Comparison of Utilidors in Inuvik, N.W.T." by A. F. Leitch and G. W. Heinke at the University of Toronto, October 1970.

The costs shown representing only those expenditures required for normal day to day operation and maintenance of the water and sewerage system. Included are the costs of labour, small tools, replacement parts, etc. Not included are costs of the initial purchase of vehicles, shops, offices, storage administration, etc. These latter expenses are included elsewhere.

Road Maintenance Costs

Road maintenance costs have been calculated by including wages, benefits and operation of the equipment costs. It is considered that the equipment listed is adequate to maintain all roads up to completion of Stage II. Before completion of Stage II, therefore there will be some equipment not working full time. After Stage III is started additional equipment will be required and again some will be idle part of the time.

From the above reasoning it has been concluded that the operating costs of equipment per mile will be the lowest at the end of Stage II, and they will be higher before Stage II is completed and after Stage III is started. The estimated cost of maintenance at the end of Stage II is $23,700 per mile per year. To the equipment operation cost estimates on per mile basis costs of materials which have to be bought have been added and the totals have been shown in the table.

It should be noted that high maintenance costs have been shown for the first three years of the roads life. This is an average figure which is expected to be higher during the first year. Normal year costs are shown separately. The reason for the very high maintenance costs during the first three years is the very high rate of fill settlement which is expected. In this case considerable amount of the cost is attributable to additional material which most likely would be bought by contract.

Usefulness of total maintenance costs for an entire stage during the initial years is only of comparative value since it is doubtful whether all roads will be built at once. Most likely year one costs will apply to one street while on another street normal costs will apply. What the calculated costs do indicate however is that initial maintenance costs will be about double normal costs.

TABLE V

Town of Inuvik
Summary of Estimated Capital Requirements

	STAGE I (1974-1976) Total Population: 4500			STAGE II Population: 2500 Total Population: 7000				STAGE III Population: 3000 Total Population: 10,000			
	Capital Cost in $	Operation and Maintenance Costs in $/year: Years 1,2&3	Operation and Maintenance Costs in $/year: Stage I Normal Years	Capital Cost in $	Operation and Maintenance Costs in $/year: Stage II Increment Only Years 1,2&3	Operation and Maintenance Costs in $/year: Stage II Increment Only Normal Years	Operation and Maintenance Costs in $/year: Cumulative Stages I & II	Capital Cost in $	Operation and Maintenance Costs in $/year: Stage III Increment Only Years 1,2&3	Operation and Maintenance Costs in $/year: Stage III Increment Only Normal Years	Operation and Maintenance Costs in $/year: Cumulative Stage I, II & III
Buildings and Equipment											
1. Municipal Plant											
(a) General Administration				328,000							
(b) Public Works				328,000							
(c) Protection of Property & Persons				182,000							
2. Recreational				400,000							
Sub-Total Buildings and Equipment				1,238,000							
Utilities and Roads											
1. Upgrade Existing Sanitary System											
(a) Main Utilidors	531,800*	N/A	Incl. in	85,000*	N/A	Incl. in	Incl. in	-	N/A	Incl. in	Incl. in Item 2
(b) Lateral Utilidors	385,400	N/A	Item 2	-	N/A	Item 2	Item 2	-	N/A	Item 2	"
(c) Treatment and Storage	310,000*	N/A	25,000	-	N/A	"	"	-	N/A	"	"
(d) Sewage Disposal	-	-	10,000	-	N/A	"	"	-	N/A	"	"
(e) Garbage Disposal	-	-	50,000	-	N/A	"	"	-	N/A	"	"
2. New Sanitary System											
(a) Lateral Utilidors	942,970	[illegible]	[illegible]	3,074,750	N/A	47,000	182,000	3,587,400	N/A	53,000	[illegible]
(b) Main Utilidors	550,740*	N/A		2,279,055*	N/A			2,754,200*	N/A		
(c) Water Treatment and Storage	-	-	-	280,000*	N/A	10,000	35,000	350,000*	N/A	7,500	42,500
(d) Sewage Treatment and Disposal	-	-	-	1,281,000*	N/A	[illegible]	[illegible]	-	-	6,000	34,000
(e) Garbage Disposal	-	-	-	507,000	N/A	130,000	130,000	-	-	56,000	186,000
3. Upgrade Existing Roads											
(a) Pave Mackenzie Road	2,920,000	35,500	35,500	-	-	30,000	65,500	-	-	13,100	78,600
(b) Drainage Improvements	186,000	Incl. in Road Mtce	Incl. in Road Mtce	-	-	Incl. in Road Mtce	Incl. in Road Mtce	-	-	Incl. in Road Mtce	Incl. in Road Mtce
(c) Alternate to Mackenzie Road	45,000	49,000	38,000	-	-	-	38,000	-	-	7,600	45,600
(d) Upgrade all Streets	161,000	240,000	220,600	-	-	(-38,100)	182,500	-	-	36,500	219,000
(e) Sidewalks	300,000	55,000	55,000	-	-	(- 8,000)	47,000	-	-	9,400	56,400
4. New Roads and Drainage											
(a) Residential Roads	326,000	73,400	37,950	1,035,075	302,000	147,000	184,950	1,140,900	352,400	176,000	360,950
(b) Sidewalks	100,000	7,900	7,900	304,000	N/A	31,500	39,400	366,000	-	37,800	77,200
(c) Bypass	-	-	-	170,000	57,600	27,000	27,000	-	-	5,400	32,400
5. Building Site Development	588,000	32,400	-	2,013,550	110,000	-	-	2,416,300	132,500	-	-
Sub-Total Utilities and Roads	4,626,000	-	614,950	11,029,430	-	-	959,350	10,614,800	-	-	1,367,550
TOTALS				12,267,430							

*Costs which will be paid by the Northwest Territories Government under Clauses 3.11 and 3.12 of the Proposed Water and Sanitation Policy for Communities in the Northwest Territories" March 1973.

NOTE: All above estimates in constant 1973 dollars.

IV. FINANCIAL RESOURCES

In order to evaluate the future financial capacity of the Town it is necessary to review past assessments, revenues, and expenditures. The review should provide an insight as to the burden the Town is capable of bearing.

In considering the priorities for Town development it is obvious that an acute competition will occur for the available municipal funds both in terms of its operation and maintenance and in terms of its capital investments. With severe limitations on its borrowing power, which is determined by the borrowing guidelines as established by the Territorial Government and even more by the ability of its citizens to repay, it is obvious that the emphasis should be placed on providing adequate services to its existing population.

The gap between what is required for the upgrading and the expansion of the Town and the fiscal ability of Inuvik to provide for the same, is a central question which merits serious consideration by the senior governments.

TABLE VI

Assessment

Year	Total	Percentage Increase	General	General as Percent of Total	Total Per Capita
1967	5,456,675	-	802,675	14.7%	2270
1968	4,803,329	-11.9%	715,398	14.8%	1715
1969	4,756,750	- 1.0%	938,300	20.6%	1585
1970	5,454,500	14.6%	1,325,700	24.3%	1772
1971	6,313,924	15.7%	1,979,124	31.3%	2010
1972	9,829,954	55.6%	3,409,929	34.6%	2960
1973	10,560,890	7.4%	3,893,074	36.8%	3150

During the five year period, 1968 to 1973, the assessment rose by 120 percent. Reassessment took place in 1972, in which year the assessment rose by 55.6 percent. From 1968 to 1973 per capita assessment rose by 83.6 percent, however, this trend cannot be expected to continue.

Table VI also reflects that Inuvik is an important administrative service centre. A large portion of the assessment is government property and thus exempt from taxation. In lieu of taxes, the Government provides grants and thus it makes its contribution to the municipal revenue.

In the past the large portion of government assessment placed a limitation on the borrowing guidelines since borrowing could not exceed 20% of the live assessment. Since June, 1973, the borrowing guideline is 20% of total assessment.

During the reassessment year, total assessment rose from $6,313,924 to $9,829,954. This drastic increase may have lead to over assessment, and there is a possibility that the 1973 assessment figure may be reduced by a reassessment. Because of the large increase during reassessment, it is difficult to project future assessment on the past trend. Rather, future assessments will be estimated by assuming the present level of per capita assessment. Using this assumption and the population projection ([1]) we arrive at the following projections.

TABLE VII

Year	Population	Total Assessment
1976	4,351	$13,705,650
1978	5,682	17,898,300
1981	7,000	22,050,000

TABLE VIII

Expenditure	1968	Percent	1972	Percent
General Administration	39,184	21.8%	106,673	16.0%
Protection to Person and Property	20,280	11.4%	37,601	5.7%
Public Works	41,265	23.0%	89,820	13.5%
Sanitation	18,428	10.2%	43,522	6.6%
Utilities	14,128	7.9%	8,256	1.2%
Municipal Property	55	.03%	109,137	16.4%
Education	8,585	4.7%	51,001	7.7%
Grants and Subsidies	3,320	1.8%	-	-
Community Center and Recreation	1,569	.9%	27,281	4.1%
Swimming Pool	5,489	3.2%	4,348	.7%
Capital Expenditure out of Revenue	25,962	14.4%	125,924	19.0%
Reserve for Land Bank	-	-	42,476	6.4%
Contingent Reserve for Loan	-	-	18,200	2.7%
Surplus or Deficit	1,742(+)	.7%	-	-
TOTAL	108,007	100.0%	664,239	100.0%

Table VIII lists the expenditures of the Town for the years 1968 and 1972. In 1968, expenditure on municipal property required only .03% of total expenditures. This expenditure was on the airport. In 1972, the expenditure on municipal property was the cost of land development and this amounted to 16.4% of total expenditure. In 1972, capital expenditures required 19% of the total expenditures. This figure is high since, during the year, $82,000 was spent on staff housing. The 1973 budget estimates that capital expenditures will be 9.4% of total expenditure. The 1973 budget estimates a total expenditure of $694,671. Making allowance for the 1972 staffing expenditures, this represents an increase of 14% over the previous years, assuming a similar increase for future years, the estimated 1978 expenditure would be $1,180,000. However, when considering the estimated increased staff requirements the 1978 expenditure would be $1,593,000. This figure would increase to $1,829,000 if the Town borrows its maximum permitted by the guidelines, since there would be debt charges to meet.

In 1969 the revenue to the Town of Inuvik was $180,007 and in 1972 it had increased to $664,239. In 1968 taxation accounted for 10.4% of the total revenue, whereas in 1972 taxation accounted for 21.0% of the total revenue. During this same period the expenditure of grants decreased from 81% to 49% of the total revenue. The increased importance of taxation has placed a financial burden upon the people of Inuvik and the Town can hardly expect an increased proportion from this source. Assuming that taxation remains the same portion of total revenue, and the mill rate remains the same, the estimated revenue in 1978 would be approximately $1,360,266.

It is very difficult to estimate future expenditure and revenue, however, the exercise seems to indicate that the revenues would be adequate if the staff additions were neglected in the analysis. However, if the present financial conditions continue and the increased staff requirements are considered the Town will not find it easy to match expenditures and revenue.

With the expansion of the Town, it is seen that there will be vast amounts of capital expenditures. Thus, it is important to determine the town's borrowing capacity. The Territorial Government has established that the Town's debt should not exceed 20% of total assessment. Using this as a guideline we arrive at the following estimates.

TABLE IX

Year	Assessment	Debt
1973	$10,560,890	$2,112,178
1976	13,705,650	2,741,130
1978	17,898,300	3,579,660
1981	22,050,000	4,410,000

The new guideline that debt should not exceed 20% of total assessment rather than 20% of live assessment, increases the amount that the Town may borrow. But before the Town borrows the amounts listed in Table IX it must examine its ability to repay such debts. If the Town borrows $3,579,660 in 1978 the debt charges would be $399,000. This figure assumes an 8% interest rate and repayment period of 15 years. This debt charge would be approximately 32% of the estimated municipal revenue. It is generally believed that debt charges should not exceed 20% to 25% of municipal revenue.

Thus the Town should be hesitant about borrowing the amount suggested by the foregoing guideline. Even if the Town was able to carry the foregoing debt it falls way short of the capital expenditures that are required to provide the necessary facilities for the growth of the Town. The capital requirements for updating the municipal buildings and equipment have been estimated at $1,238,000. If the Town carried this debt, the debt charges would be 13% of the estimated municipal revenue in 1978. Considering that there is no existing debt, the Town should be able to carry the debt necessary to provide for these facilities. However, the cost of upgrading present roads and utilities and providing new roads and utilities for a population level of 7000 is estimated at $15,655,430. If the Town carries the debt for the municipal buildings and equipment, the finances for the roads and utilities must come from other sources. These other sources should be from those whom derive a benefit from the expansion of the Town, i.e. oil companies that use the Town for their operations, and the people of Canada as a whole.

V. DEFINITION OF RESPONSIBILITIES

GENERAL RECOMMENDATIONS

Previous chapters dealt with the history of the Town, the existing conditions, and the capital projections. The capital projections indicate that there is a major amount of work and expenditure facing the Town, while on the other hand, the projections of revenues, and the borrowing power indicate that only a small portion of these expenditures could be met by municipal resources.

It was also stated previously that the projections dealt only with the basic necessities of existence in Inuvik and they do not touch the range of community amenities; neither do they deal with any significant improvements to the urban environment.

It was also concluded that Inuvik is continuously a "new town" since it never had a long enough time period without growth pressures in which it could consolidate both its physical development and the financial situation. There are strong possibilities that the growth pressures will stay with Inuvik for considerable time to come, and in all possibilities be intensified. If this pressure accelerates then there is no doubt that the entire method of the up to now approach has to undergo drastic change. It should be also accepted that the growth of Inuvik is not only the responsibility of municipality but also of the Government and the petroleum industry, which are both major beneficiaries of this growth and, at the same time, major generators as well.

At this point, providing that the above premise is accepted, the consulting and implementation machinery must be established. While the Town is capable, particularly with the expanding administrative structure, to handle the questions of the direction and implementation of the growth, the Town has no resources with which it could finance this growth. On the other hand, both the Government and industry have much larger economic base, and the financial involvement in development of Inuvik could be considered as a legitimate expenditure related to the operation and the benefits thus obtained.

It would be, therefore, our recommendation that a joint committee be established whose task will be to review and define the physical and financial problems of Inuvik and whose duties as well would be to devise the formula on a base of which the financial resources could be generated. Without this it is doubtful whether the development of the Town could proceed in a manner which would assure the Government and the oil industries of an adequate base of operation.

In addition to creating the necessary conditions in urban facilities which will facilitate the development of this part of Canadian North, there is a question of economic hardship for those permanent citizens of Inuvik, which are without Governmental or major industrial backing. The rapidly rising costs of serviced land and the cost of housing has eliminated considerable segments of Inuvik population from the housing market and it is doubtful whether this could be resolved by greater provision of public housing. As unpopular as this label could be, the development of a "two-price system" could help the permanent residents of the Town in obtaining adequate accommodation. A "two-price system" in terms of housing exists in Inuvik insofar as the governmental and industrial employees are heavily subsidized in their accommodations.

In addition to dealing with pressures of physical and financial aspects of the Town's development we found that environmental and ecological issues are as a rule neglected and the next chapter dealing with the environment and the ecology of Inuvik especially, does shed considerable light on some of the issues which are basic to creating a proper human environment in the Arctic.

UTILITY SYSTEMS

The development of the Town of Inuvik to 7000 or greater populations requires a much clearer definition of responsibility than now exists, regards the utility systems.

The development of land for residential, institutional or commercial purposes requires an interplay between all sectors involved so that the political, financial, legal, technical and physical work involved can each receive proper consideration.

It has become clear that the Town is responsible for planning of subdivisions and in the past two years has taken the lead role in such planning and in extensions of the utilidor system to serve them. These have been relatively minor extensions involving approximately 1/4 million dollars.

The development plans now envisaged will involve approximately $1.6 million and will affect every part of the supply and disposal systems, together with the heating and power plants that form essential auxiliaries to them.

The utility system as developed in Inuvik is unique in Canada. It does not lend itself to separation of responsibility for water and sewer utilities from the supply and distribution of high temperature water, which is used to heat a major segment of the Town, as well, as to act as a protective item for the whole utilidor system.

The technicalities of hot water distribution do not permit it to be divorced from the central heating plant. The skills required for operation and maintenance do not lend themselves to delegation of personnel trained in water and sewer utilities. For this reason it will be most difficult to divorce NCPC and its technical operating staff from the role of operators of the utilidor system.

The minor utilidor extensions recently completed do not contain hot water pipes. Nevertheless the major trunk lines being proposed will include them primarily to protect the utilidor. Branch lines will contain only water and sewer. It is thus not possible to divide responsibility on any basis of area. The system must be considered as one.

The Northwest Territory Government, in response to democratic pressures, is attempting to place control of local affairs, wherever possible. in municipal, political and administrative hands - this is as it should be. The Town administration, however, finds itself given responsibility, but without adequate or clear-cut methods of financing utilities, and without clear-cut procedures for arranging either planning, engineering, construction or management contracts.

NCPC, as a Crown Corporation, is responsible to the Minister of Northern Affairs and operates quite independently of local political pressures and complaints of service. It does not participate in the planning of subdivisions, but it does retain an approval role on purely technical matters.

It is not the intention of this examination to enlarge on the terms of reference under which NCPC does act. These terms of reference are summarized in the "Northern Canada Power Commission Act, Office Consolidation, November 1960".

A brief history and content of the operations of NCPC are as follows: "The original Inuvik heating plant, water plant, utilidor (including heat, water and sewer lines), sewer outfall and sewage lagoon were financed by means of an interest free loan from the Federal Government. On completion the loan was cancelled and costs charged to the Town development. The resulting fixed assets were, by direction from the Auditor General, shown as an asset on NCPC balance sheet.

In 1963-64, 1967-68 and in 1968-69 the utilidor system (heat, water and sewer) extended to serve new areas and these were handled in the same way. Capital NCPC paid out was repaid by the Federal Government.

In 1969 NCPC built an extension to the water and sewer system only. Construction took the form of a plywood box on a gravel pad. Costs of about $50,000 were recovered from the Northwest Territories Government.

In 1970 NCPC built about 3500 feet of water and sewer service for about $250,000. Again costs were recovered from the Northwest Territories Government.

In 1971 the water and sewer lines were extended 6800 feet as well as rebuilt the old DIAND econodor - total value about $385,000 - paid by Northwest Territories Government.

In 1972 - Federal Department of Public Works extended water, sewer and heat lines in Block 45 to serve their 24-unit apartment. All costs paid by Department of Public Works.

A summer water line from Lake B (Northeast Lake) has just been completed to Hidden Lake in Inuvik as have additional filters and one 100,000 gallon wood stave water storage tank. Funds for this work was supplied by the Northwest Territories Government.

Present Inuvik rate for water and sewerage services is $10 per month per residential unit or for 10,000 gallons of water where metered.

Annual revenue from water and sewer approaches $110,000 per year which approximately covers our costs (which do not include any repayment of capital nor interest thereon).

Approximately 80% of the revenue comes from Government accounts (25% Northwest Territories Government; 55% Federal Government), and almost one half of these charges are for Government residential servi...

About 1/3 of the non-Government revenue comes from some 65 residential housing units; the balance is from stores, shops and apartment blocks."

This outline is important on two major points:

1. The cost of the basic system is carried on the books of NCPC as a capital asset. This indicates ownership.

2. The rates charged for services are only sufficient to recover operating costs without including repayment of capital or interest.

There is no financial procedure wherein the Town can recover the capital costs of the major utilities' expenditures. It has been recommended to the Town that they finance extensions through the sale of land. Estimates show that a 60' x 100' lot, serviced with only a water and sewer utility and a roadway, will have to sell in the range of $10,000 and this pays only for the roads and the lateral utilidor and not for the supply and disposal system, nor the major trunks. Politically the sale of land at this price is not acceptable.

The foregoing indicates the magnitude and complexity of the problem. There are four Governmental bodies involved:

1. The Federal Government through the Department of Indian Affairs and Northern Development.

2. Northern Canada Power Commission as a Crown Corporation.

3. The Northwest Territories Government.

4. The Town of Inuvik.

The solution to the problems of responsibility cannot be arrived at without participation of all four parties.

We recommend that a technical group, representing the above, meet at the earliest convenient time to further define the problem and recommend acceptable solutions. This would be followed by a meeting at the policy level of the four participants to work out the Terms of an Agreement.

VI. ENVIRONMENTAL IMPLICATIONS OF NEW DEVELOPMENT

The purpose of the following dissertation is to enquire into the environmental questions relevant to the proposed expansion of Inuvik toward the north of the present townsite. The primary objective of this inquiry is to examine available construction materials and methods so as to make a contribution toward a plan of environment protection and quality living.

SITE CONDITIONS

It was realized some years ago that "because of the variable soil and permafrost conditions at Inuvik, every precaution would have to be taken to prevent thawing of the underlying permafrost, or at least to keep thawing to an absolute minimum" [1]. Work at Inuvik, and elsewhere, has demonstrated beyond doubt that where high ice content soils are encountered, the preceding statement can no longer be taken as an enunciation of policy to be followed where expedient, but is tantamount to a natural law where construction activities are concerned. Numerous problems in, and in the vicinity of Inuvik have evidenced the lack of exceptions.

The townsite of Inuvik was chosen in 1954, as the administrative center for the Mackenzie Delta and the western Arctic, primarily for its soil characteristics. It is located adjacent to the east arm of the Mackenzie Delta, on a gently undulating terrace bounded on the south by Boot Lake, Duck Lake, Twin Lakes, the east channel of the Mackenzie Delta, and adjacent boggy ground. Its approximate northerwestern boundary is a shallow swale, which will be traversed by the new development, and the northeast limit is formed by steeper slopes of hummocky hills and ridges. Subsurface materials throughout most of the developed area are composed of brown gravels containing small quantities of sand or silt, under approximately two feet of black or brown peat [2].

Spruce and birch trees grow to over 15 feet in height when associated with gravels overlain by two feet or less of peat. In these areas, the active layer is normally about four feet deep. Their growth is reduced, such that heights range from 5 feet to 15 feet on gravels overlain by two to four feet of peat or on fine grained soils of well drained sites, where massive ice is often present beneath an active layer of only one or two feet. In the isolated pockets of greater than four feet of peat over gravel, where the active layer is less than a foot in depth, trees are stunted to two to five feet in height, or are absent entirely [2]. Birch predominates on south facing slopes or in other areas which still have an active layer a foot or two deep. Similarly, dense thickets of willow and alder grow along stream courses or adjacent to small lakes where thaw zones resulting from standing water have made for saturated, deeply thawed, soils in summer. Few trees or large shrubs grow on the low, flat peaty areas where massive ice remains within a foot of the surface year round. The ground throughout the Inuvik area is generally hummocky, extremely so over soils in which ice content is high. Labrador tea and sphagnum mosses predominate beneath the denser stands of spruce; grasses seem to be the major form of vegetation beneath roses and other shrubs in the south facing birch stands (which, where slope is not excessive, are the only local areas which appear to be suited to agriculture); reindeer lichens with some mosses, berry plants and ground birch appear to predominate under open forests of stunted birch and spruce; and tussocks of sedge or cotton grade predominate on the broken and heaved soils of open, sparsely treed or treeless areas of frozen silty soil.

As indicated, development to date has occurred primarily in areas where gravels are within four feet of the surface. A few deep peaty areas have been encountered, now evidenced by such problem spots as the polygonal cracking which occurs beneath the West Hostel. Fine grained soils underly much of the townsite at depth, beneath the gravel layers. However, in the isolated areas where fine grained soils are near the surface, they have been, either by design or fortune, avoided until this last summer (1973). In this instance, the sloppy ground produced during utilidor construction was worsened during the installation of the NCPC pole line to the point of making parts of the site virtually inaccessible. This can be regarded as indicative of the sensitivity, to relatively minor activity, of soils adjacent to Inuvik on the north. It is fortunate that ground slope in the area is negligible. Soil subsidence (with much of the vegetative cover intact) seems to have reached an equilibrium rather than producing the kind of devastation evident where water can flow away, removing the silt and constantly baring a new soil-ice interface to solar radiation, or where evaporation from bare, dark soil can remove the water of melting ice and create great depressions on level ground.

The area proposed for townsite expansion is almost entirely one of fine clays and silts immediately beneath an organic layer less than a foot thick (2, 3, 4). This "upper flat" has abundant lenses of ice with silt inclusions beginning within a couple of feet of the surface and extending to considerable depth. Ice content may be as great at 60% but averages 5% to 20% [4]. Construction in this area obviously cannot go on by the same rules as have been followed in the present townsite (where massive ice is normally not encountered until 12 or 15 feet with exceptions never shallower than three feet. The potential for thermal erosion in the new area, particularly wherever construction is to be on even slightly sloping land, is extreme.

A great deal of recent effort has been put into permafrost research, and much of this is dealt with in the publication "Annotated Bibliography of Permafrost - Vegetation - Wildlife - Land Form Relationships" by Dr. Patricia Roberts-Pichette, available from the Forest Management Institute, Ottawa, Ontario as Information Report FMR-X-43(1972). Two of her notes, from major contributors to this literature, are quoted in part as follows:

Black, R. F. 1954. Permafrost. A Review. Geological Society of American Bulletins 65:839-856.

> "Permafrost results when the net heat balance of the surface of the earth over a period of several years produces a temperature continuously below 0°C . . . Freezing of the mantle completely eliminates ground water movement, preserves organic remains indefinitely, reduces or prevents

mass movements within the frozen material, and promotes frost action in the overlying active layer."

Genesis: "Although the general thesis [of the genesis of permafrost, whether fossil or formed recently,] is relatively simple, it is extremely complex in detail. Some of the primary factors in the heat exchange are 1) climatic - solar radiation, atmospheric radiation, counter-radiation, air temperatures, wind, humidity, cloudiness and precipitation; 2) chemical and physical characteristics of the ground - distribution, types, and textures of material, heat capacities, thermal conductivities, thermal diffusivities, and horizontal and vertical gradients, and 3) the changing interface between the ground and atmosphere - the active layer, surface water, snow, vegetation, and their albedo (reflectivity). The factors in (3) commonly are more important than the others in the heat exchange . . . Areas in which the average annual air temperature is several degrees below 0°C may be free of permafrost; conversely, areas with average annual air temperatures above 0°C may contain sporadic permafrost in equilibrium with the climate (Muller, 1952). These conditions can be brought about by the fact that a thick, dry active layer covered with dry mosses and very thick, light snow provides excellent insulation, conversely, a thin, wet, active layer with little or no vegetation and with thin, dense snow, freezes quickly and becomes an excellent conductor. The interface changes markedly from low to high altitude and latitude and so do the winter climatic factors . . .

Geologic Significance: "The active layer is commonly supersaturated, so that mass movements, frost heaving, frost thrusting, frost stirring and frost splitting are commonplace. Patterned ground, involutions, solifluction phenomena, block fields and other micro-features result . . .

"Thawing of permafrost containing much ice commonly result in pits, ponds, and lakes on level ground and slumps and earthflows on sloping grounds."

Brown, R. J. E. and G. H. Johnston. 1964. Permafrost and related engineering problems. Endeavour 23(89):66-72.

The most important features of permafrost with engineering construction significance are given as:

(a) The great sensitivity of permafrost to thermal changes,

(b) The relative impermeability of permafrost to moisture,

(c) The high ice content of fine grained and organic soils containing permafrost.

Various suggestions are given for conserving the frozen condition.

"The thickness of permafrost . . . is determined by the close and complex interaction of a large number of climatic and terrain factors, the most important of which are air temperature, relief (slope and aspect), vegetation, drainage, snow cover and soil type." The factors which affect permafrost also determine the thickness of the active layer.

There is a relationship between mean annual air and mean annual ground temperatures, with mean annual air temperature being about 2°C to 5°C less than the mean annual ground temperature and averaging about 3°C less. e.g., Resolute, Northwest Territories (continuous zone) mean annual air temperature is -16.1°C and mean annual ground temperature is -12.8°C; Thompson, Manitoba (discontinuous zone) mean annual air temperature is -4°C and mean annual ground temperature is 0.5°C.

"Over a long period of time a change in mean annual air temperature can result in a significant change in the extent and thickness of permafrost. Geothermal gradients from about 1°C per 20 m to 1°C per 60 m - depending to some degree on the type of soil or rock - have been observed. A change of 1°C in mean annual air temperature could result, over a long period of time, in a change of 1°C in the mean annual ground temperature. This would cause a change in permafrost thickness of approximately 20 m to 160 m [[sic]]."

Relief: In the discontinuous zone, south-facing slopes usually have no permafrost while it is present on north-facing slopes; in the continuous zone it appears thicker and the active layer thinner on north-facing slopes.

Vegetation provides "resistance to heat flow by conduction. By transpiration, it draws water from the soil, which is thus depleted of heat held by water. Furthermore, the process of evaporation (including that due to transpiration) withdraws heat from the surrounding atmosphere and from incident solar radiation. In the present context, mosses and lichens are particularly significant. Mosses are strongly hygroscopic, but can lose moisture rapidly and in large quantities. Lichens, however, have very dry surfaces at all times, even when the lower layers near the soil are very wet; possibly they protect the soil against heat gain more by an insulating process than by one of evaporative cooling [[Lichens are also light in colour; they have a high albedo]]. It is possible, however, that rapid evaporation or diffusion exchange of water vapor from the wet basal layer to the atmosphere above the lichen may contribute to low soil temperatures and a high permafrost table. The underlying peat formed from the accumulation of decomposed vegetation, also influences the heat transfer between the atmosphere and the soil beneath.

[[It has been noted by Russian authors, and on the Mackenzie Delta, that revegetation after disturbance, or careful removal of spruce trees growing over reindeer lichens, can result in quite rapid permafrost aggradation accompanied by increase in ground elevation - D. Gill, personal comment]]

"Snow Cover influences heat transfer between the air and the ground and hence affects the distribution of permafrost. The snow-fall regime and the time that snow lies on the ground are critical factors. A heavy fall of snow in autumn and early winter will inhibit winter frost penetration and the formation of permafrost. On the other hand, a thick snow cover that persists on the ground in spring will delay thawing of the underlying frozen ground."

"In the southern fringe most permafrost is confined to peat bogs. The thermal properties of the peat are to a great extent responsible for its formation in this type of terrain and changes in the extent of permafrost is also largely dependent on changes in the thermal properties of the peat. The mechanisms which caused the formation of permafrost in these bogs are associated with variations in the heat exchange at the surface of the moss and peat. When dry, peat has a low thermal conductivity equal to that of snow (i.e. about 0.00017 cal/cm°C/sec). Peat can absorb large quantities of water; when wet, its thermal conductivity is greatly increased. Unsaturated peat has a conductivity of about 0.0007 cal/cm°C/sec . . . When frozen, its thermal conductivity is many times that of dry peat and approaches the value for ice; saturated frozen peat has a conductivity of about 0.0056 cal/cm°C/sec. During the summer, a thin surface layer of dry peat having a low thermal conductivity prevents warming of the underlying soil. During the cold part of the year, the peat is saturated from the surface, and when it freezes, its thermal conductivity greatly increases. Because of this, the amount of heat transferred in winter from the ground to the atmosphere through the frozen ice-saturated peat is greater than the amount transmitted in the opposite direction in summer through the layer of dry peat and underlying wet peat. A considerable quantity of heat is also used during the warm period to melt the ice and to warm and evaporate the water. The net result is a loss of heat, and conditions conducive to the formation of permafrost.

"This thermal mechanism does not cause the permafrost to increase in thickness indefinitely. Rather, a quasi-equilibrium is reached whereby the downward frost penetration is balanced by heat transfer from the unfrozen ground below. The thermal sensitivity of this permafrost is vividly demonstrated by its rapid thawing when the overlying moss and peat layers are removed."

This applies to the southern fringe. "Further north the thermal properties of peat and other terrain feature assume a relatively minor role and the thermal properties of the ground as a whole, together with climate, become dominant. Variations in thermal properties such as conductivity, diffusivity, and specific heat affect the rate of permafrost accumulation. For example, the thermal-conductivity of silt is about one-half that of coarse grained soils and several times that of rock. Variation in thermal properties alone will not, however, necessarily result in differences in permafrost thickness within a particular area . . .

[[[illegible] an area within which relationships described in the preceding two paragraphs are of approximately equal significance.]]

"Three features of permafrost are significant in engineering construction: 1) Permafrost is particularly sensitive to thermal change. Any natural or man-made change in the environmental conditions, however slight, will greatly affect the delicate natural thermal equilibrium. 2) Permafrost is relatively impermeable to moisture. Drainage is vital, therefore, because all movement of water occurs above the permafrost, in northern areas, surface water is conspicuous despite the generally low precipitation. If natural drainage is impeded or proper drainage structures not provided, construction operations can be seriously complicated by intensified frost action during the winter and accelerated thawing during the summer. 3) The ice content of the frozen ground is a most important consideration. Solid rock, gravel and sand, usually contain little or no ice at temperatures below 0°C and few difficulties are encountered in building on these materials. Most problems arise with fine-grained materials and organic materials such as peat, which usually have extremely high ice [illegible] susceptible to frost action. As long as water remains frozen in such soils, the ice binds the individual particles together to produce a material of considerable strength; when thawed, however, these soils change to a soft slurry with little or no strength. All forms of ice layers or lenses, ranging from hairline sizes to several meters in thickness - can occur within the same material. In silty soils, for example, the volume of ice may be as much as six times that of soil . . ."

DISCUSSION

Accepting for the moment that development within the area proposed is feasible - that the project is possible at all within the limits of current technology, and that measures necessary to work within environmental constraints do not make the economics of such a project prohibitive - the alternatives of high density multiple family dwelling within the boundaries of the present townsite, or construction of a satellite townsite for industry on the gravelly soil in the vicinity of Long Lake, will not be discussed beyond this statement of their existence.

There are [illegible] objectives which are normal, although seldom stated, in northern townsite development. These are:

1. Permanency in a region where environmental conditions fluctuate violently.

2. [illegible] residents, so they can perform their appointed tasks without devoting major attention to survival.

3. Surroundings, either natural or man-made, which are sufficiently pleasing and varied such that permanent residency is encouraged.

All three of these considerations must be taken into account at the inception of new development, as repair or modification after the fact are extremely difficult and expensive, or impossible within normal time constraints. Therefore, this discussion will emphasis techniques of construction. The environment of the [illegible] tundra does not allow for the spectrum of alternatives available in more moderate climate.

The overriding concern in the proposed expansion, one which has been stated numerous times in the past, is that the permafrost be protected. It has been most fortunate, in the early stages of Inuvik development, that consequences of experimentation and expected mistakes have been minimal because of the soil types for which the site was chosen. It would be folly indeed, as can be deduced from the material presented in the foregoing section, to expect a similar degree of environmental resilience in the area adjacent to Inuvik on the north.

The science or art associated with study and control of environmental damage and terrain degradation is rapidly developing in the wake of advances made in the related sciences of engineering technology and ecological research. It is receiving additional impetus with the awakening of other individuals in the fields of land use and development to the fact that tremendous costs can often be averted by relatively minor investments in reconnaissance, thoughtful site and route selections, and in consideration of the effects of such massive natural forces as are associated with water and temperature in an Arctic environment. Unlike the conditions met in southern climes, where man has been able to, by force, beat nature as an adversary, environmental conditions in the North necessitate passive construction within the constraints of terrain, soils, drainage, exposure and vegetation. In most cases where severe environmental damage has resulted from permafrost degradation, it has been due to excessive removal of the vegetative mat to expose peaty soils of low [illegible] or due to disruption of drainage resulting in channelling or ponding of runoff water. The practice of removing the vegetative mat has ceased, except for the odd case caused primarily by ignorance or carelessness [5]. Preservation of natural drainage patterns is more difficult. These two subjects will be dealt with in the order in which they have been presented, by the use of quotations selected as representative of the literature and supplemented by personal observations following:

Maintenance of Subgrade

From Brown, R. J. E. 1970. Permafrost in Canada. University of Toronto Press Page 234 - Remarking on road construction northwest of Whitehorse:

> Roads - "The most difficult construction problems caused by permafrost were encountered northwest of Whitehorse. During the initial construction engineers with no previous experience in permafrost areas tried to ditch a considerable stretch of the highway and encountered difficulties. In some places the road sank 10 to 15 feet as the permafrost was thawed by heat penetration through the ditches. The permafrost table lay only one or two feet beneath the ground surface in the undisturbed areas and the right-of-way was easy to clear because of the shallow tree roots. After clearing, the topsoil was stripped and attempts were made to grade the road. As fast as the insulating vegetation cover was removed, the ground thawed, creating a morass that became worse the more it was worked. As a remedy, the vegetation was left in place and a layer of brush and timbers four to five feet thick was added. Gravel fill was then placed on top by end dumping."
>
> Air Fields - "In the late 1940's an attempt was made to construct a strip at Aklavik in the Mackenzie River Delta, where adverse soils and permafrost conditions exist. A bulldozer was used to strip the vegetation and thaw soil down to the permafrost table. In a very short time, the perennially frozen, ice laden silts thawed, turning the stripped area into a quagmire . . . This area was never used as an airfield and the initial mistake of stripping the surface could only have been rectified by placing a tremendous quantity of coarse grained soil over the area and allowing the permafrost regime to be re-established . . .
>
> "At the Town of Inuvik . . . a special design was used for the air strip . . . The trees were cut by hand and laid on the ground after which a minimum of eight feet of crushed dolomitic limestone fill from a nearby quarry was placed on the undisturbed ground surface. Temperature measurements in and beneath the fill 10 years after construction reveal that the permafrost was aggraded to the original ground surface and even into the fill. No difficulties attributable to permafrost or any other cause have been encountered and the air strip has performed and is in excellent condition."

From Brown, R. J. E. and G. H. Johnston. 1964. Permafrost and related engineering problems. Endeavour 23(89):66-72. - From Dr. Roberts-Pichette's summary:

> Ventilation or insulation is needed to preserve the frozen condition on the fine-grained ice-rich materials. On suitable sites, buildings may be put on stilts to give sufficient ventilation. Normally highways, air strips and railways need insulation. "Normally fill methods are used throughout and disturbance of the surface cover is kept to a minimum."

A combination of these techniques has been used for the hangar at the Inuvik Airport: U-shaped ventilation pipes, open in winter and closed to provide a dead air space in summer, were placed, and then approximately five feet or so of crushed rock fill was dumped over them. On top of this is the concrete foundation and floor of the hangar. This technique has worked admirably well.

Russian authors Porkhaev and Sadovskii (1959) in (5) state that they have found retention of the surface vegetation to be advantageous beneath grade of permanent roads [equally applicable to berms, foundations and other fill areas]:

> "The preservation of vegetation in the foundation of the embankment is imperative when constructing according to the method of preserving a frozen subgrade. While improving the thermal insulation properties of the embankment foundation, vegetation also interferes with the penetration of fines into the body of an embankment made of coarse material. In addition, the presence of vegetation under an embankment reduces heaving. Thus, according to the data of K. M. Krasnov (1944), a road with permafrost in its subgrade constructed in Kolyma in 1937 over a hillocky area (cemetery mounds) was subjected to exclusively [sic] strong heaving in those stretches where the vegetation layer had been removed and the cemetery mounds levelled. Heaving was less intense in areas where the cementery mounds were preserved, even though the vegetation had been removed, and there was no heaving at all in those stretches of the road where the mounds were left untouched and the vegetation was not removed."

From Brown R. J. E. and G. H. Johnston. 1964. Permafrost and related engineering problems. Endeavor 23(89):66-72. - Remarking on engineering considerations:

> "Perennial freezing can be neglected when engineering works are sited on well-drained, coarse-grained soils or bedrock . . ."

From Reference ? :

> "The maximum observed depths of thaw experienced at Inuvik just 3 years after occupation are . . . approximately 5 feet in areas stripped of moss and underlain by fine-grained soils; and 8 feet in areas stripped of moss and underlain by coarse-grained soils."

Gravel pit operations at Ya Ya Lakes on Richards Island north of Inuvik rely on natural conditions to produce permafrost regression after surface stripping; the thin ice coatings on individual particules bind them into such a matrix that any other method of extraction would be economically prohibitive, but by the technique used approximately three or four feet of material is freed each season.

Oil rigs on deltaic soils of the northern Delta flood plains use approximately two to five feet of gravel fill on a site prepared by first stripping off and stockpiling the peaty surface layer (this to be used in site repair after withdrawal and removal of the gravel pad). The drilling rig itself is set on piles driven through the gravel pad and frozen into permafrost. This technique of maintenance of the frozen condition of the site soils seems to be satisfactory. Where minor subsidence occurs, regrading by filling the depressions with gravel seems to be adequate to halt the process.

In the Inuvik airfield area, peaty soils to eight feet in depth contain abundant ice. These have been adequately protected by placement of approximately five to eight feet of crushed rock fill over a base in which as much organic material as possible has been retained. (The air strip itself, for which specifications were somewhat more severe, received the greater quantity of fill and is discussed in a quotation from R. J. E. Brown given earlier in this report.) The airport buildings, with the exception of the hangar mentioned earlier, are placed on piles extending into the permafrost through the gravel pad. Although the ice content of soils in this area is high, and the site is on a gradual slope with the buildings across the high side, no problems, to the authors knowledge, have been encountered to date.

Maintenance of Drainage

There does not appear to be any readily available literature dealing with proven solutions to maintenance of natural drainage over frozen soils for such massive projects as that under consideration at Inuvik. However, the literature is full of references to the sort of environmental devastation which can occur when such measures are overlooked. For permanent highway crossings, frequent, large and often paired (in a side by side or staggered configuration) culverts are used for small creeks and lesser flows, with an adequate area rip-rapped or otherwise protected both upstream and downstream to gather and redistribute the water. For intermittent flows, the difficulty in determining drainage patterns and therefore the proper placement and frequency of culverts during road reconnaissance and construction has set the scene for numerous failures. The results of insufficient allowance for adequate drainage, particularly for those patterns which exist through and obscured by mosses, heaths and sedges rather than in recognizable channels, have often been so severe as to necessitate complete rerouting and reconstruction of roads.

The foregoing remarks apply specifically to simply traverses of territory, and operations of a larger scale in areas of high ice content permafrost will generally require techniques of a more passive nature than culverts. The Inuvik airport is a case in point, where the porocity of the fill materials and underlying vegetation, particularly in the form of felled trees, is sufficient to permit uninterrupted natural seepage. However, no major flows were encountered in this instance.

SUMMARY OF DISCUSSION

From the foregoing, there are several points readily apparent:

1. The maintenance of permafrost, as it exists in the southern tundra, is dependent to a great degree upon the four inches or so of living organic material at the ground surface; the importance of this layer is increased where underlying organic soils are absent or very thin.

2. The living organic layer in tundra plant communities is extremely fragile; it can be destroyed by even slight disturbances.

3. A particularly unstalbe situation exists where a thin organic layer is immediately underlain by clay or silt soils with characteristically high ice content.

4. Where the surface is disturbed over high ice content soils depth of thaw can be increased from the normal one foot to about five feet in depth and even on level ground, subsidence resulting from water loss through evaporation can produce rather massive depressions.

5. Where any sort of intense human activity is contemplated over high ice content permafrost soils, measures must be taken to ensure soil stability, or environmental reaction will rapidly result in conditions which prohibit such activity.

6. As the living organic layer will be destroyed as a result of any intensive activity, even repeated foot traffic, and as natural insulative materials either involve the entrainment of air in dry vegetation or between particles in unconsolidated sediments, or involve the low thermal conductivity of consolidated sediments, the solution to the problem of permafrost preservation is clear: to replace with a sufficient volume of fill, any passive (insulative) or dynamic qualities lost by crushing of the organic layer.

7. The thermal properties of peat are attractive, but the surface this presents is of inadequate strength; the thermal properties of silts and clays are attractive but use of these materials, because of their impermeability to water, invites the problems consequent to drainage disruption; therefore the use of relatively clean, coarse gravels or crushed rock over a layer of vegetation (with relative thicknesses of vegetation and mineral fills determined by insulation and strength considerations), and capped, only infrequently and where absolutely necessary, with an impervious surface, would appear to be the reasonable approach (excluding the use of styrofoam except for restricted operations, because of its expense).

8. Arctic vegetation may not be as nonrenewable a resource as Arctic soils are within our scale of time, but as far as their use as an insulative layer beneath fill is concerned, they are a resource of great value and short supply. Therefore, they should be conserved with the utmost care. It might also prove economical to import barge loads of wood chips from mill operations on the upper river, as chips are high in insulative value similar to unprepared local vegetation and they may be less expensive than the much greater quantity of granular fills required to produce an insulative blanket of equal quality. Chips would still, of course, have to be covered by a layer of gravel or crushed rock, particularly where foundation strength is a requirement.

9. Disruption of the natural drainage pattern, except possibly in the most minor and temporary sense, cannot be tolerated; as any unnatural channeling or ponding over high ice content permafrost soils will produce an unstable situation because of its thermal properties and erosive capacity of water.

CONCLUSION

In statements and discussion of statements relavent to the choice of a construction policy for the proposed Inuvik townsite expansion, the field has been steadily narrowed to the following:

1. For site stability, all areas which will be subject to anything more than infrequent, light foot traffic will be insulated with approximately five feet of crushed rock; the ground surface and natural ground vegetation prior to placement of fill by end dumping will be disturbed as little as possible; trees will be felled by hand and left in place or used as cordury beneath the road grades; and fill will be placed with some very coarse material will be present in the deepest layer, particularly in low areas which may collect or channel runoff water. Where major runoff channels occur, as across the northwest of the present townsite - if the area cannot be avoided completely - the majority of the water should be able to flow across the top of the gravel pad on a prepared, rip-rapped channel. No ponding of water on the upstream side can be permitted. No ditching into the permafrost can be permitted. Building foundations must be adequately ventillated. Roads or other areas beneath which fill may eventually become compacted should be oriented as much as possible at right angles to the slope of the land rather than across it. Adequate recreational facilities and areas of aesthetic attraction should be provided on the gravel pad such that, as is the case with resource extraction operations in the North, human activity over the surrounding tundra is discouraged. In areas within the townsite where very little traffic is expected, a blanket of wood chips placed as a lift within granular fill, or perhaps (subject to investigation) by itself, is a possibility to be considered.

LITERATURE CITED

1. Johnston, G. H. 1963. Pile construction in permafrost. In Section IX - Earthwork and Foundation Engineering. In Proceedings of the Permafrost International Conference (November, 1963). National Academy of Sciences, National Research Council Publication No. 1287. Washington, D.C.

2. Pihlainen, J. A. 1962. Inuvik, N.W.T., Engineering Site Information. National Research Council, Division of Building Research. Technical Paper No. 135.

3. (a) Test Pits Excavated by Department of Transport

TP-91 (DOT-2)
TP-92 (DOT-3)

Logs of test pits are available from the following source:

Department of Transport Air Services Branch - Construction Division
Plan Profile: Aklavik, Northwest Territories Soil Survey of Possible Town Airport
Scale 1"-200'
Survey or plotted by Department of Transport. Drawn by J. H.
Date - 30. August 1955.
Edmonton District Drawing No. Aklavik 16.

(b) Bore Holes Drilled by National Research Council

1B - 16

Logs and laboratory test results of the bore holes available from the following source:

Project P - 174, Inuvik, N.W.T.
From 6.8.59. to 16.9.59.
Building in the North Forms No. N-2
Borings by N.R.S. Plotted by G. H. J.
Northern Research Station, Norman Wells, N.W.T. Canada

(c) Test Pits Excavated by Development Engineering Branch of Department of Public Works.

DE - 10
DE - 11
65 - 1
65 - 5
65 - 6

Logs and laboratory tests results of the test pits available from the following source:

District Engineer's Office
Development Engineering Branch - Department of Public Works
File No. 94 - 0 - 9
September 1964. Edmonton - Alberta

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