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SETTLEMENT PLANNING IN THE ARCTIC

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CHAPTER I

INTRODUCTION

The geographical area of concern in this study is the Canadian Arctic. For the purpose of this study, the term "Arctic" will be used to refer to that portion of the northern hemisphere where no significant tree cover exists. The southern limit of this area approximately coincides with the 50°F isotherm for the warmest month and is illustrated at Figure I.

Despite the recent rapid advances in education, communication, and transportation, the average Canadian has only a vague idea of the size of the territory of the Canadian Arctic and relative locations of northern settlements, much less an appreciation of Canada's position on the globe and her spatial relationship with other countries. There are at least two main reasons for this; one historical and political, the other cartographic. The first is the strong east-west emphasis in the development of Canadian settlement, primarily astride the transcontinental railway lines. This relatively narrow band of settlement contains most of Canada's population and therefore is best known to the average citizen. The second reason is the type of map commonly used for study and reference - the standard Mercator Projection. The mercator map treats the world as an unrolled cylinder centred on the equator with the northern and southern areas of the world severely stretched out of proportion. Only a polar projection, (see Figure I), gives a true perspective of Canada's position in world geography. As most people are unaccustomed to using such a map, it seems strange and unreal with either North America or Eurasia appearing upside down.

Regardless of how strange or confusing it may seem that is the special relationship of the Arctic region. A few statistics will emphasize some of the significant facts which follow from Canada's northerly setting. The northermost tip of Canada, Cape Columbia on Ellesmere Island, is only a little more than 1,000 miles directly across the pole from Severnaya Zemlya in the Soviet Union, and less from Franz Josef Land, the northern extremes of the Soviet Union. Cape Columbia is 1,750 miles from Churchill, Manitoba, and 2,600 from Ottawa, Ontario. Resolute Bay, in the centre of the Canadian Arctic Archipelago, is only 900 miles farther from Moscow than it is from Ottawa. The relationships within Canada itself can be pointed up by two facts. First, of the 3.8 million

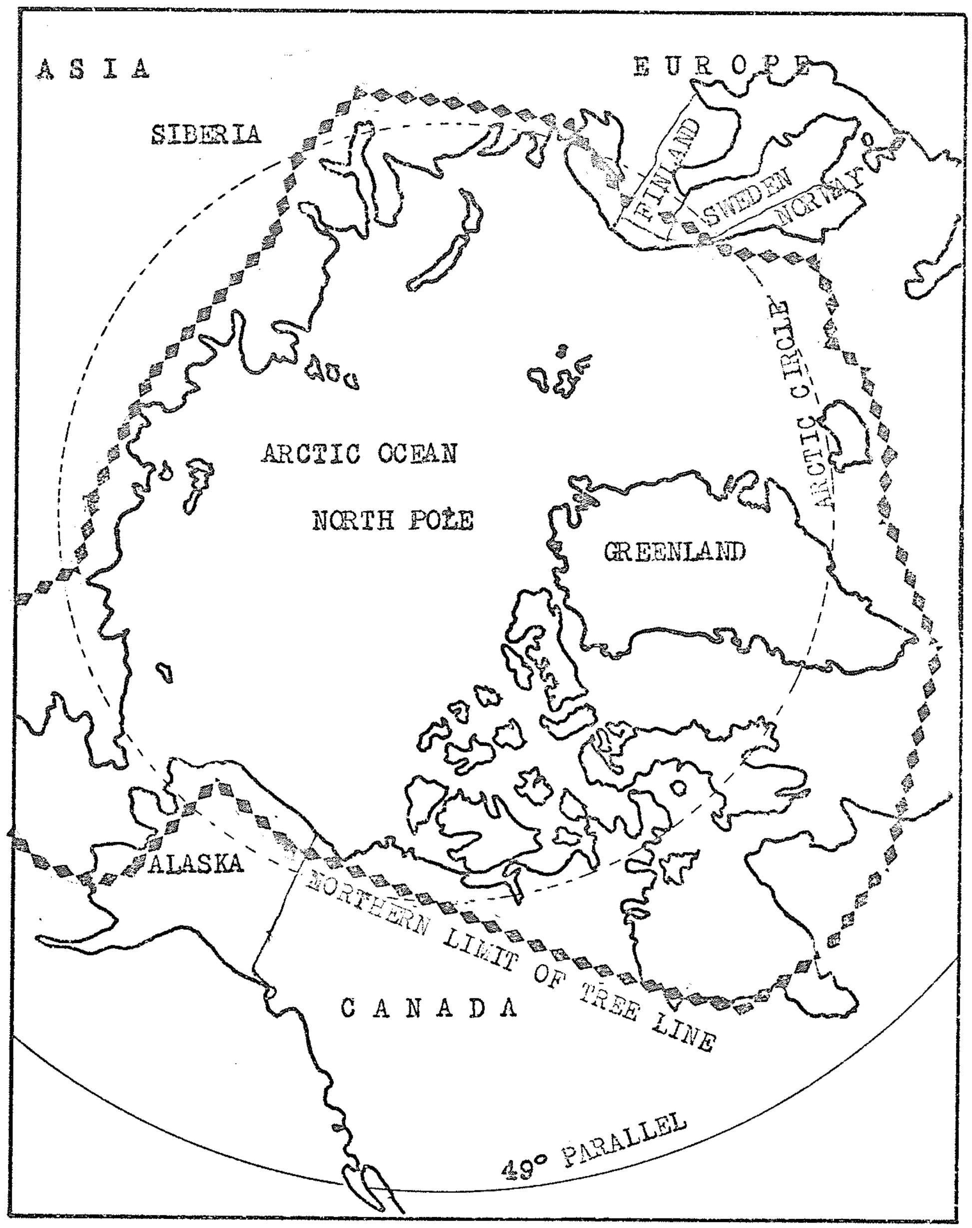

Figure 1

THE ARCTIC REGION

square miles of land and water that make up the area of the country, over one million are in the Canadian Arctic while less than a quarter of the total area of Canada can be said to lie within the southern belt of continuous settlement. Secondly, the geographical centre of Canada lies near Chesterfield Inlet some 250 miles north of Churchill, Manitoba.

Canada, then, is unquestionably an Arctic nation, and must consider the implications of this geographic position. The implications were not very great as little as twenty or thirty years ago because the difficulties of Arctic travel made the "fiction" of the Mercator map seem like a reality. The more than two million square miles of bush, tundra, and frozen sea that separate southern Canada from Eurasia formed so restrictive a barrier that the two continents were effectively isolated by the Arctic. With the development of long range aircraft and stronger ice breaking cargo vessels the distances have now shrunk to their true proportions and the implications of Canada's position in Arctic development have become considerable.

The Arctic region is a land of contrasts and extremes which create many problems for the people who inhabit this area. The harsh natural environment, coupled with the vast empty spaces, and the rapid man-made changes which have occurred due to settlement growth, are some of the factors influencing the extremes to be found in the Arctic region.

Until recent years there was little concern with Arctic settlement development or with the living conditions of the residents. This is rapidly changing with recent trends in public values and the development of governmental policies that strive to provide for all residents to share fairly in the national wealth. With increasing interest and activity in the Arctic by both private and governmental agencies, the problem of settlement development has become one of the most pressing problems in this vast Arctic region. The relatively uncontrolled and haphazard growth of some of the Canadian Arctic settlements has shown that expansion must be more rigorously controlled or future development and settlement habitability will unduly suffer.

This study is concerned with an analysis of the environment and current construction technology and for the purpose of examining the planning of settlement development in the Arctic. This study will also present settlement concepts developed for a comprehensive planning approach that is more in tune with the Arctic environment and current construction technology. By applying these settlement concepts it is hoped that greater benefits can be obtained from Arctic resources, and that improved settlement habitability and human amenity can be provided for those who reside in these Arctic settlements.

To provide background data, the requirement for Arctic settlement is discussed in Chapter II and the Arctic environment and its effect on settlement planning is set out in Chapter III. With this background information concerning the Arctic, Chapter IV details the settlement planning concepts appropriate to the Arctic environment and the permanent and non-permanent Arctic settlement. The application of these concepts along with current construction technology is elaborated upon in Chapter V along with some conceptual settlement plans to illustrate how a comprehensive planning approach could improve the habitability of Arctic settlements.

CHAPTER II

IS SETTLEMENT PLANNING REQUIRED IN THE ARCTIC?

Present Situation

Several world nations have land which stretches north of the tree line; Soviet Union, United States (Alaska), Denmark (Greenland), Finland, Norway, Sweden, and Canada. All have attempted settlement to some degree for natural resource development, administration of indigenous people, and for scientific and defense installations.

The Soviet Union has developed several Arctic settlements based primarily on resource development. Four cities north of the Arctic Circle have greater than 50,000 population while many more range between 5,000 - 20,000. The largest Arctic centre is Murmansk, famous as the Arctic port through which Allied aid flowed during World War II, has a present population in excess of 300,000.[1] The fastest growing city is the mineral based centre of Norilsk located at the same latitude as Cambridge

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[1]Luman H. Lang (ed.), The 1970 World Almanac (New York: Newspaper Enterprise Association, 1970), p. 576.

Bay and Tuktoyaktuk. Norilsk, through forced growth resulting from the establishment of a penal camp, grew from a trading post settlement in 1940 to a city of 130,000[2] by 1966 based on the mining of copper, nickel, gold, cobalt, and coal resources.

Alaskan development has not been overly significant because its major cities of Anchorage and Fairbanks with a population of 45,000 and 15,000 respectively,[3] are not located within the Arctic region. Several native, scientific, and military settlements have developed near or north of the Arctic Circle. The main ones are Nome with a population of 2,500, Point Barrow with 1,500 people, and Wainwright with 500.[4] Defence installations have contributed greatly to Alaskan development especially since 1940 with the construction of the North-west Highway System from Dawson Creek, B.C. to Fairbanks, Alaska and the staging route airfields throughout Alaska. The establishment of the Distant Early Warning Line (DEW Line) and Ballistic Missile Early Warning System (BMEWS) (both radar chains spanning the north arctic coast), greatly

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[2]Ibid., p. 576.

[3]Luman H. Long (ed.), The 1970 World Almanac (New York: Newspaper Enterprise Association, 1970), p. 264.

[4]Ibid., p. 264.

contributed to Arctic settlement and technology in the late 1950's and early 1960's. Recent discoveries of large quantities of gas and oil on Alaska's north shore promise increasing activity and settlement in its Arctic regions.

Northern development in Danish administered Greenland is presently directed towards concentrating the scattered population of the west coast of Greenland into five main centres. These five centres all previously existed and this policy of concentrating the population enables the government to provide more and better support services. The planning being carried out attends to environmental control by utilizing careful site selection, sheltered pedestrian walkways, and building orientations that produce a wind shielding effect. The United States Air Force has contributed significantly to Greenland's development through its elaborate radar and airbase installations. The huge airbase at Thule and the DEW Line radar stations on the ice cap have contributed valuable technical knowledge as well as considerable employment for residents. Extensive research within the ice cap was carried out by the US Army Corps of Engineers during the late 1950's and early 1960's. Large scientific laboratories, including a small nuclear powered generator, were constructed and operated from within tunnels cut deep into the ice cap. From this research much useful data on ice mechanics and construction techniques was developed. With the shift in military defence from manned aircraft to guided missiles the need for large fixed land installations is decreasing and as a result most military and research installations in Greenland are being consolidated or completely abandoned. Very little research is currently being carried on by the US military and the airbase at Thule is now largely staffed by Danish personnel.

Both Norway and Sweden have had a second chance to plan and develop better cities and towns in their Arctic areas due to the "scorched earth" policy of the retreating German armies in 1944. Some 65,000 residents of Norway alone were evacuated from the northern areas. Despite the desire of these people to return to their homes, the government remained firm in its policy of establishing properly planned environments either upon the ruins of former settlements or in new areas better suited to community developments. Generally settlements have been located on mountain sides surrounding an all weather ocean harbour. Similar to the cities of Kirkenes and Hammerfest, most take advantage of side hills for improved microclimate and visual appeal.

The Scandinavian countries have tried two concepts of personnel accommodation in regard to natural resource development. At Kiruna, Sweden, a well planned city containing both single family dwellings and apartments has been developed very near the site of an open pit iron ore mine. A copper mine located 500 miles south of Kirkenes flies in its workers from anywhere in Scandinavia on an alternating cycle of three weeks work and one week at the workers' homes. Both systems appear to be meeting the requirements of both the individual and the industry. The system used depends on such factors as location, existing facilities, transportation, and expected duration of the industrial operation.

Canada probably has done the least of any Arctic nation in developing or settling its Arctic regions. Virtually no form of planned settlement or development was evident prior to 1940 and only after the threat of possible northern attack during World War II were any specific measures taken. These measures were primarily in the form of emergency airfields to be used to ferry aircraft to Europe or Asia and a highway and oil pipeline to Alaska. Prior to this period the southern Canadians who ventured into the Arctic were predominantly missionaries, Hudson's Bay Company employees, and members of the Royal Canadian Mounted Police.

During the late 1940's and early 1950's the needs of the northern indigenous peoples became more evident and programs of education, health, and social development were implemented. Administrative centres were established to provide facilities for supplying these needs at Aklavik, Yellowknife, Fort Smith, Churchill, and Frobisher Bay. The building technology was crude, utilizing prefabricated metal and wooden structures laid out with emphasis on fire separation of 100 feet and little thought to other amenities. Canada did attempt an experimental Arctic town in the mid 1950's - Inuvik, near the mouth of the Mackenzie River. Inuvik's southern configuration and physical amenities for the white people only were accomplished by means of pile foundations and an extensive and expensive utilidor system for water, sewage, and heat.

Currently increased effort is being directed to development plans for Arctic settlements. Most governmental programs are currently aimed at the development of settlement infrastructure predominantly in the area of education, health, and particularly communications in the form of improved roads, airfields, radio, and television coverage.

The current intense exploration for mineral and petroleum reserves particularly in Canada's western Arctic and Archipelago, portend increased population, investment, and probably settlement. With such intense interest in Canada's Arctic, future development seems inevitable but the form and exact location it will take must be tightly controlled to ensure that the delicate ecosystem of the Arctic is not damaged. The Arctic ecosystem cannot support unlimited development and therefore settlements must be limited in overall population size, the physical area that they occupy and the location in which new settlements are established. If this settlement does take place, now is the time to plan the development to try and avoid the problems now being experienced in many of the existing settlements.

Natural Resources

Of all the possibilities that are being examined in the Arctic for man's future, probably the first to be exploited will be the mineral resources. The Soviet Union is rapidly developing the resource riches of Siberia; much of Europe's high-quality steel already comes from the big Swedish iron mines at Kiruna, north of the Arctic Circle. Large American corporations are turning to the iron ores of the Canadian Shield and Arctic islands as the nearest available rich and dependable source of the most vitally important of all industrial raw materials.

Before long much of the steel produced in the United States may be made from iron ore brought from the Canadian Arctic. Already huge mines have been opened in Labrador and northern Quebec. Geologists have meanwhile established the existence of rich iron deposits still farther north on Baffin Island.

The Arctic promises to become a rich source of oil for the World. The United States Navy has taken rights to a huge oil and gas field under the permafrost south of Point Barrow, Alaska. American and Canadian firms have recently confirmed discoveries of large quantities of oil and gas in the Prudhoe Bay area of Alaska's north shore. These discoveries are of a sufficient magnitude that consideration is being given to the construction of oil and gas pipelines from the Arctic coast to the central USA. Some of the world's largest oil deposits are believed to exist in the Canadian Arctic. Reserves in the Mackenzie Delta and northern Yukon alone are estimated at 10 billion barrels.[5] Still farther north an oil rush is sweeping over the Canadian Arctic islands, where a drilling team recently discovered a large quantity of gas on King Christian Island. Geologists

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[5]P. Queneau, "Utilization of the Arctic's Natural Resources", Man Living in the Arctic, U.S., National Academy of Sciences (Washington: Government Printers Office, 1961). p. 121.

estimate that the arctic islands may contain another 20 billions barrels of oil.[6]

World-wide natural resource demand will continue to grow due to unprecedented increasing per capita demand created by rising living standards and developing technology. The Arctic's contribution to the world's mineral and energy needs will be determined by the extent to which the more accessible sources of world supply become depleted and the extent to which products based upon Arctic resources can be made competitive in world markets. Another factor currently of increased concern is how successfully the natural environment can be protected and preserved if the natural resources are exploited.

Increasing world demand for natural resources will create a great pressure for Arctic exploitation. To avoid the possible devastated landscape and irreversable environmental damage specific Arctic development policies will be required. It is quite possible that after a comprehensive analysis is completed that the risks to the Arctic environment will show up as too great and that alternative sources will have to be utilized. Only

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[6] Ibid., p. 121.

a comprehensive planning approach to Arctic resource utilization will ensure an orderly, economical, and efficient tapping of needed resources that will not only provide for present demands but will ensure sufficient reserves for future generations.

Sovereignty

In the field of international politics national sovereignty over relatively uninhabited territory has in most cases been ill-defined. This is especially true in the case of Antarctica and to a lesser degree in the Arctic.

It was the Canadian Parliament in 1925 which first broached what turned out to be the generally accepted resolution to the sovereignty question - the Sector Theory. This theory is based on lines of longitude which of course all meet at the two poles. The country nearest to the pole, according to the theory, has sovereignty over all lands that fall within the lines of longitude bounding the countries' outer limits. In Canada's case, all the islands contained within the "pie-shaped" sector of approximately 55^{o} to 142^{o} west longitude. This theory became popular with countries who would benefit from general acceptance of this principle, such as the Soviet Union, who formally adopted the sector theory of sovereignty in the following year, 1926.

No serious challenges have been made against Canadian sovereignty in the Arctic Archipelago. However the United States has not formally accepted the validity of the sector theory in the Arctic although it abides by the principle in the Antarctic.

The agreement between Canada and the United States to construct the DEW line in November 1954 marked a milestone in Canadian sovereignty history. As a result of the DEW Line agreements, Canada secured from the United States an explicit recognition of sovereignty in the Arctic. The planning, research, and construction associated with the DEW Line project greatly contributed to the knowledge of Arctic conditions. The subsequent manning and operation of this system has provided an increased physical military presence in the Arctic and also increased the safety of air travel in this area due to the constant surveillance of their movements. Numerous instances are recorded of information being transmitted to aircraft on their position and the heading to follow to their intended destinations.

Two Parliamentary statutes passed in 1970 concerning the Arctic should be noted. One was the extension of the three mile territorial limit to 12 miles. The significance of this move was that it effectively closed the Northwest Passage to international navigation. Now any foreign vessel wishing to sail this route must formally apply to the Canadian Government for permission. This authority permits Canada not only to control Arctic shipping for political reasons but also permits Canada to impose any safety regulations necessary to control environmental damage from shipping mishaps. The other significant statute was the establishment of a 100 mile pollution control zone around the ocean boundaries of Canada. In essence this legislation empowers Canada to set regulations regarding safety measures and damage responsibilities of all ships entering this 100 mile zone. This move generated considerable international controversy at the time but the potential benefits of this legislation are gaining support as more instances of environmental damage occur.

National concern over sovereignty in the North and the possibility of permanent ecological damage could lead to increased settlement as personnel are required for regulatory activities.

Environmental Control

Pollution of lakes and streams with human and industrial wastes is one of the major environmental problems facing society today particularly in urban areas. In most cases the rehabilitation of these contaminated water courses will cost billions of taxpayers dollars and in some cases it may already be too late to save a body of water such as is suspected with Lake Erie.

This problem of water pollution is also emerging in the Arctic where many settlements such as Inuvik, Cambridge Bay, Churchill, and Frobisher Bay discharge raw sewage directly into the ocean waters. Relative to more southerly areas these Arctic settlements are small in size and hence the amount of sewage discharge is also correspondingly reduced. However, the seriousness of this problem arises from the fact that the cold Arctic environment inhibits the action of bacteria required to break down and decompose wastes as fast as can happen in warmer waters in southern areas. Thus the ability of Arctic water courses to absorb wastes is considerably less than that of equivalent water courses further south. This problem of waste disposal is one area that requires further research to develop workable solutions before damage is caused to Arctic water courses.

The Canadian Government has recently passed or is presently studying several pieces of legislation to control the problem of Arctic water pollution. One such Bill is the Northern Inland Waters Act (Bill C-187) passed by the House of Commons on May 5, 1970. This Bill has four main points:[7]

1. To provide for the equitable distribution of sharing of rights to use water in the North among interests with legitimate and sometimes conflicting claims on this resource;
2. To ensure that the disposition or allocation of water rights is done in a manner that is consistent with immediate and long-term regional and national interest;
3. To ensure that all works and undertakings planned for the use, diversion, storage or treatment of water are designed and constructed to acceptable engineering standards; and
4. To establish and maintain the principle that rights to the use of water are dependent on the users accepting the full responsibility for maintaining its quality or restoring its quality to acceptable standards before returning the water to its natural environment.

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[7] House of Commons Debates, 114:78, March 3, 1970, p. 4313.

If this Act is implemented and enforced, water pollution in the Canadian Arctic should be non-existent.

The Arctic Waters Pollution Prevention Act (Bill C-202)[8] passed April 8, 1970, extends Canada's pollution prevention zone to 100 miles adjacent to the mainland and the islands of the Canadian Arctic. This Act allows Canada to regulate and enforce safety and environmental standards on all vessels operating within this 100 miles zone.

On May 11, 1970, Bill C-212 was tabled in the House of Commons dealing with amendments to the Territorial Lands Act.[9] This Bill would allow the establishment of northern land use regulations and zoning of the entire Canadian North.

These three pieces of legislation are of considerable importance as they are the first steps towards legislative controls to regulate the development of the Arctic. It is indeed unfortunate that neither the Northern Inland Water Act nor the Arctic Waters Pollution Prevention

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[8] Bill C-202, An Act to prevent pollution of areas of the Arctic waters adjacent to the mainland and islands of the Canadian Arctic, Ottawa: House of Commons, June 9, 1970.

[9] James Woodford, The Violated Vision: The Rape of Canada's North. Toronto: McClelland and Stewart, 1972, p. 103.

Act have been "proclaimed" to date.[10] Until this proclamation is official neither Act can be enforced. The amendments to the Territorial Lands Act are still under review and therefore are also ineffective. Arctic Canada is still legally unprotected and subject to the actions of individuals and corporate identities currently operating in the Arctic.

When these Acts are proclaimed and some system devised to enforce them it is anticipated that additional personnel located within the Arctic region will be required. This will in turn generate additional support personnel and an overall increase in the total population of the Arctic region is likely to occur.

Military Significance of the Arctic

Prior to World War II, Canada's northern regions represented a vast and impenetrable strategic barrier. In 1940, Professor C.P. Stacey wrote:

> On the Dominion's northern territories those two famous servants of the Czar, Generals January and February mount guard for the Canadian people all year round. It is not impossible that the continuing development of aircraft will lend these Arctic and Sub-Arctic Regions an increased military significance in the future; but for the moment, though they cannot be entirely forgotten they are

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[10] Ibid., p. 9.

> clearly not particularly important, and this fact greatly narrows, for practical purposes, Canada's actual areas of defence."[11]

This is not, however, the whole story. During the twenties and thirties the armed forces made an important contribution to northern development; the army in the field of radio communications, and the RCAF in the development of northern flying.

On the North American continent the United States and Canada have coordinated their efforts since 1940, when the Permanent Joint Board on Defence was set up. During the war U.S. forces and materials were employed on Canadian soil in the construction of the Alaska Highway, the Canol pipeline, and the survey of the Trans Canadian Alaska Railway Line. After the war Canada assumed full control of all activities within its borders. In the 1950's, with the development of jet aircraft and longrange missiles, one of the coldest areas became potentially one of the "hot spots" of the world, resulting in construction of the DEW Line and the Mid-Continent Line of radar bases and sites. These brought people, jobs, new types of equipment and new concepts of construction to both the Arctic and Sub-Arctic regions.

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[11] C.P. Stacey, The Military Problems of Canada. (Toronto: Ryerson, 1940), p. 5.

Air operations across the polar sea are in the forefront of defence planning in both North America and Eurasia. Return flights to the region of the pole and reconnaissance flights along the margins of the sea are regularly made from each side. An example of the tremendous scope of postwar military-geographical polar research was the establishment of experimental stations, jointly by the Canadian and U.S. air forces on the floating ice islands, discovered in these reconnaissance flights.

Much effort is also being put into trying to discover the reasons for the special behaviour of radio and electronic devices in northern latitudes, and so to eliminate the present interruptions in communications. Cosmic ray and other studies in northern Canada are providing information from altitudes up to 60 miles above the earth's surface.

As a result of the attention given military planning of Arctic operations, gains of more permanent value for the future development of the Arctic have accrued: greatly increased knowledge about natural conditions in the Arctic and about techniques of living there; and permanent improvements in communications, particularly in the inauguration of transpolar civil air lines, the construction of harbors, the provision of aids to navigation, and the building of pipelines.

With increasing awareness of the value of the natural resources in the Arctic, continued military presence is necessary to maintain sovereignty in this vast region. This could be accomplished by establishing permanent military bases for the purpose of surveillance and assistance to isolated residents. To utilize effectively expensive physical installations, such as utilities and community facilities, these permanent military bases could be co-located with settlements established for other purposes. However, only if positive settlement concepts and policies are formulated now can this type of settlement integration be effectively accomplished.

Population Growth

Beginning with an estimated world population of a quarter of a billion at the beginning of the Christian era, it took 1,650 years to double this number to one-half billion. The doubling periods then occurred with startling rapidity; two hundred years to double to one billion; eighty years from one to two billion; and it probably will take only forty-five years to increase to four billion by 1975. A levelling off of the growth rate is expected to take place about and after the year 1980 on the assumption that some population control methods and practices will have found more general acceptance. Even so, world population is expected to reach somewhere between five and seven billion by the year 2000.[12]

Based on this estimate Canada will have an additiional seven million people by the early 1980's, 15 million by the year 2000, and perhaps 100 million more people over the next 100 years. The current distribution of Canada's total population indicates that less than one quarter of one percent[13] now reside in the N.W.T. and the Yukon and considerably less in that area that is defined as Arctic.

Assuming that the current emphasis on northern and Arctic development continues thus bringing more residents to Canada's Arctic, it would not be unrealistic to assume that 2½ percent of Canada's total population could reside in northern and Arctic areas. Thus by the year 2000 Canada will probably contain close to 40 million

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[12] U.N., Future Growth of World Population (New York: United Nations, 1958).

[13] Based on a population of 43,120 residing in the Yukon and N.W.T. in 1966 and a total Canadian population of 20,014,880.

people of which one million might reside in northern and Arctic Canada.

If only 15 regional centres were to be established or developed in northern and Arctic Canada, this would mean 15 cities of about 30,000 people each serving a regional area of approximately 70,000. Due to the harsh Arctic environment, limited transportation modes, and delicate ecosystem, settlements developed in Arctic Canada would necessarily be limited to a maximum population in the order of 10,000 residents and many would probably accommodate 5,000 and perhaps even less depending on the economic base of the settlement.

Therefore, based on the assumption that world population will continue to grow and also that no major changes occur in Canada's foreign and domestic policies concerning immigration, it appears that Arctic Canada will also share in this population growth. This growth will require the establishment of new cities and numerous smaller settlements to adequately accommodate these new Arctic residents who will probably be employed in resource exploitation and service industries.

Administrative Requirements

Providing administration and public services for a growing northern and Arctic population requires a large number of physical facilities and a sizable staff to operate them. Health, education, and social development are the main areas of concern. Facilities are also required for transportation, communication, justice, and research. Considered in total, this administrative requirement represents a large investment in facilities and salaries and therefore the location of these facilities must be carefully selected to ensure adequate and efficient use.

To operate such a system efficiently a considerable amount of centralization has been carried out particularly where the facilities are technically complicated. A small community of 100 - 200 inhabitants is provided with a nursing station for emergency medical care; however, well equipped hospitals capable of delicate surgery are located only in larger communities of 2,000 - 3,000 population. Individuals requiring the facilities of a hospital are transported to them from the small outlying settlements.

The same system applies to education. Instruction to grades six or eight is available in small communities. Further education is provided at regional centres and students live either at the school, in hostels, or in private homes. A system of regional centres has begun to develop in the Canadian Arctic with Inuvik, Cambridge Bay, Resolute Bay, Churchill, and Frobisher Bay all containing established secondary facilities in the education, health, and social development fields.

With the current emphasis on increased benefits for the peoples of the Arctic, the growth of facilities and increased staff to operate them is assured. As of 1 April 1968, the size of the N.W.T. Public Service was 102, a year later it was 365 and the estimated strength as of 1 September 1969 was 1,050.[14] Not all of this increase was pure growth as some positions and incumbents were transferred to the Territorial Public Service from Federal Departments as in the cases of Federal Game Management Program and the N.W.T. Highway System. The significant point being that some of these positions were located in Ottawa and have now been transferred to northern Canada thus increasing their presence and authority in Canada's North.

The exact number of Territorial and Federal Government employees is difficult to ascertain during this current period of transition between the two levels of government. The magnitude of the number can be visualized if the Federal Civil Servants of the Departments of Indian Affairs and Northern Development, Forestry and Fisheries, Transport, National Defence, Public Works, Justice (RCMP)

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[14] Northwest Territories, Canada, Annual Report of the Commissioner of the Northwest Territories, (1969) pp. 24-25.

and Agriculture are added to the 1,050 employed by The N.W.T. Government. Considering that the total population of the N.W.T. in 1966 was 28,738, it is apparent that any increased population due to natural resource development will result in a corresponding growth in the number of governmental administrative and service personnel due to the requirement for public facilities and personnel services such as health, education, and recreation.

Summary

Is settlement planning required in the Arctic? Considering the projected development of natural resource exploitation, the need for a military presence, the concern over the sovereignty question, and the potential population growth with its resulting administrative requirements, it is clear that some form of positive settlement concept and planning is required for the Arctic to adequately accommodate this possible increased growth. This planning should be started now before existing activities and operations become so deeply entrenched that they are difficult or impossible to change thus necessitating additional effort to attain better physical configurations that afford improved settlement habitability and human amenity.

Assuming that the population estimates are of the correct magnitude, planners must start thinking, not in terms of experimental towns such as Inuvik with 3,000 people, but of cities located in the Arctic ranging in size possibly up to 10,000 citizens. Plans to accommodate a settlement of this size must not be reproductions of more southerly communities but imaginative and technically feasible solutions resulting in desirable communities with a distinctive Arctic atmosphere to which potential residents will be attracted. Settlements in the Arctic region with fewer people, due to the fragile nature of the Arctic environment, however new and modern facilities will nevertheless be required. A more positive comprehensive planning approach is now required to analyze and mold this future development to a form and magnitude that will benefit not only the Arctic residents but that will also preserve and conserve the resources of the Arctic region for future generations.

CHAPTER III

THE ARCTIC ENVIRONMENT

The factors that distinguish the Arctic from other areas in Canada are the climate, the unusual terrain, the relative isolation of most areas, and the delicate nature of the ecosystem. Climate is not much more severe than conditions experienced in other cold areas of Canada, such as the Prairie Provinces, but differs mainly in the duration of cold weather rather than in the extremes of temperature. Thus technological problems arising directly from climate are not significantly different from those encountered in more southern regions. Nevertheless, the climate does have several important implications in the Arctic. The long winter periods accompanied by almost continuous darkness severely restricts biological growth thus creating a delicately balanced ecosystem. The short summer season is further restricted by the periods of break-up and freeze-up during which many areas are completely isolated from each other due to restricted transportation movement both by land and air. The continuous periods of daylight and darkness along with the isolation affect human activities and neurotic and psychotic problems develop necessitating that special provisions be made to reduce these adverse effects on human performance.

An important feature of the terrain of Arctic Canada is the presence of permafrost in most areas which leads to many of the technological problems associated with northern construction. Most of the Arctic has a shallow covering of organic fibrous material which is capable of holding vast quantities of moisture. Its low bearing strength creates many obstacles to surface movement and to construction activities. This organic covering also provides an effective insulating layer to protect the permafrost. If this covering is removed or disturbed severe erosion of the terrain can occur due to the melting permafrost.

The great distances between Arctic settlements combined with the limited transportation facilities in the Arctic, exert an important influence on the economics of northern activities. The relative isolation of most sites where these activities must be carried out, with the added problems of lack of locally available manpower and materials, means that practically all labour and material requirements must be met from outside sources at extremely high cost. Similarly, maintenance and replacement of damaged or lost parts create further difficulties. This one aspect alone demands that equipment and structures have, as their prime features, simplicity of design, reliability in operation, and standardization of components. These factors jointly introduce serious economic and logistic considerations in the execution of any activities in the Arctic thus requiring comprehensive planning and detailed organization to effectively complete even minor tasks.

Arctic Ecosystem

The fragile Arctic ecosystem is one of the more important aspects of northern development. The complex of organisms and their environment form a delicate balance in the Arctic and any disturbance could have far reaching effects which could create severe damage and hardship not only to the inhabitants but also to the environment. This is particularly true in the case of surface cover which, if disturbed, precipitates dramatic shifts in the perma-frost table which in turn creates erosion and eventually severe surface scarring.

The success of any organism within a given community depends on a number of environmental conditions and the presence of other species. Each species has specific environmental requirements if it is to be successful in its community. When any one of these factors, such as temperature or the available amount of water, light, or minerals, does not satisfy the needs of the species, the species will have limited success. This is directly applicable to organisms which degrade and decompose matter. In the harsh Arctic environment bacterial growth is severely reduced due to the low temperature, poor quality soils, and limited amounts of sunlight particularly during the winter period. This severe decrease in biochemical reaction rate has some far reaching effects in the Arctic region. Metal rusts very little due to the dry atmosphere and sewage wastes decompose very slowly within the shallow top layer of seasonally thawed ground, and not at all within the permafrost zone. The permafrost prevents sewage properly leaching into the soil and resulting poor drainage causes veritable cesspools on the surface, rendering unsafe the use of surface water supplies.

The Arctic region is characterized by a small number of species of both plants and animals. For example, of the 9,600 species of birds found throughout the world, only 80 breed in the Arctic and few remain during the winter period. There are approximately 3,200 species of mammals found in the world, but fewer than 30 live in the Arctic region. Of the 30,000 species of fish in the world, less than 50 can be found in the Arctic seas.

Arctic flora also number relatively few when compared to more southerly areas. Most Arctic flora are perennials thereby not relying on annual seed production to perpetuate the species. Mosses, algae, lichens and small flowering plants are found extensively throughout the Arctic region. Approximately 500 species of insects are found in abundant quantities and these form the diet for many Arctic birds.

The Arctic ecosystem appears to be active and diverse; however when compared to more temperate areas the Arctic regions contain relatively few species and its productivity is relatively low. It is these two characteristics that make the Arctic region biologically delicate and extremely sensitive to natural or man-made changes. In addition, the Arctic ecosystem is intimately tied to the ecosystem of more southerly areas. For example, if the Arctic nesting grounds were fouled in some way, such as by oil pollution, millions of ducks, geese, swans and other bird species would be severely affected and might even be lost forever. In this way the Arctic ecosystem, even though seemingly remote, forms an intricate part of the larger continental ecosystem and any disruption to it could have far reaching effects in more southerly regions. Therefore any development contemplated in the Arctic region must be limited in magnitude to that which the Arctic ecosystem can accommodate without adverse effects.

These phenomena create problems that must be carefully considered when future development is contemplated. If adequate solutions are not instituted they will contribute greatly to settlement habitability problems and in severe situations could completely change the environment to the extent that continued human habitation would be impossible.

Climate

There are probably more misconceptions about the climate of Arctic Canada than about any other aspect of northern work. It is, for example, popularly imagined that precipitation in the form of rainfall and snowfall is heavy in the Arctic. Over most of the Canadian Arctic it is actually rather light being less than ten inches per year.[15] Figures 2 and 3 illustrate the mean annual snowfall and rainfall for the Arctic region of Canada.

Receiving less than ten inches of annual precipitation, the Arctic can be described as the equivalent of a desert. It is the wind which creates the impression of much snow, since the strong winds of the Arctic do create snow drifting that leads to individual deposits of snow of surprising depth whenever obstructions interfere with the free flow of the wind. Gusts of wind up to 130 mph can be

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[15] One inch of rain is assumed to equal ten inches of snow.

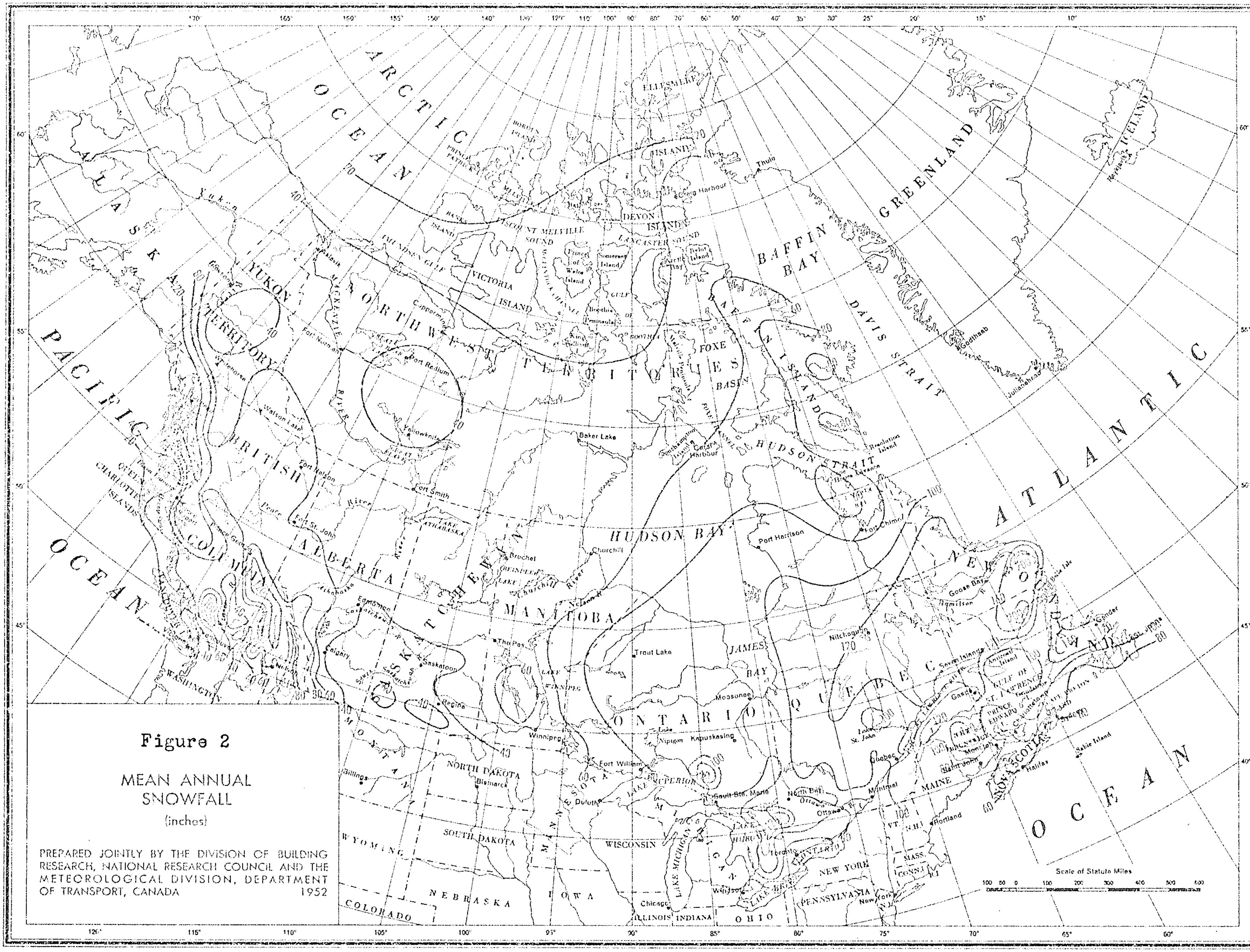

Figure 2

MEAN ANNUAL SNOWFALL

(inches)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

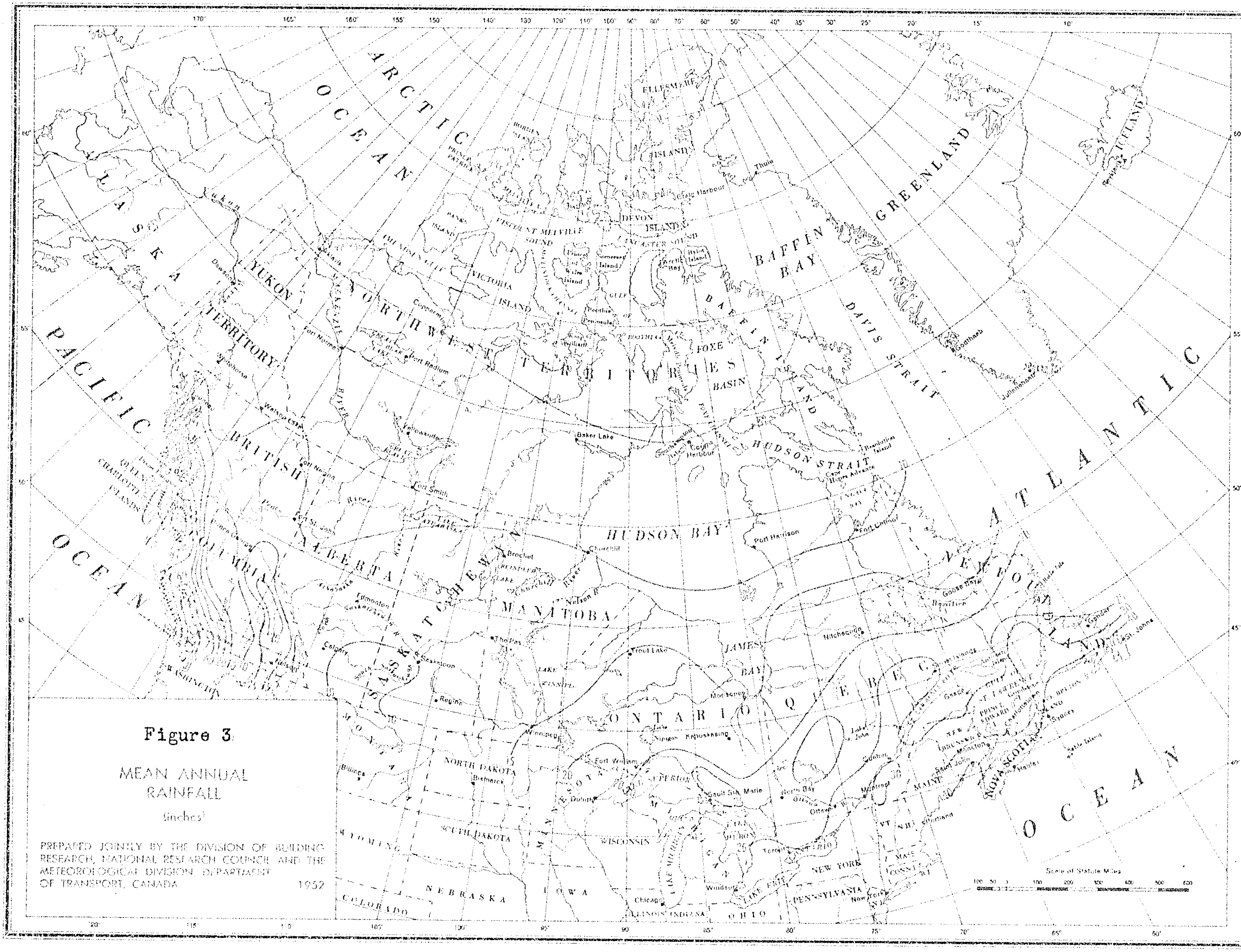

Figure 3

MEAN ANNUAL RAINFALL

(inches)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

expected on the southern tip of Baffin Island (see Figure 4), while the mean summer and winter wind speed varies between 10 and 15 mph (see Figures 5 and 6).

Another popular misconception is that the climate of the Arctic is very much colder than anywhere else in Canada. This is not the case. Temperatures in the Arctic are somewhat lower than those experienced elsewhere in Canada, but there are many occasions when temperatures in the cities of western Canada, in the winter, are not far different from those in the Arctic. Figure 7 illustrates the mean January daily temperatures. A brief study of this figure indicates that the temperature regime of the eastern and western Arctic is similar to that of northern Manitoba and only slightly colder than at Winnipeg, Manitoba.

The mean July daily temperature is illustrated by Figure 8. These data indicate that the summer temperatures are quite high especially in the Mackenzie Delta region and surprisingly high in the far northern islands. Figure 9 illustrates the mean annual temperature which forms a relatively uniform gradient from 45°F in the northernmost islands.

A more realistic evaluation of the climate of

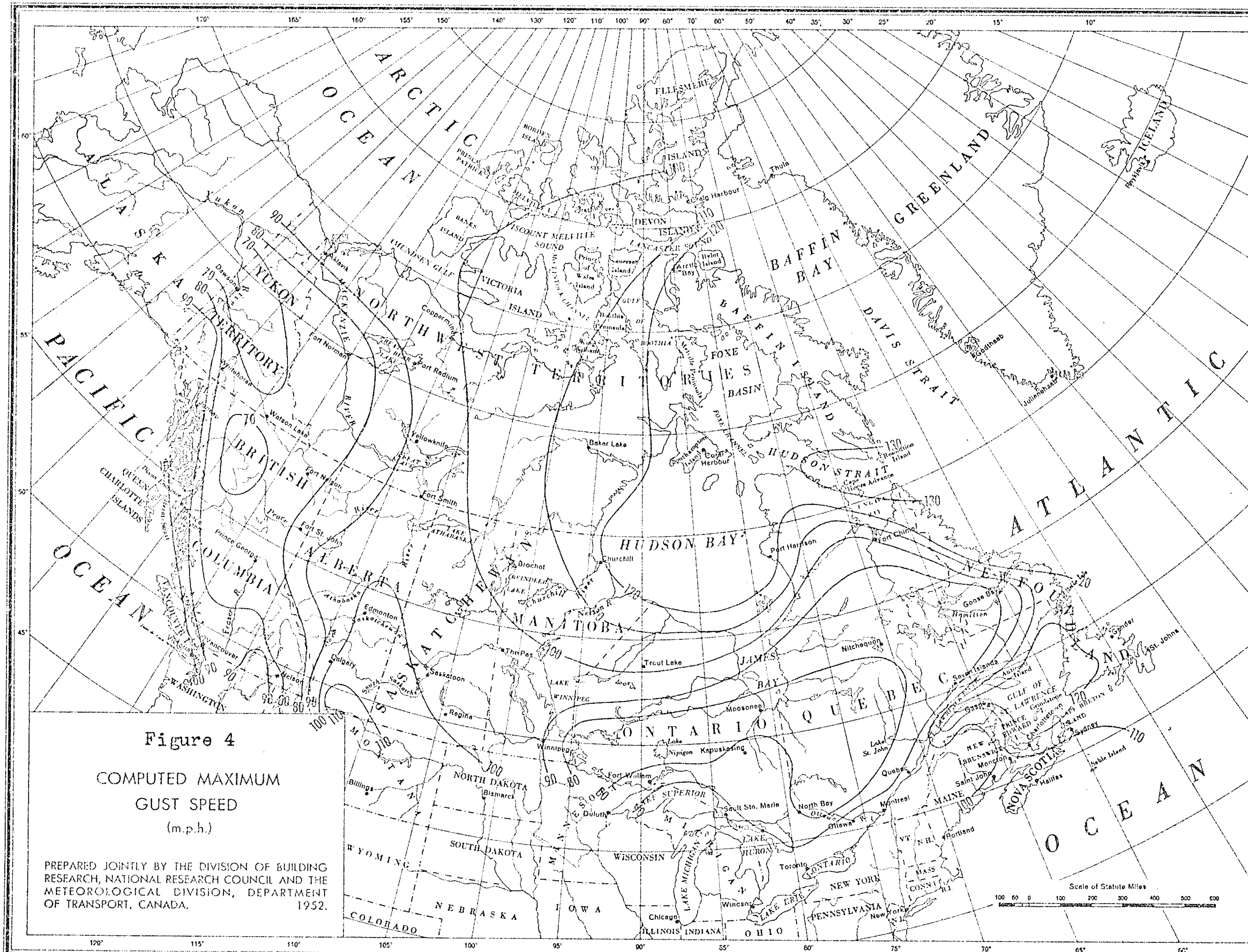

Figure 4

COMPUTED MAXIMUM GUST SPEED

(m.p.h.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA. 1952.

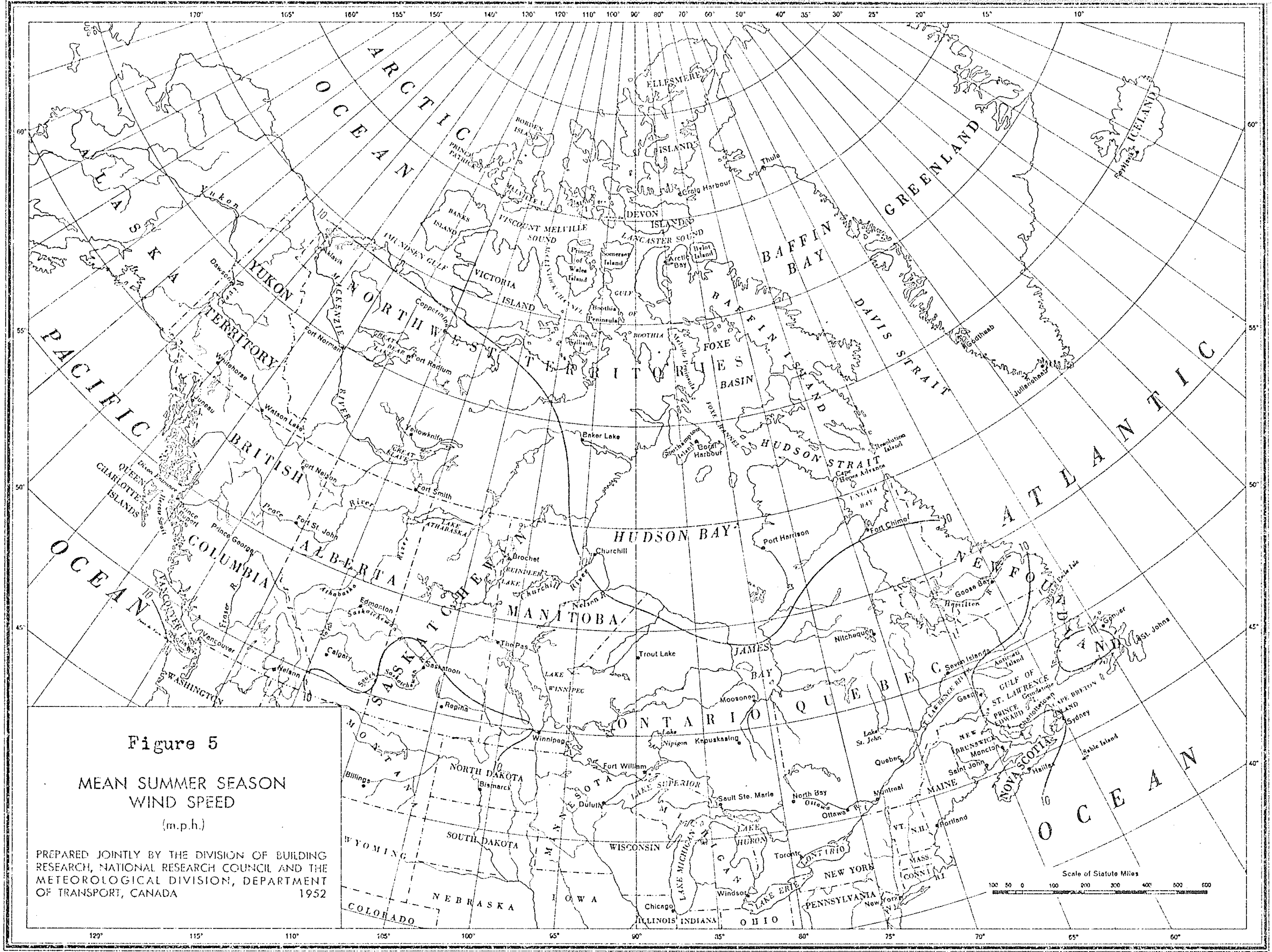

Figure 5

MEAN SUMMER SEASON WIND SPEED

(m.p.h.)

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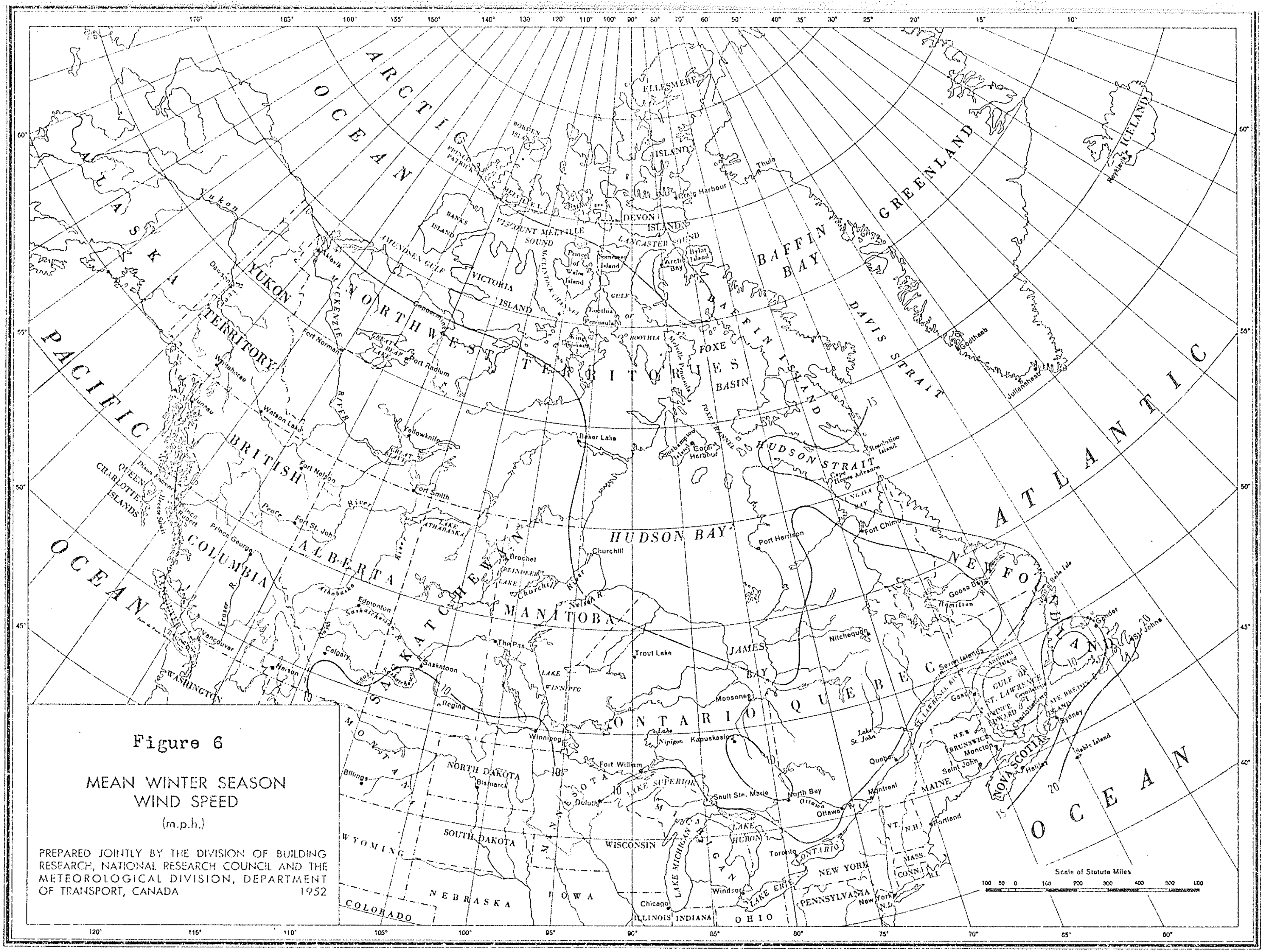

Figure 6

MEAN WINTER SEASON WIND SPEED

(m.p.h.)

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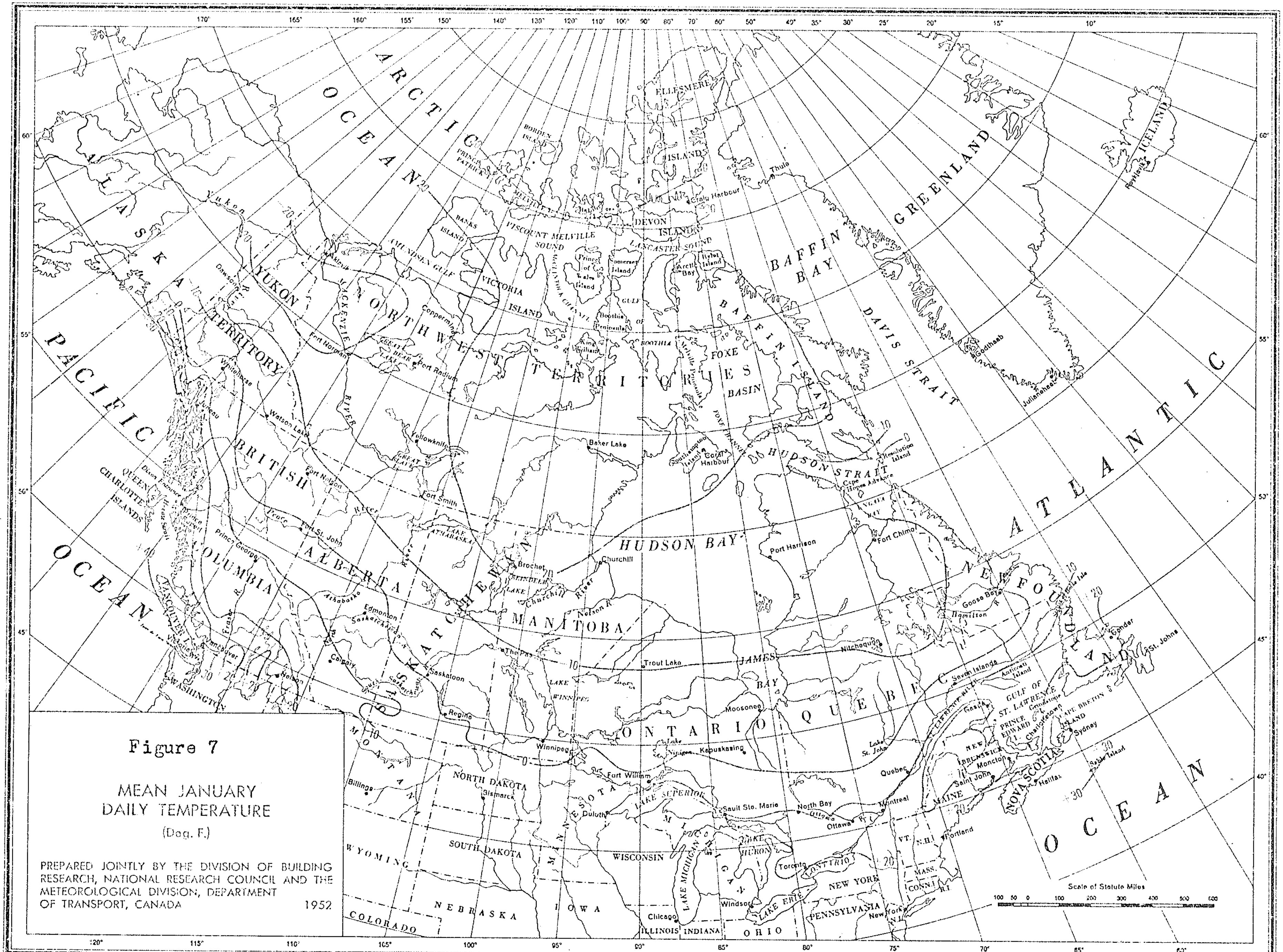

Figure 7

MEAN JANUARY
DAILY TEMPERATURE
(Deg. F.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

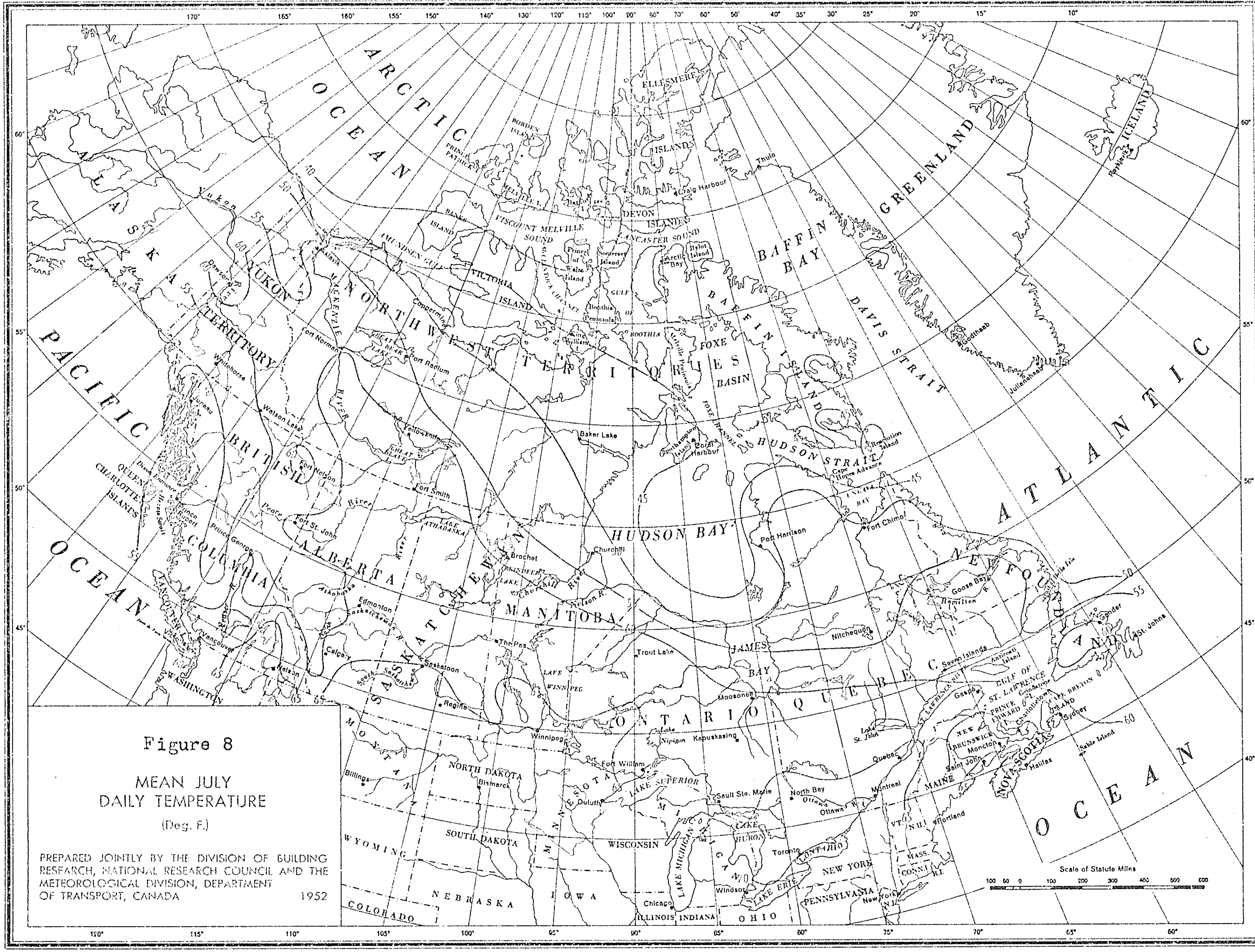

Figure 8

MEAN JULY
DAILY TEMPERATURE
(Deg. F.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

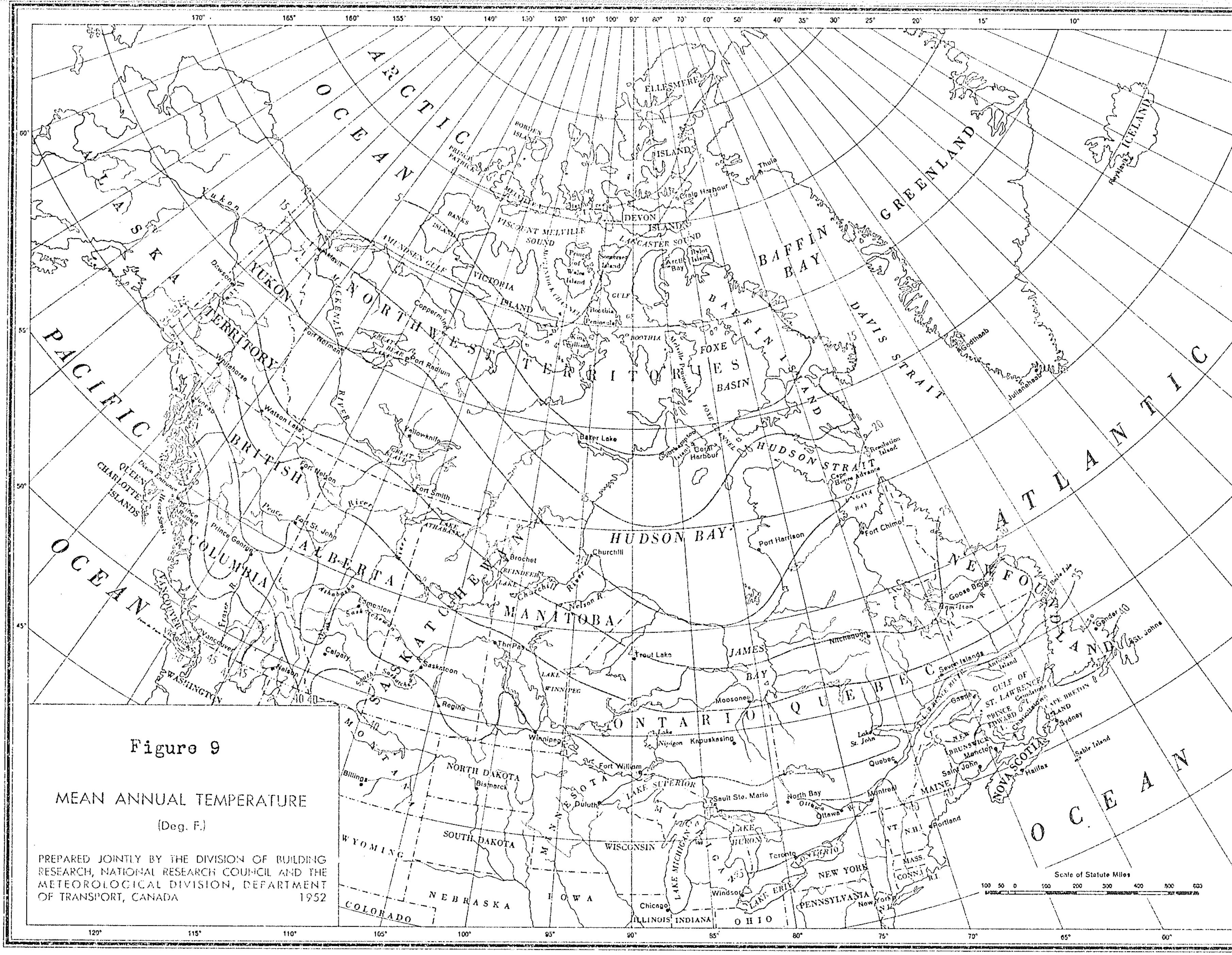

Figure 9

MEAN ANNUAL TEMPERATURE

(Deg. F.)

PREPARED JOINTLY BY THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL AND THE METEOROLOGICAL DIVISION, DEPARTMENT OF TRANSPORT, CANADA 1952

northern Canada is one which considers not only temperature but the duration of light as well. Figure 10 shows the duration of light that can be expected on the 15th day of each month depending on latitude. The Arctic Coast is roughly located along the 70th parallel of latitude and Figure 10 indicates that during June and July there is continuous light over the 24 hour day. By contrast, during the months of December and January there will be almost continuous darkness. Alert, located on the northeast tip of Ellesmere Island at 82° latitude, would receive five months of continuous daylight and in turn four months of continuous darkness.

This long duration of darkness coupled with the low temperatures of January which average -20°F, create an unpleasant and difficult environment for human habitation. The changing durations of light also create daily living problems such as the difficulty of sleeping during the midnight sun and conversely the difficulty of working in continuous darkness.

Another characteristic of the cold Arctic climate is its low water vapor content. As the water vapor carrying capacity of cold air is relatively low, any water vapor added to Arctic air quickly condenses, forming ice

The Total Possible Duration of Sunlight on the 15th of Each Month

North Latitude	January 15	February 15	March 15	April 15	May 15	June 15	July 15	August 15	September 15	October 15	November 15	December 15
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
40°	9 39	10 43	11 55	13 15	14 23	15 00	14 45	13 46	12 28	11 11	9 59	9 21
45°	9 09	10 27	11 53	13 29	14 51	15 35	15 17	14 06	12 34	11 1	9 35	8 48
50°	8 33	10 07	11 51	13 45	15 24	16 21	15 57	14 30	12 39	10 49	9 04	8 06
55°	7 47	9 43	11 47	14 06	16 08	17 21	16 49	15 00	12 46	10 33	8 25	7 13
60°	6 43	9 12	11 44	14 34	17 08	18 49	18 05	15 41	12 55	10 13	7 34	5 56
65°	5 02	8 28	11 40	15 11	18 43	21 53	20 15	16 39	13 07	9 46	6 16	3 42
70°	- —	7 20	11 33	16 09	22 41	24 00	24 00	18 15	13 26	9 06	3 52	- —
75°	- —	5 10	11 23	17 56	24 00	24 00	24 00	23 19	13 57	7 58	- —	- —
80°	- —	- —	10 50	24 00	24 00	24 00	24 00	24 00	15 10	5 00	- —	- —
85°	- —	- —	9 50	24 00	24 00	24 00	24 00	24 00	18 15	- —	- —	- —

From "Tables of Sunrise, Sunset and Twilight" Supplement to the American Ephemeris 1946 U.S. Naval Observatory

Figure 10

fog or frost. Physiologically, the result of the low water vapor content in Arctic air is that the skin and nostrils quickly become dry and cause personal discomfort. This situation requires that structures occupied by humans have some form of humidity control to raise the relative humidity to the 30 - 40% range. This requirement in turn necessitates special insulation requirements be designed into the enclosing structures.

The Arctic climate is harsh to be sure, but human settlement can cope with it providing planners and designers fully understand the extent of the climate characteristics and take them into account when planning and designing settlements located within this Arctic region.

Permafrost

The presence of permafrost in the Arctic has been known for many years; however misconceptions about it have developed due to some detailed reports concerning structural failures attributed to permafrost action. Permafrost is simply perennially frozen ground which occurs when the ground temperature remains at or below 32^{o}F during all months of the year. The climate of the Arctic is such that some surface thawing does take place, however the extent of this thawing is dependent upon location and may vary from a few inches in the northern Canadian Archipelago to a depth of 10 feet near the southern fringe of the continuous permafrost region. Beneath this layer - called the active layer - which freezes and thaws each year, the soil remains permanently frozen.

The occurrence and distribution of permafrost is influenced by climate and the heat exchange characteristics of the earth surface. The permafrost region is divided into two zones, the discontinuous in the south and the continuous further north. Figure 11 indicates the approximate southern limit of permafrost in Canada; however the discontinuous zone can extend further south of this line coinciding approximately with the mean annual air temperature isotherm of 30°F. The continuous zone generally occurs further north of this line coinciding approximately with the mean annual air temperature isotherm of 17°F. Permafrost depths within the continuous zone have been measured from 200 to 1300 feet with the active layer varying from a few inches to approximately four feet.

Permafrost, which is the result of a thermal condition reflected in ground temperatures below 32°F, is particularly sensitive to thermal changes. The delicate natural thermal equilibrium is greatly affected by any

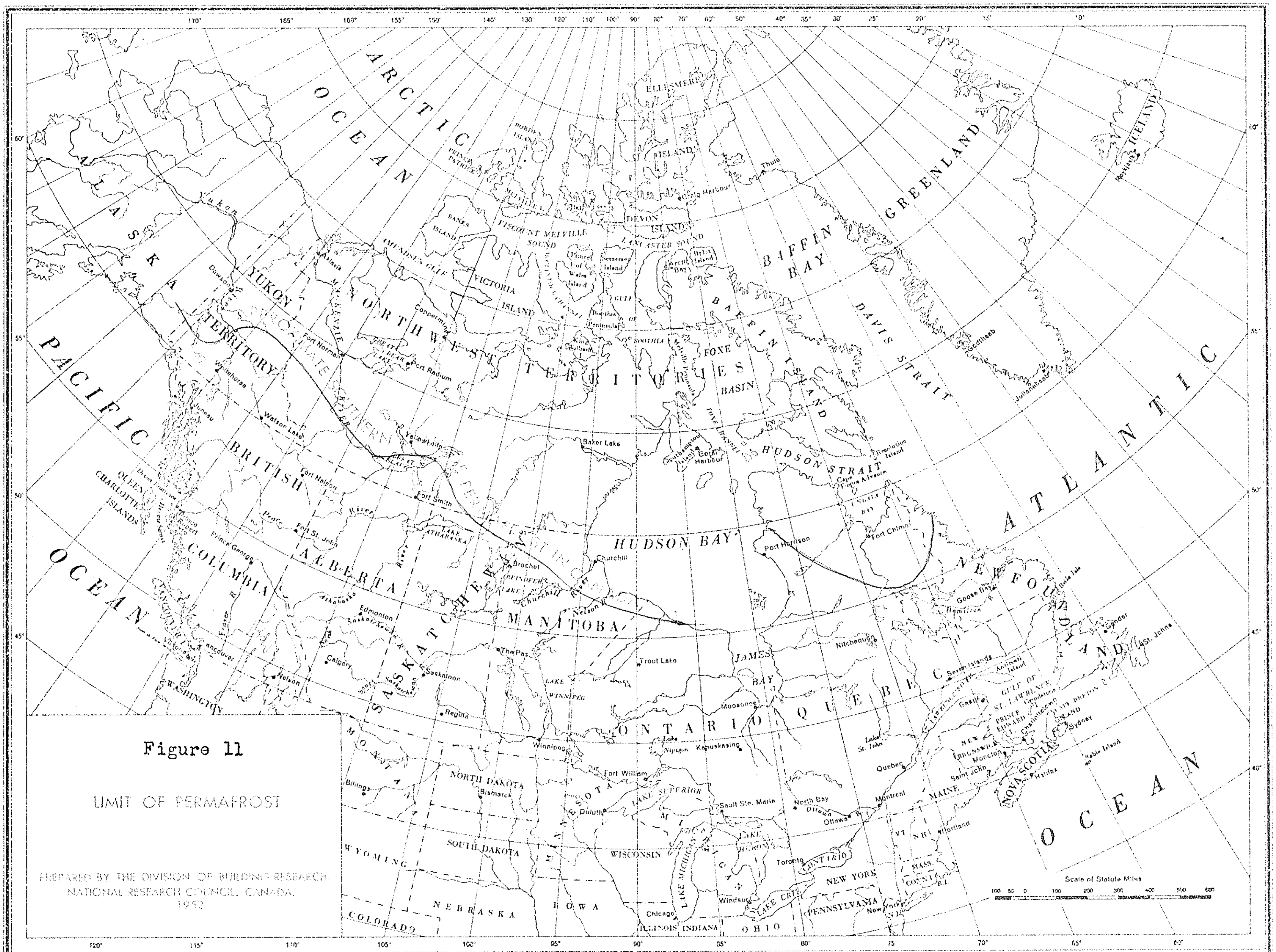

Figure 11

LIMIT OF PERMAFROST

PREPARED BY THE DIVISION OF BUILDING RESEARCH
NATIONAL RESEARCH COUNCIL, CANADA,
1952

natural or man-made changes in the environmental conditions under which permafrost exists. The clearing of an area, disruption of drainage, or erection of a structure may result in a significant change in the ground frost table. Figure 12 illustrates a typical ground thermal regime in the permafrost zone. The slope of the mean annual ground termperature line is determined from the geothermal gradient for Canada which is between one and two degrees Fahrenheit for every 100 feet of depth. A study of Figure 12 indicates that any disturbance at the surface that raises the mean annual ground temperature will not only increase the depth of the active layer but more important is that the total depth of permafrost at the site will decrease significantly.

The strength of frozen soil is understood only in a very general sense. The strength is obviously dependent on soil composition, moisture content, and temperature. If the soil contains a large quantity of ice it will exhibit the creep properties of ice which will affect its long term load bearing capacity. The most critical strength period is when the soil temperature approaches the thawing point. At the thawing temperature frozen soil will rapidly lose its bearing capacity and failure will most certainly occur. The key factor to permafrost

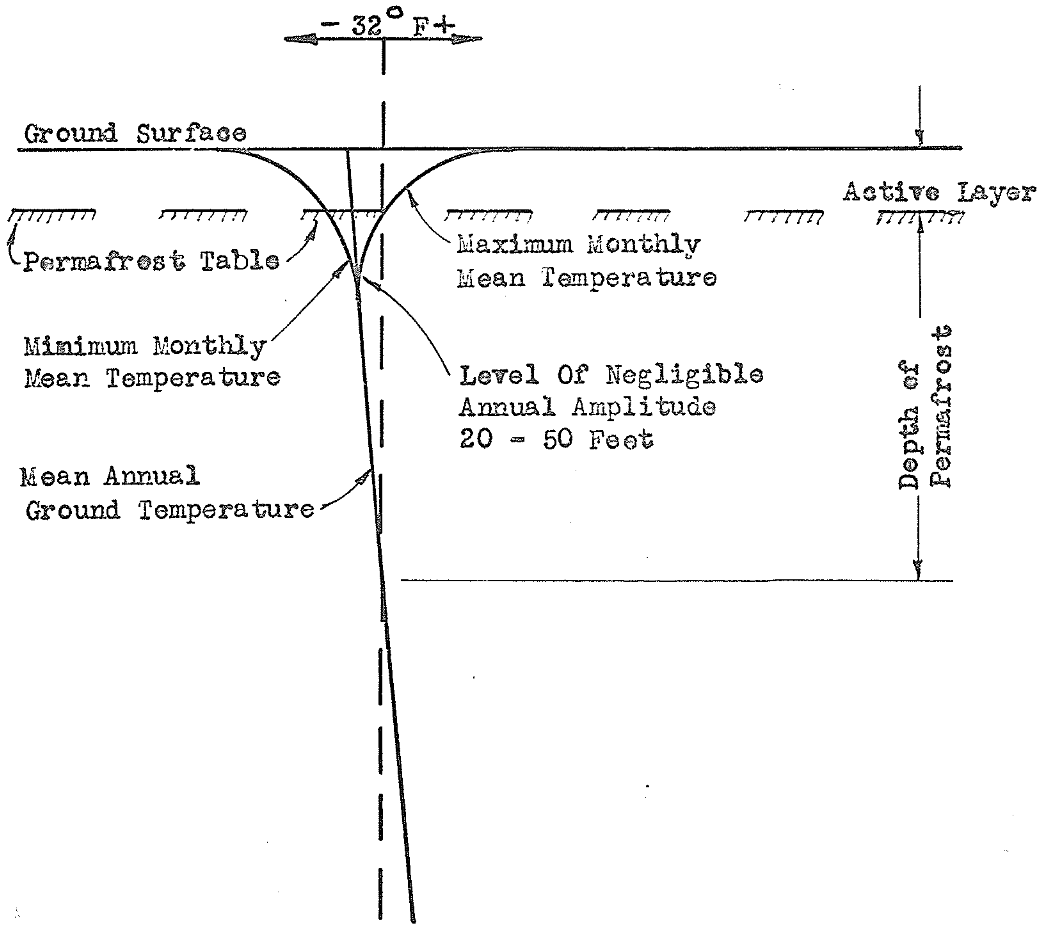

Figure 12

TYPICAL GROUND THERMAL REGIME IN PERMAFROST

Source:

C. B. Crawford and G. H. Johnston, "Construction on Permafrost", Canadian Geotechnical Journal, 8:236, 1971, p. 241.

stability and load bearing capacity is to maintain the soil in a frozen condition. If maintained in a frozen state permafrost will provide adequate bearing capacity for most structures. If thawing is permitted the soil may be transformed into a slurry of soil particulars and water unable to support any significant load. The degree of change will depend on the original ice content, the rate of thaw, and the type of soil. Even bedrock cannot be assumed to be ice free as investigations have produced large ice lenses between the strata of rock formations.

Permafrost can create structural design problems; however, the basic mechanics of permafrost are known and if these characteristics are applied correctly, construction upon permafrost need not create insurmountable difficulties.

Sites for Settlement

When considering the actual location of an Arctic settlement geomorphology is a prime factor. Geomorphology affects the orientation of structures, transportation systems, and the location and type of utilities and services to be utilized.

Geomorphology and the correct use of it can greatly change the effect of the elements of climate within the local area. This "microclimate" can increase the amenity of life in the settlement or it can greatly increase the hardship. For example, if the transportation channels (streets, walkways, or openings) are orientated parallel to the prevailing winter winds then snow removal will not create an excessive problem. However, channels at an oblique angle to the wind will quickly fill with snow due to the turbulence created. The location of adjacent bodies of water will affect the microclimate by cooling in the summer when the water surface is open and cool and also a chilling effect in the winter created by increased wind speed sweeping across the frozen open area of the lake.

Orientation is especially important when considering the effects of sunlight. Buildings, and in particular the windows in them, must receive special design attention to eliminate the undesirable effects of sunlight. In Arctic regions the angle of the sun changes greatly from winter to summer. In winter the angle of the sun is low and close to the horizon while in summer its angle is much higher and its duration is also greatly extended. This extended duration, or midnight sun, must be controlled by window shading and orientation or discomfort will result to building occupants. Figure 13 illustrates the need for a well designed window shutter to not only block out the midnight sun but also to provide additional insulative protection against the extremely low temperatures and almost continuous wind and blowing snow.

"Air drainage" is an important climatic element when settlement location is considered on sloping topography. Under relatively still air conditions, cool air will flow into flat or depressional areas. This phenomenon creates slight breezes on the upper parts of a slope thus creating a cooling effect and more important, limits mosquito and fly activities which tend to be swept to the lower areas. During the spring and fall seasons this air drainage effect can create frost pockets in the low areas thus affecting habitability and vegetation. Considering this principle of air drainage, sloping sections and particularly midslope areas, are the most desirable for settlement purposes. Low or depressional areas which are periodically flooded with cold air and are also more subject to insect infestation, are less suitable for settlement development. Frost pockets also create additional technical design problems related to structures and facilities that may by necessity be required to be located in these areas.

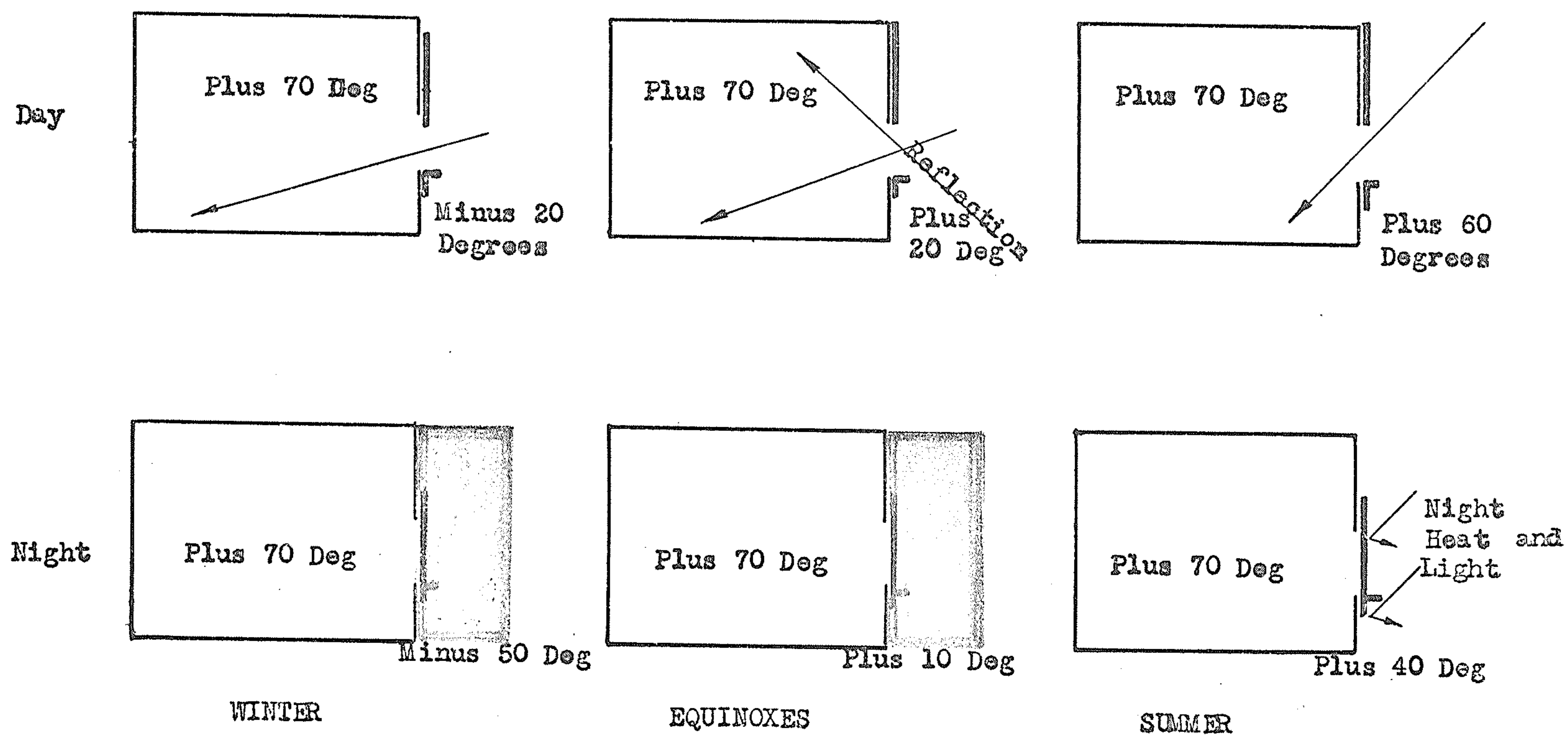

Figure 13

REQUIREMENT FOR A VARIABLE WINDOW DESIGN

Source:
Ralph Erskine, "Building in the Arctic", Architectural Design, May, 1960, p. 115.

From the foregoing it must be concluded that environmental factors are important determinants both in site selection for settlement purposes and in structural design. Failure to consider or to recognize these effects in any given situation could result in serious habitability problems or at the very best, an uneconomical or undesirable settlement situation which will ultimately detract from the settlement's amenity and attractiveness to prospective residents.

Native People

The origin of the Eskimo people is still conjectural and their historical movements across the continents are not definite. It is generally accepted that the present Canadian Eskimo has evolved from the western Thule culture group who migrated to the eastern Arctic about 1,000 years ago. The Thule culture was more advanced than the Dorset Eskimos, who had occupied the Canadian Arctic region from approximately 700 B.C. to 1200 A.D.

The Eskimos who inhabited the Arctic coast depended upon sea mammals for their main source of food, clothing, and shelter, while those who live inland depended upon the caribou for their livelihood. To survive the harsh environment of the Arctic the Eskimo developed the snow-house, or igloo, as a means of an effective and expedient shelter during the long winter periods. Caribou skin tents were utilized during the short summer period and when the absence of snow precluded the construction of an igloo. Skin covered boats, kayaks and umiaks, were used for open water travel while pack dogs carried supplies overland during the summer. A large sled pulled by a dog team was the prime method of winter travel.

The Eskimo community was loosely organized with no formal authority outside the family, although individuals of unusual hunting ability would gain local prestige and might exercise temporary and informal leadership across kinship lines. The senior male member was the head of the family and was the authority for all decisions within that kinship line. Eskimo religion was centred on supernatural beings believed to control the weather and hunting. The religious leader, or shaman, was respected for his supposed powers to intercede with the supernatural forces.[16] The Eskimo had no written language but they had a strong oral tradition in which legends of fact and fiction were transmitted from one to another.

The Eskimo people first came into contact with Europeans when the 17th century explorers sailed into the Arctic regions of North America in search of the

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[16] R.A.J. Phillips, <u>Canada's North</u>. (Toronto: MacMillan of Canada, 1957), pp. 34-35.

Northwest Passage to the Orient. Continued contact was maintained by the whalers who hunted the Arctic waters in the 18th and 19th centuries.[17]

With the establishment of the trading posts of the Hudson's Bay Company there has been an accompanying trend toward concentration of population around these posts. The trading posts were established in the proximity of good trapping areas, but the exact sites were chosen so that there was water access to the south and safe harbour anchorages. The native people visited the posts to trade and began spending considerable time at the posts to the extent that many families settled permanently. When the missions, police detachments, schools, and government agencies were established throughout the Arctic it was generally at these populated sites, thus further adding to the size of the settlement. With the concentration of people at these original trading post sites the surrounding areas were rapidly depleted of their wild-life resources and the traditional food supply for the Eskimo people was rapidly exhausted. It has therefore become necessary for the Eskimo people to depend upon a wage economy in order to purchase goods imported from the south, to exist at a reduced standard of living, or to depend on welfare payments for their

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[17] M. Dunbar, "The Arctic", Encyclopoedia Britannica (Chicago: William Benton, Vol. 2, 1963), pp. 331-338.

needs. This dependent status in which the Canadian Eskimo finds himself has not developed because of ecological circumstance, but due to outside forces over which he has had no control.

At the present time the Eskimo society combines features of the traditional ways of native life and features adopted from the external influences of the past one hundred years. For many of the older Eskimo people there has been little or no organization beyond the family as they hunt in small groups following the movements of game and the changing seasons. For others, particularly the younger generations, the traditional ways are only dim memories of early childhood. They have been educated in the white man's schools and have been taught trades and skills required by the more southern Canadian society. These young Eskimos have been taught that education is essential to obtain the skills necessary to earn a living, however many have not or cannot employ the skills in many Arctic settlements and are now listed on welfare rolls the same as their older relatives who did not receive the benefits of education. This situation in which the Canadian Eskimo finds himself is the result of advanced technology being forced upon a society at a rate faster than the people can adapt. Also Arctic development has not taken place at a rate that will absorb these educated Eskimos. This situation is further aggravated by the rapidly increasing population due to improved medical services and the provision of improved shelter. In 1966 the total population of the Northwest Territories was 28,738. Of this total there were more than 15,000 Eskimos living in the Canadian Arctic plus approximately 6,000 Indians located primarily along the southern edge of the Arctic boundaries. Therefore the native peoples of the Arctic constitute 70% of the inhabitants and as such contribute considerably to the Arctic environment and therefore must receive special attention when any aspect of Arctic settlement planning is considered.

CHAPTER IV

PLANNING CONCEPTS FOR ARCTIC SETTLEMENT

What is settlement planning? How can planning benefit Arctic settlements? It is important to establish the meaning of the term "settlement planning" and how its process can assist Arctic settlements to attain better living conditions primarily in the areas of improved housing, sanitation, health care, and social amenities. This chapter will define the meaning of settlement planning and how the comprehensive planning approach can be of benefit to Arctic settlement development.

Change is always occuring in any settlement and it is with this constant realignment and restructuring that planning is concerned. Planning is a method of guiding these changes, which will probably take place in due course, towards defined conclusions or goals to which these changes may not have otherwise lead as quickly. Therefore the purpose of settlement planning is to make these changes less disruptive, of greater benefit, and more equitable for the maximum number of residents.

Settlement planning is concerned with the goal of providing the best possible environment in which to live and work. To be effective settlement planning must be concerned not only with goals but also with the means of attaining these goals. Planning is "future oriented" in that it accommodates change in a pre-arranged pattern and through an orderly and co-ordinated method, the results of which are superior to those that would have otherwise developed by spontaneous decisions. This latter form of activity is often referred to as "crisis management" because decisions are made as urgent problems appear, leaving no time for investigation of long term effects or consequences.

The past is history and cannot be changed therefore it must be accepted as fact. However the lessons which the past can reveal are important determinants for directing future development. Planning is a long term activity and therefore directive in nature although some short term activities such as building siting and facade control are often part of the planning scheme. However the elements of changing technology, shifts in the economic base, social change, and trends in population growth are more often the core matters of the comprehensive planning approach.

Due to the continuing nature of settlement change, plans derived to provide the best possible environment in a settlement must be considered in the light of these on-going activities. This continuing process consists of deriving, organizing, and implementing programs which are designed to satisfy goals for social, economic, and physical well being, considering both immediate needs and those of the predictable future. While these phases of the planning process may be separately identified, they are also directly inter-related. It is often necessary to reconsider, re-analyze, and redesign all aspects of the planning process to adjust to changing conditions and circumstances.

Past settlement development in the Arctic has been characterized by uncoordinated and random patterns of growth. Only in very recent times has any form of planning, even in its elementary form of site planning, been considered and applied to Arctic settlements. Little or no consideration has been given to the special physical, socio-economic, and technical requirements peculiar to the Arctic environment. The random distribution of buildings in widely separated locations, as in Cape Dorset and Frobisher Bay both on Baffin Island, cause the residents unnecessary exposure to the severe climatic conditions and also make it overly difficult to provide adequate transportation, water, and sewage systems. The location of dwelling units in hollows or small valleys, as in Repulse Bay, allows them to be quickly covered with snow, resulting in physical damage to the structure in addition to creating an increased fire hazard due to blocked exits . In the absence of conscious planning, the siting and orientation of structures appears to have been decided on a very subjective individual basis. Their relation to terrain, grouping of facilities, and climatic factors have not been adequately considered while the limiting constraint of current road patterns appears to be an over-riding factor. In effect these decisions, made mainly by individual preference, have exaggerated Arctic hardships through inadequate planning considerations. Consequently the provision of new facilities and the re-arrangement of existing structures required to improve settlement conditions will be more costly and difficult to attain in the future stages of settlement development.

As settlement planning is concerned with a particular area, it cannot be divorced from the local scene. Local participation is required to ensure that the values and priorities which the residents hold are accurately translated into an action program which contains an adequate balance between physical efficiency and human satisfaction. In recent times many decisions affecting Arctic settlements have been made by non-Eskimo people residing in the settlement or in some cases by administrators located in southern urban areas. Thus the affairs of many Arctic settlements have been influenced primarily by outside forces and not as a part of an on-going social and cultural adaptation by the local people.

These few examples indicate that past activities have not resulted in a better standard of living for the majority of Arctic residents. There is an evident need to consider the variety of activities which are carried out in each settlement on a more comprehensive and rational basis. In addition to the physical aspects, social considerations must be adequately studied as the form of settlement is influenced by the ideas and values of its residents. As many of the present Arctic settlements are predominately native it is unacceptable to think of imposing standards and values upon the Eskimo people which are totally alien to their way of life. Therefore any improvements in settlement habitability must be closely tied to local educational and employment programs. For example, if a major resource development occurs near a native settlement improved housing must be provided for the native residents, but only as the individual native families are ready and desire relocation.

Only through well founded programs aimed at the social, physical, and economic problems of native settlements can this integration take place. The benefits of modern Arctic settlement development will only be meaningful to native peoples if they have an opportunity to participate in the formation and development of Arctic settlement plans.

Settlement development in the Arctic is inextricably linked with northern regional development policies. In its simplest form two phases of community development can be distinguished, the "camp" phase and the "planned settlement" phase. The camp phase saw the establishment of an ephemeral community, dominantly male in composition. The mining or logging camp has been the classic example in more southerly areas, though other resource-based settlements have been similar. Together with the "trading posts", these have until recently formed the traditional Arctic settlement.

Planned communities have only developed in the Arctic since the late 1940's. They are a reflection of two things: the wish to attract a larger percentage of married workers to Arctic settlements in order to encourage a more stable labour force; and a longer life expectancy for these settlements. This latter condition in turn reflects a change in approach to non-renewable resource development. Very large deposits of industrial minerals, such as iron in Labrador-Ungava, have displaced the precious minerals of gold and silver which historically have been short term bonanzas. Similarly there is increasing recognition of responsibility to harvest the Arctic's renewable resources of furs and fish rather than literally exploiting them for short term profits. These two factors have considerably strengthened the economic base of settlements founded on these activities.

The planned Arctic settlements which have recently developed are modern, comfortable, and essentially little different from suburban districts of more southern urban areas. Frobisher Bay and in particular Inuvik with its single family detached and row house dwellings located on spacious lots, are little more than Arctic adaptations of southern suburbia. There has been surprisingly little debate over the relative merits of reproducing, in an Arctic setting, the familiar features of modern southern suburbia versus the innovative introduction of an Arctic architecture combining the functional and the attractive. It has been assumed that the present day Inuviks and Frobisher Bays meet the requirements of Arctic residents. This assumption aggravates the common attitude of banishment held by many short-term residents in the Arctic. To make believe that an Arctic settlement is the same as a southern community does nothing to foster regional pride in the Arctic resident. To date no distinctive Arctic architecture has been developed except perhaps the adaptation of foundations and the use of utilidors which, although functional, can scarcely be labelled aesthetically pleasing.

There will be an increasing requirement for settlements in the Arctic due to natural resource exploitation, sovereignty, the need for a military presence, and to accommodate the increasing native population growth. But these new settlements will be fewer, larger, and better situated to meet the transportation and development needs of the present and the future. It is only in larger settlements ranging in size up to 10,000 residents, that the costly and permanent services and facilities now expected by all can be justified. Smaller camps, ranging in size up to 1,500 residents, with a relatively short life expectancy will operate out from one major centre, with a variety of commuting developed between them. With the increasing capital outlay involved in establishing a modern settlement in the Arctic, it clearly will be more and more difficult to abandon or relocate it in later years. To an unprecedented degree Arctic settlements such as Inuvik and Frobisher Bay represent a long term commitment in an area where large capital investments in physical plant have been recently made. Therefore an Arctic settlement policy must be undertaken based on concentrating future development at locations that can be delineated as regional centres and the remaining locations developed only as non-permanent settlements.

The regional approach to Arctic development provides the best alternative to the political and administrative rigidity of the past. "Region" can be a vague term, since there are numerous criteria on which it can be based; however, the one essential element is territorial space. The decision to develop a permanent regional settlement to service the smaller and more remote settlements must be based on a comprehensive planning approach involving such factors as; economics; Arctic settlement policy; transportation; local resources; the need for education, cultural and medical facilities; and engineering and construction restraints. Only a thorough, balanced assessment of the regional potential can provide the necessary background for such vital decisions. The need for a comprehensive planning approach has never been more critical than at present due to the pending development tide that will soon sweep the Arctic region.

The Non-Permanent Settlement

Most of the mining towns in Canada have been planned as permanent communities, that is, the physcial development in the community has been of a long term nature. Many of these communities have been provided with modern facilities and services; however, many have ended up as ghost towns or suffered serious growth and economic setbacks. The mines at Rankin Inlet and Port Radium no longer operate and the growth of these settlements has stagnated or declined as a result.

The abandonment of communities is forced upon the residents when the basic economic activity is terminated. This abandonment causes community losses in social capital, in housing, recreational and cultural facilities. Further, there are social costs incurred by the residents in the disruption of community life, the loss of friendships, and possibly changes in human values. A resource development company is able to "write-off" for taxation purposes the capital investment in the industrial plant but the residents may not be able to write-off their investments in dwellings and small businesses . Such was the case in Elliot Lake, Ontario, in 1962 when the uranium market evaporated. Thus the present practice of establishing elaborate fixed facilities does not appear to be the panacea for every new settlement. Every non-renewable resource-based activity has a limited life expectancy and the settlements that support these activities must be planned around flexible and dynamic concepts.

In theory, the non-permanent Arctic Settlement would be completely portable. It could be established on one site, picked up and moved to a new site as conditions dictate. The settlement would contain modern facilities and services that would provide a desirable living environment. Physical relocation of the town would be speedily accomplished with a minimum of inconvenience and expense to the residents. The buildings would be mobile or capable of being readily made so; the services and utilities would be capable of reclamation and re-use in a new townsite.

Present technology indicates that it is possible to build physical mobility into the structures of a settlement. Through the technique of prefabrication, a structure can be readily moved by simply dismantling it. Mobile and transportable homes also can easily and quickly be readied for movement. Utilities and services are less mobile and tend to be presently designed as fixed installations. If an entire settlement were to be relocated certain portions of the utility systems would have to remain as it would probably be uneconomical to remove them; however, major equipment could readily be relocated effecting considerable financial savings.

The principle of flexibility is an integral part of the concept of non-permanence in settlement. The feature of flexibility is essential to enable the physical community to adjust to the changing economic, social, and physical environment. The non-permanent settlement will be no exception to the fact that few communities remain stable or static in size and composition. The principle of flexibility must therefore be built into the community through the use of a flexible development scheme. The scheme must provide space and program for orderly expansion, consolidation in facilities and dwelling units, or shift in composition of the settlement, while trying to maintain a suitable standard of settlement services and basic facilities. For example, a settlement will expand to the extent that the basic resources will permit. Although based on a single industry, the non-permanent settlement must be capable of expansion to accommodate such functions as transportation and storage, mineral exploration, and additional mining activity. However, should the basic mining activity terminate, the community must be able to adjust to a decrease in population and/or complete relocation. Should the economic base of the settlement broaden, through the establishment of other basic and secondary industries and services, the settlement must be able to expand and develop into a permanent settlement.

This flexibility in community size, structure, and location requires physical mobility in the components of which the settlement consists and is the basis for flexibility. Flexibility in the siting of structures both within the same settlement and in a new townsite, flexibility in the grouping of the structures, and flexibility in the size of housing accommodation to suit the changing family requirements and life style. These are all necessary and can be achieved through the feature of mobility in the settlement's components and a physical layout that allows for expansion and contraction in size without loss of facilities, services, or amenities.

The major feature of the physical layout of the non-permanent settlement will be its compact nature due to the difficulties of distributing utility services. The proposed use of smaller, portable structures should permit the provision of smaller residential lots. This means a higher residential density and a more compact development than presently found in many Arctic settlements such as Inuvik, Cambridge Bay, and Frobisher Bay.

An important consideration in the settlement design is the successful integration of physical mobility in the buildings with the physical site. Much depends, of course, on the design of the structures. There must be, however, a sensitivity for the physical features of the site, and a knowledge of how they may be used to advantage in settlement layout. Desirable site features should be preserved and utilized to create a unity of building and site, of community and setting. Grouping of buildings should be employed to create livability and aesthetic harmony and to protect and preserve the natural environment.

A policy of land leasehold is proposed for the non-permanent settlement as such a policy would permit town relocation by eliminating the conflict with private land interests. It would also facilitate settlement adjustments including expansion and consolidation in size and number of facilities. Leases would in effect cover the use of the land occupied and the rental charged would only pay for the servicing of the lot. Land would in effect have no monetary value. Leases would terminate in the event of relocation and the land would revert to the Crown.

The principle of individual home ownership is proposed for the non-permanent settlement. The role of the resource development company as landlord generally makes for poor labour relations. Therefore many companies are following policies of promoting individual home ownership. The role of the company is properly that of resource exploitation. Thus, the dominance of the company may be reduced in the community through private home ownership, a policy which in all probability would be accompanied by community pride on the part of the residents of the settlement. Many new Arctic residents would probably prefer to rent their accommodation; however, if this is not provided by the company, purchase would be the only alternative. Either way the financial costs to the company are equal. If the company provides accommodation the wage scale is lower by approximately the amount invested in accommodation facilities.

From the foregoing discussion several planning criteria can be identified concerning the non-permanent settlement. These criteria are:

1. Physical mobility of all structures;
2. Physical mobility of most portions of the utility systems;
3. High degree of component standardization;
4. Flexible development scheme to accommodate expansion or consolidation in size and facilities;

5. High density development;

6. Physical layout must conform to the natural landscapes;

7. Leasehold land system; and

8. Individual home ownership.

The Permanent Settlement

During the first years of settlement development in the Arctic, mainly one and two storey wood structures were built, and these are still being built in many settlements such as Tuktoyaktuk, Cambridge Bay, and Frobisher Bay. Timber, usually delivered to the Arctic by ship, is the least expensive building material with which to build in the minimum amount of time, with unskilled labour, and with little mechanization and specialized tools.

Under the harsh environmental conditions prevailing in the majority of the Arctic regions, current designs for wooden structures do not provide the inhabitants with warm dwellings during the long winter period. This is primarily due to the drafts created by cold exterior walls and by air leaks around joints, windows, and door openings. The continuous and strong Arctic wind coupled with severe cold require a great quantity of heat, which puts undue strain on installed heating equipment, and this in turn is the cause of frequent fires which are quickly spread to nearby structures by the wind. As a consequence, wood structures of current design must be separated by a considerable distance, usually 100 feet, for fire safety.

Wood is good insulating material if utilized in sufficient thickness. Large wood timbers are also fire resistant under common fire conditions. Large wooden members in a normal fire, such as a small dwelling unit, will burn only on the outside surface usually to a depth of one-half to one inch. By the time this charring action takes place the main fuel for the fire has been exhausted and the timber still retains much of its original strength. A structure utilizing large wood timbers for walls, roof, and floor would provide good insulating values and be relatively fire resistant. The greatest disadvantage of this design is the large quantity of wood used to enclose a given area, and as trees do not grow in the Arctic region, all wood must be imported; therefore this design is most uneconomical for the Arctic region.

Wood has relatively low compressive and tensile strengths as compared to reinforced concrete and steel, and therefore the height to which wooden structures can be built is limited. This, together with the requirement for large fire safety separations, creates a very low settlement density which in turn provides little shielding protection against wind and blowing snow conditions. This situation creates little in the way of a favorable micro-climate for the inhabitants. The provision of services and utilities is more difficult and more expensive in low density settlements, which again is a disadvantage of current designs of wooden structures in the Arctic. Consequently, low density wooden structures are unrealistic under the environmental conditions prevailing in the Arctic from the point of view of both quality and economics. Hence they should be excluded from further large-scale permanent construction in the Arctic as far as possible.

Masonary structures consisting of reinforced concrete and/or concrete block provide not only a good insulating value but also are virtually fire proof (except for the contents stored inside). They have the added advantages of relatively unrestricted height to which they can be built due to the strength of the materials, and that most basic fabricating materials (sand, gravel, and water) are readily available in most Arctic areas.

The fire proof nature and the unrestricted height to which masonry structures can be built allow high density settlement development, thus improving the possibility of creating a milder microclimate by utilizing the shielding effects of these larger structures. The high density also decreases the unit cost of providing services and utilities. Consequently, high density masonry structures appear realistic from the habitability and environmental aspects and should receive serious consideration for large-scale permanent settlement development in the Arctic region.

The problem of the height of structures in Arctic settlements is one of the important considerations in Arctic construction. Even under ordinary conditions, the height of buildings affects the main aspects of settlement development, i.e. architectural, economic, and social. In the Arctic, the height of buildings predetermines the effectiveness of adopted wind and snow protection measures, the extent of pedestrian and transport communications, and the area covered by social and public services. All these factors play a very important role in the severe Arctic environment, and therefore it is only natural that the height of structures is more important in the Arctic than in more temperate zones.

The distribution of residential and public buildings within Arctic settlements must be compact to create areas of improved microclimate, reduce the time residents must spend in the dry frigid Arctic air when travelling between buildings, and to reduce the overall area to which utilities and services must be provided. As walking will be the prime means of mobility within Arctic settlements walking distances must be limited to approximately 1,000 feet to enable residents to easily walk to all activity areas in five to ten minutes. Suitable areas of microclimate can be created by shielding structures over six storeys in height, however, these buildings are not as economical to construct as structures in the ten storey range.

Following these criteria, an Arctic settlement of 5,000 residents would occupy an overall gross area of 50 - 67 acres thus producing a gross residential density in the range of 75 - 100 persons per acre. Population densities would vary either upward or downward depending on factors such as topography, climate, social characteristics of the residents, the economic basis of the settlement, and availability of construction materials.

Existing motor vehicles are not adapted to operate successfully in the Arctic. Their service life is reduced by two or three times, and even the use of frost-resistant rubber, antifreeze, and nonfreezing lubricants does not ensure reliable performance. The construction of roads and streets in Arctic regions is an expensive and often complicated task especially in permafrost areas containing extensive rock outcrops. It is essential that the mass reliance upon the motor vehicle for the transportation of passengers, goods, and services be limited and alternative means be developed and utilized within northern settlements.

If multi-storey structures are utilized, the settlement will occupy a compact area and may become a city of pedestrians. The traffic between residential and public buildings would flow along covered passages and open bridges or platforms raised above the surface of the ground, from which the snow may be cleared away without disturbing the natural thermal regime of the permafrost. In such a settlement there would be no need for private or public transport vehicles for people. The delivery of goods and services and the removal of refuse could be accomplished by means of small cars and trolleys travelling along the same galleries and passage ways.

The fact that the residents must be protected from the effects of the severe climate does not mean that it must be fully and permanently isolated from the natural environment. The inhabitants of northern settlements must be given an opportunity to spend some time in the open air when the weather is good, both in summer and winter.

Areas for people to walk, play games, skate, etc. should be provided in the immediate vicinity of the settlement, and the areas immediately surrounding it should also be converted into a recreational zone. Settlements in the Arctic must be habitable and contain most modern amenities. This requires a complex system of utility installations, the construction of which in permafrost presents many engineering problems, is expensive, and may possibly endanger buildings and structures located nearby. Therefore it is essential to eliminate underground utility systems and to install them within the buildings or in the galleries connecting them, but this above surface utility distribution system must not unduly restrict pedestrian or vehicle movements.

New architectural designs should be such that settlements in the Arctic will not only be habitable but will have a beneficial effect on the morale of the residents. It is essential to ensure that the morale of Arctic inhabitants is high and this may be achieved with the help of paintings, sculptures, colorful architectural designs, the planting of shrubbery in the artificial climate of public centres, and by providing artificial "daylight" during the Arctic night.

From this discussion concerning the permanent Arctic settlement the following planning criteria can be formulated:

1. The prime construction material should be masonry or other fire resistant materials;

2. Medium density development in the order of 75 - 100 persons/acre;

3. Structures ranging up to ten storeys in height would be sufficient to ensure economical construction costs and also to provide an artifical microclimate for the settlement;

4. Modern facilities and services must be provided within easy walking distance for residents;

5. Physical layout of the settlement must be such as to limit the reliance on the motor vehicle for basic transportation of residents, goods, and services.

6. Outdoor recreational facilities must be provided for use both in summer and winter; and

7. Physical layout must conform to the natural landscape.

CHAPTER V

APPLICATION OF PLANNING CONCEPTS FOR ARCTIC SETTLEMENT

The planning of dwellings and settlements for the Arctic in practice is carried out by a combination of many government and private organizations. Owing to the lack of a firm settlement policy for the Arctic region, certain problems are frequently solved differently even in the presence of identical conditions. These organizations make wide use of designs evolved for the middle latitudes. This is due in part to the widespread misconception among workers in these organizations that it is merely necessary to introduce small corrections in the southern design of enclosing structures and foundations in order to adapt to Arctic conditions any design meant for the southern regions. Another retarding factor to Arctic design innovation has been the type and style of accommodation and facilities that new residents expect to find in the Arctic. As most of these new residents have arrived from more southerly locations they expect to find and live in accommodation very similar to the type and standard they occupied in their last place of residence. As a result of these two factors many new

Arctic settlements such as Frobisher Bay and particularly Inuvik, have been developed by using southern techniques and methods. To remedy this situation the Arctic settlement policy should encourage new residents to migrate to the Arctic region who are young, energetic ambitious, and who expect to encounter a new and invigorating life style.

If the Arctic is to be developed for the reasons discussed in Chapter II then plans and designs must be developed that will more adequately provide for the needs of the Arctic resident. This distinctive Arctic architecture must fully exploit the extensive construction technology that has been accumulated over the past three decades and utilize it to provide dwelling and facility designs to tame the severe environment of the Arctic.

Only through a comprehensive planning approach can this requirement be fully accomplished. At the broad level factors to be considered include; the policy of Arctic settlement, the size and location of these settlements, the relationship between the need for a resources settlement and the need for an administration based settlement, the type of residents, the level of physical infrastructure the residents will require, and the access and egress of various transportation modes. On a narrower level which pertains to the actual settlement the factors that must be considered include; the site and natural environment and how this affects the engineering and construction technology, the architectural design and its relationship to engineering restrictions, the economic base and its effect on physical layout and architectural design, and the type of resident that will live and work in the settlement and what accommodation and social facilities will be required.

All of these factors and others must be adequately considered, debated, and analyzed to determine possible combinations and effects upon the planned Arctic settlement. This comprehensive planning approach is the only method by which more amenity and economy can be injected into Arctic settlements. There is no substitute for sound deliberate thinking on the factors that affect Arctic settlement and plans and designs developed by this method will prove more efficient and economical in the long term. The hasty solutions which are currently being employed as stop-gap measures, such as compact prefabricated dwellings situated on individual lots, provide only a temporary solution to Arctic habitation and will require replacement in the near future with more permanent types of structure and facilities. These temporary dwellings provide adequate housing suitable for occupation up to five years, but the error in this type of housing is that it is being utilized extensively in all Arctic settlements to provide permanent accommodation for the residents. For example, 52 single family detached units of wooden prefabricated bungalow design were erected on 50 - 60 foot lots at Tuktoyaktuk, NWT, during the summer of 1969 and 1970. These units were designed and fabricated by a company in Regina, Saskatchewan, and were very similar in design to units manufactured for rural Saskatchewan, 1,500 miles south of Tuktoyaktuk.

A brief visit to most of Canada's Arctic settlements will adequately illustrate that little has been accomplished in progressing towards a coordinated logical settlement policy or a settlement development plan. More research and actual experimentation is required, similar to the Inuvik project, to develop a suitable design for the Arctic. Once a basic design is developed that provides the required habitability then further refinements can be instituted as new settlements are constructed. Through this on-going process of "design - analyze - improve" an evolution will undoubtedly occur which will lead to settlements in the Arctic that will provide the residents with a high standard of comfort and convenience which will ease the effects of the harsh environment and often bleak landscape.

As previously discussed in Chapter III, the Arctic environment is characterized by low termperatures, blizzards, drifting snow, and the prevalence of permafrost. During the long winter, the hours of darkness grow longer, eventually persisting around the clock. In the short summer the hours of daylight eventually becomes 24 hours long. Considering the combined effect of the winds, the low temperatures, and the drifting snow, it is obvious that these factors must have a profound effect on the choice of heat-conserving measures, the layout of structures, and their placement on the site.

To reduce the harsh effects of the wind, taller structures can be used to shield lower buildings thus creating an artificial climate or microclimate. Special designs can be adopted in settlements utilizing an artificial microclimate in order to provide protection against snowdrifts in regions with strong and frequent winds. This will first of all involve the use of multi-storey buildings for protection against snow and for the modification of wind directions so as to prevent accumulation of snow in undesirable places. This will require special orientation of buildings relative to the prevailing wind direction, the streamlining of buildings, provision for ventilated crawl spaces beneath the buildings to permit the free passage of snow, and the installation of special aerodynamic devices on buildings. These measures will considerably reduce the precipitation of snow within the residential areas and will result in considerable financial savings for snow removal.

Microclimates[18] can be created by placing large structures on the windward side of the settlement. These structures break the force of the wind and also tend to deflect the drifting snow around the edges of the settlement. The structures utilized as wind shields must be designed specially for that purpose as the winds will produce a considerable temperature drop and create drafts in rooms on the windward side. This condition precludes the use of standard residential buildings; however, residential structures which have been specially designed

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[18] Microclimate relates to a specific area within which the climatic conditions are significantly different from the area as a whole. Microclimatic areas are usually created by eliminating natural elements such as wind, sunlight, or rain.

for this shielding purpose may be used. One such design is the gallery apartment in which the common hallway is placed along the windward wall. This in effect provides two wall thicknesses plus a heated space between the windward side and the apartment. This design also has the advantage that no windows or doors need be provided on the windward side of the building therefore making the structure virtually draft free. Figure 14 illustrates a simple gallery type apartment layout.

Structures which are not used for wind shielding can be of a design more suited to their accommodation task, as they will be located within the microclimate area created by the shielding structures. It is important to ensure that high quality workmanship is obtained in all construction projects throughout the Arctic as poor joints and improper alignments can cause excessive heat losses creating drafts as well as increased heating costs.

The Non-Permanent Settlement

Non-permanent settlements could be established when extensive future growth is unlikely and the economic base upon which the settlement is founded has a relatively short life expectancy. Settlements of this nature could

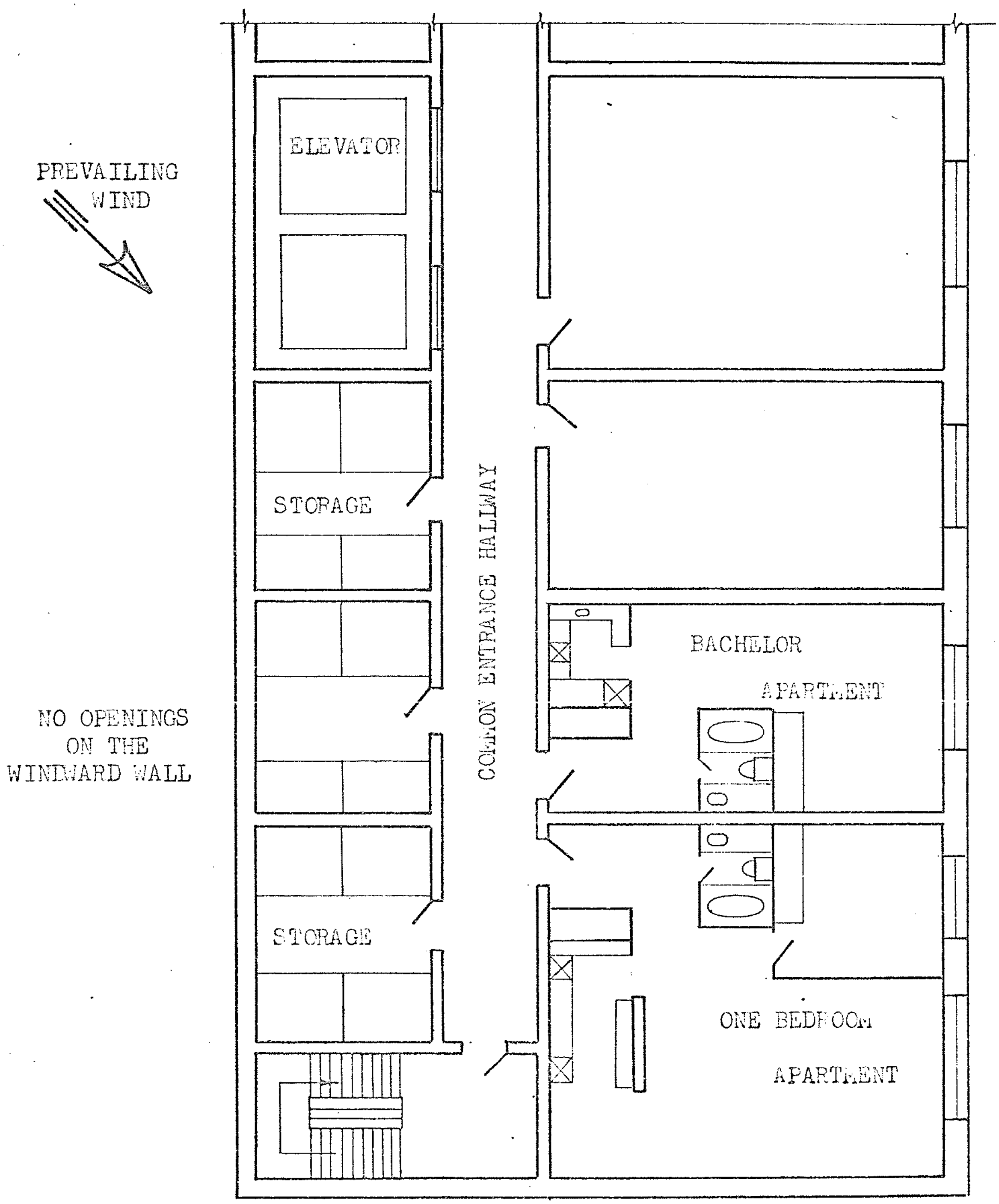

Figure 14

TYPICAL GALLERY TYPE APARTMENT

range in size up to 1,500 residents and could consist of dwellings and public facilities which are mobile and possibly air transportable. A site suitable for an all weather airstrip is a requirement due to the distances between these remote Arctic settlements necessitating the requirement for fast and convenient travel.

Dwellings could consist of pre-built or prefabricated units not unlike contemporary mobile homes. The dwellings could be either single or double width units depending on the amount of floor space required by the resident. The mobile dwellings could be connected to a central pedestrian corridor leading to a central area containing commercial, recreational, and other public facilities and services. Figure 15 illustrates a conceptual layout for a non-permanent settlement.

If suitable areas are limited in size or the creation of a microclimate is desirable, multi-storey structures could be created with standard mobile dwelling units. A structural framework could be built to support the individual units. A header gallery would be required as part of the pedestrian corridor to provide individual access and to carry utilities to each unit. These multi-storey structures would be only two units wide to enable each unit to have a view from its windows. Individual

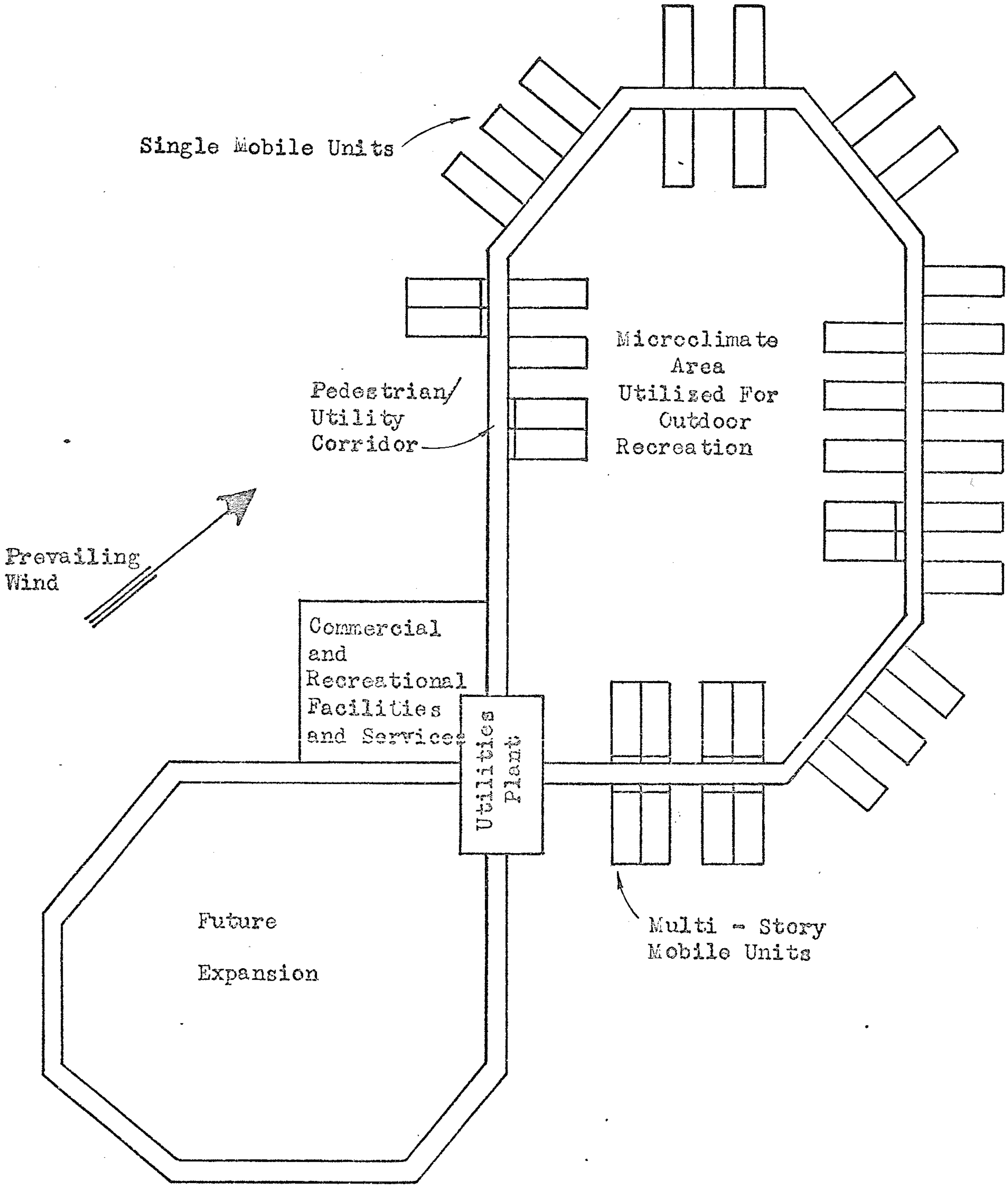

Figure 15

CONCEPTUAL NON - PERMANENT SETTLEMENT

units should not touch one another allowing the space to be utilized as a fire wall.

The commercial, recreational, and public facilities complex could consist of mobile units interconnected to provide the required space for the facilities and service. In the early stages of development it is unlikely that highly diverse commercial facilities could be provided. Most likely only one shop of each type could be established, stocking only common and large demand articles. Selective purchasing and speciality items would be obtained from other larger settlements on a periodic commuting basis by each resident concerned.

The distribution of service utilities in Arctic regions does create serious problems. The normal method of burial below the frost line cannot be used in permafrost regions as the liquids would freeze in the pipes. A distribution system is required that not only prevents the liquids from freezing but also does not disturb the permafrost. One system successfully used distributes the utilities through an above ground insulated piping system commonly referred to as an "utilidor". The typical utilidor is an elevated insulated box containing utility lines laid out in loops from a central utilities plant.

A utilidor system often contains sewage collection lines, heating pipes, and electrical cables in addition to the water line. Figure 16 shows two types of utilidor systems that have proven successful in Arctic regions. Utilidors are expensive, approximately $100 per foot at Inuvik,[19] and therefore can only be justified for settlements where permafrost conditions are severe. In this situation where a non-permanent settlement could have a pedestrian corridor, the utility distribution system would be built into the floor of the corridor and constructed similar to the large utilidor illustrated in Figure 16.

The interaction of a structure with the ground is always the primary consideration in foundation selection and design, but in permafrost areas this must include thermal interaction as well. In a few ideal locations where bedrock is sound and ice-free, coarse grained soils are present, and the thermal factor can be neglected, conventional design practices can be followed. Such conditions in the Arctic are rare but do occasionally occur as at Frobisher Bay on Baffin Island. In most cases the design approach is to preserve the permafrost in its original frozen state by insulating the base of the structure to prevent heat transfer. The elimination

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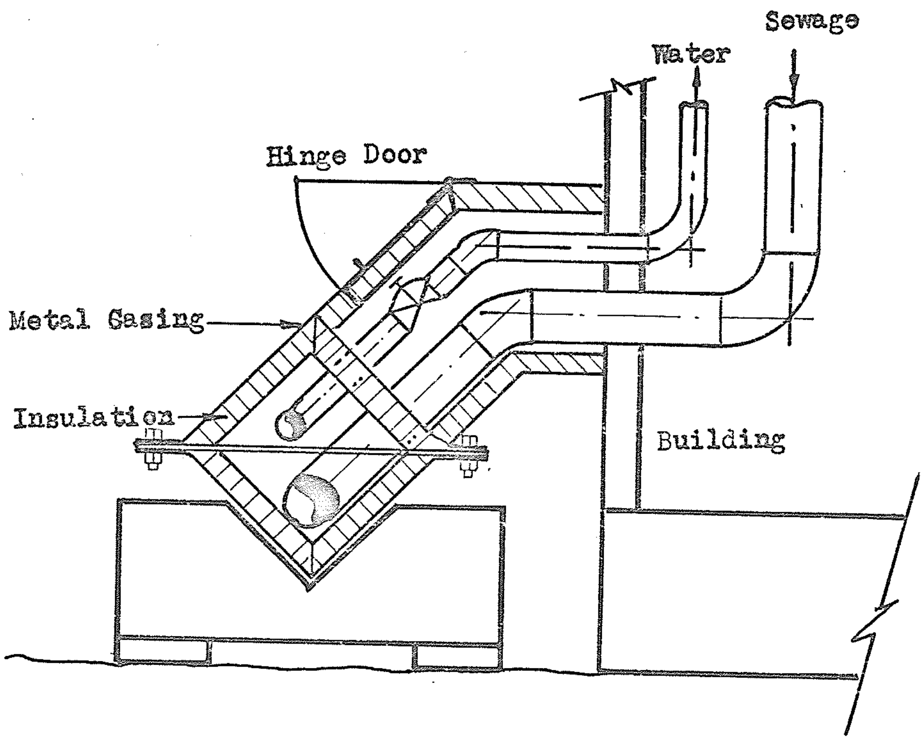
[19] R.F. Legget and H.B. Dickens, Building in Northern Canada, Division of Building Research Technical Paper No. 62 (Ottawa: National Research Council, 1959), p.15.



SMALL UTILIDOR WITH CONNECTION TO BUILDING

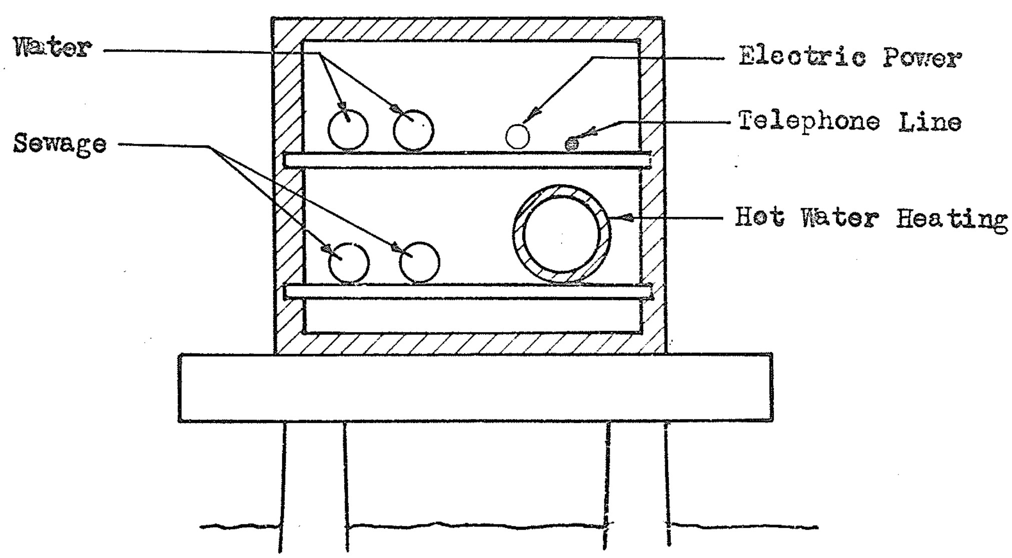


Figure 15

LARGE UTILIDOR

Source:

N.A. Lawrence, "Northern Engineering and Construction", paper presented to the Northern Development Conference, Regina, November 25-26, 1968.

of heat transfer can be accomplished in many ways, the most common being: piles with a free air space of at least three feet; massive gravel pads varying in depth from three to ten feet; artificial insulation material such as styrofoam placed under floor slabs, refrigeration, and ventilation by large ducts circulating cold air.

Pile foundations have been found to be a suitable type of foundation as they can be readily coupled with a free air space to prevent heat transfer. Piles are also the best type of foundation for use in regions where the active layer is relatively deep (between five and ten feet), for structures with heavy floor loads, and for building sites which are poorly drained.

Site preparation is important prior to the actual placing of the piles. The entire site should be covered with a layer of gravel to a depth of 18 to 24 inches to preserve the natural moss cover which insulates and protects the permafrost. Holes are either bored or steamed into the permafrost, the pile is placed butt end down and driven to refusal with a drop hammer. Wooden piles may be of any suitable type of wood with the most common being fir, pine or spruce. The minimum size of the smallest end should not be less than eight inches in order to provide an area large enough to support structural members.

The pile tranfers its load to the permafrost through a combination of end bearing and adfreezing strength.[20] On this basis, the depth of the pile into the permafrost should be sufficient to keep it well below the thawed area. Another consideration in using pile foundations is the tendency for piles to be lifted upwards by the forces developed by the freezing of all or part of the active layer. These forces are significant only in frost active soils such as silts and fine sands. To overcome this uplift force, the pile should be set into the permafrost far enough that the adfreeze or friction force plus the load on the pile is greater than the uplift force. Using a rule of thumb, a pile is generally placed into the permafrost at a depth equal to at least twice the thickness of the active layer. Alternatively,the pile may be anchored in the permafrost by means of shoes or collars. Occasionally, the pile may be greased or loosely wrapped with tar-paper over that part of its length situated in the active layer to prevent adhesion of the frozen soil over that section. Piles may be of wood, precast concrete, or metal, though the two latter do transfer more heat downward into the permafrost layer. Figure 17 shows a typical

[20] Adfreeze strength is the force developed through the action of the solid freezing to the surface of the pile.

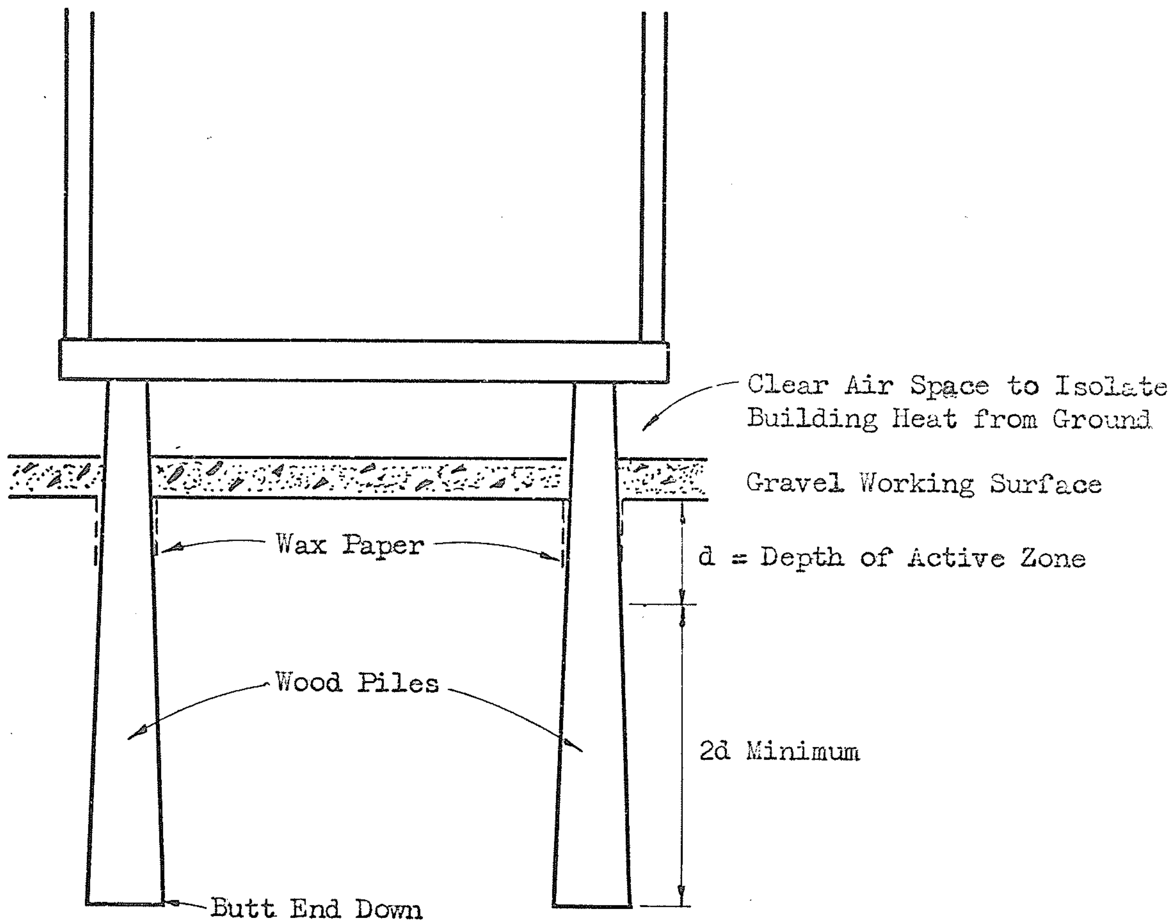


Figure 17

PILE FOUNDATION

Source:
N.A. Lawrence, "Northern Engineering and Construction", paper presented to the Northern Development Conference, Regina, November 25 - 26, 1968.

piled foundation. The spacing of piles depends on the type of structure and the load to be supported. At Inuvik where most buildings and houses are limited to two storeys, the piles are set on a ten foot grid.

Massive foundations consisting of large gravel pads have proven successful for many northern structures. Gravel or other non-frost susceptible soil is laid upon the undisturbed natural ground cover. These pads vary in depth depending on the location but are usually three to ten feet in depth. As with piled foundations heat transfer must be minimized and again this is accomplished by the use of a free air space. Concrete or wooden mudsills are laid upon the gravel pad which support the raised structural floor. Figure 18 illustrates a typical massive foundation utilizing a thick gravel pad and mudsills.

Massive gravel pads protect the permafrost table by insulation due to their depth. In regions where gravel is not readily available or where structural floor levels must be at grade, artifical means of insulation can be used such as a layer of styrofoam to act as a heat barrier. Figure 19 illustrates two examples of the use of an artificial insulation layer. This system is often used in structures

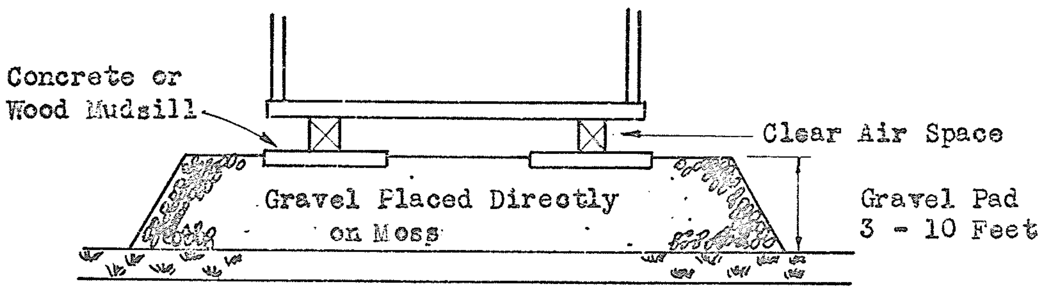


Figure 18

GRAVEL PAD ON MUDSILLS

Source:
N.A. Lawrence, "Northern Engineering and Construction", paper presented to the Northern Development Conference, Regina, November 25 - 26, 1968.

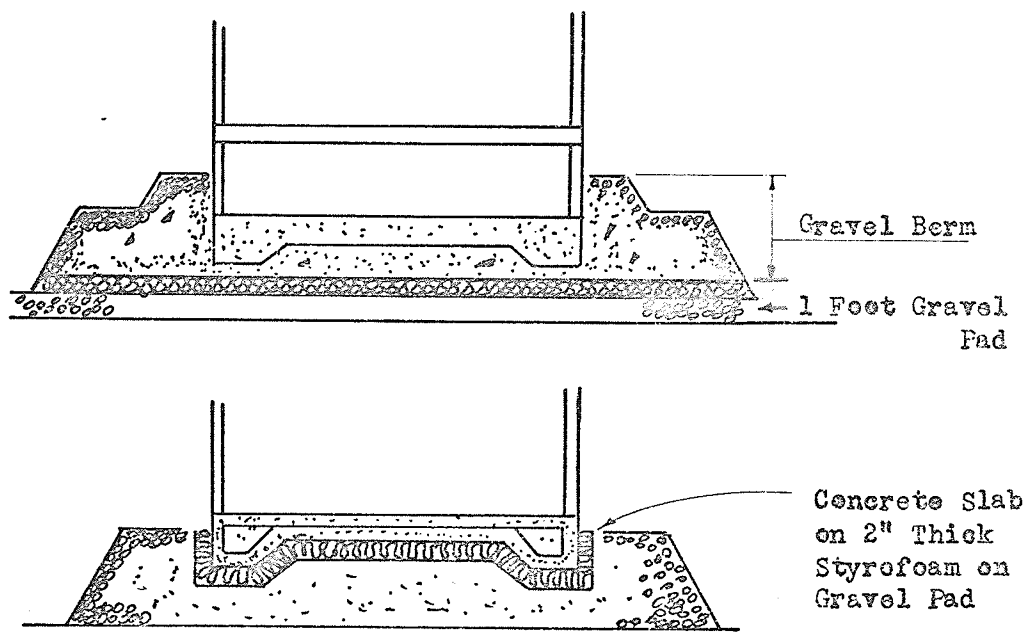


Figure 19

CONCRETE SLAB ON GRAVEL PAD WITH INSULATION TO RETAIN PERMAFROST

Source:
N.A. Lawrence, "Northern Engineering and Construction", paper presented to the Northern Development Conference, Regina, November 25 - 26, 1968.

that must be heated and are subject to heavy floor loads such as central heating and utility plants.

Foundation design for the non-permanent settlement could possibly consist of a simple piled foundation with approximately eight piles supporting each 12 by 50 foot dwelling unit. Another method could be to use a gravel pad with mudsills supporting the structures to create a free airspace in order to eliminate heat transfer to the frozen ground. Whatever design is chosen the principle of minimum natural ground disturbance is of the utmost importance. The Arctic environment is so fragile that any surface disturbances can cause severe damage and scarring through thermal erosion of the entire layer caused by shifting of the permafrost level.

When the economic base of the non-permanent settlement begins to falter or is completely exhausted, the entire settlement is capable of being moved either over land or by large cargo aircraft. The dwellings can be readily disconnected from the pedestrian corridor and moved as units. The pedestrian corridor also can be readily taken apart in sections for ease of mobility. The utility plant is the only component of the non-permanent settlement which could not be moved as a unit. Some portions of it would probably remain at the original site as it would be unecomonical to remove them; however, mechanical components could certainly be moved and utilized at a new location.

Current construction technology appears to present few difficulties in establishing and maintaining this form of non-permanent Arctic settlement.

The Permanent Settlement

Permanent settlements will be required in the Arctic to accommodate and service the growing number of native residents and those employed in resource exploitation , sovereignty, military and scientific activites, and administration. These permanent Arctic settlements could be established on a regional basis to provide for the needs of not only the immediate settlement but also to service the surrounding area which in some parts of the Arctic would contain a considerable number of square miles. These regional centres could contain most of the services and facilities that would be required to provide the amenities of everyday life such as; hospitals, academic institutions, department stores, specialty shops, restaurants, movie theatres, entertainment spots, and small service shops.

The permanent settlement could service the surrounding non-permanent settlements by providing a greater number and variety of services and facilities to their residents as they commute periodically to these permanent regional centres. This commuting to and from the regional centre could be accomplished by air travel because a large airfield complex capable of handling most large cargo and passenger aircraft would be an essential part of the permanent Arctic settlement.

Permanent settlements could be high density developments designed to minimize walking distances to various facilities and services. The entire complex could be interconnected by a system of interior streets and protected pedestrian passages thus eliminating the need to venture outside unnecessarily. The buildings could range up to several storeys in height in order to create microclimate areas for smaller structures.

The first floors of buildings, elevated as much as ten feet above the ground, could be utilized to accommodate the lobby, meeting rooms, storerooms, and for the installation of utilities. The residential buildings could be connected with the commercial centre by covered passages to protect the residents from the severe Arctic environment. The commercial centre with shops, schools, and entertainment facilities could be designed in the form of an elongated block that could resemble a covered mall illuminated by skylights and landscaped with decorative shrubs and plants, with benches and small recreational areas interspersed.

The age structure of the permanent Arctic settlement will be biased towards the young due to the age characteristics of the current native population and also because of the type of southern residents that will be attracted to the Arctic. The 1966 Canadian census indicates that more than one-half the residents of the Northwest Territories were aged 19 years or less. This factor coupled with the proposed settlement policy of attracting those individuals who are young, energetic, and ambitious will probably produce an Arctic population that has the following characteristics; youthful; many single males of working age; native families with three to five children each; and few older persons.

This abnormal age structure will dictate the type and form of dwelling units that will be required. An age structure of this nature could be adequately accommodated in compact apartment units for the single and childless couples while terrace type units would house the larger families. No single family detached dwellings are envisaged due to the increased cost of initial construction and servicing plus the problem of low density land utilization.

A permanent Arctic settlement of this nature would require few conventional motor vehicles as most areas of the settlement would be within walking distance for residents travelling through climate controlled passages and elevated walkways. The limited requirement for surface transportation of people, goods, and services could be provided by small cars and trolleys travelling along the same passages and walkways used by pedestrians. Transport to more distant facilities such as airports and industrial sites could be provided by advanced forms of air cushion vehicles which cause little damage to the delicate natural tundra. These transportation methods would prove more economical to operate than current methods such as conventional passenger cars and trucks requiring extensive road networks which permanently scar the terrain. Unlike current conventional motor vehicles, air cushion and ultra light wheel load vehicles cause little damage to the natural terrain and require little surface preparation to permit effective operation. In this way the delicate natural surface of the Arctic region could be protected from extensive surface scarring through heat and water erosion of disturbed areas.

Foundation design for the permanent Arctic settlement is an important and often critical factor. Ideally, foundations should be set upon solid rock to ensure structural stability; however this is often impossible in the Arctic and other effective methods can be utilized. A foundation design similar to the simple pile type is the pedestal and footing system illustrated by Figure 20. This system involves more site work and involves excavation to or into the permafrost layer. The advantage is that fewer pedestals than piles are required and this may be advantageous if timber piles are not readily available and suitable aggregate for concrete is available.

Refrigeration by mechanical means may be justified for maintaining the foundation soil in a frozen condition where rigidity in the foundation is absolutely necessary. The technology associated with this type of foundation is to use the refrigeration coils as a heat barrier. A thick gravel pad is used to level and raise the area to provide adequate drainage. The refrigeration coils are usually bedded in a six inch layer of concrete and then a thick concrete slab is constructed to carry the structural load. The refrigeration would induce the permafrost table to move up to the level of the refrigeration coils providing a solid frozen foundation directly under the concrete slab. Figure 21 illustrates a typical refrigerated foundation installed at Thule, Greenland, to support a

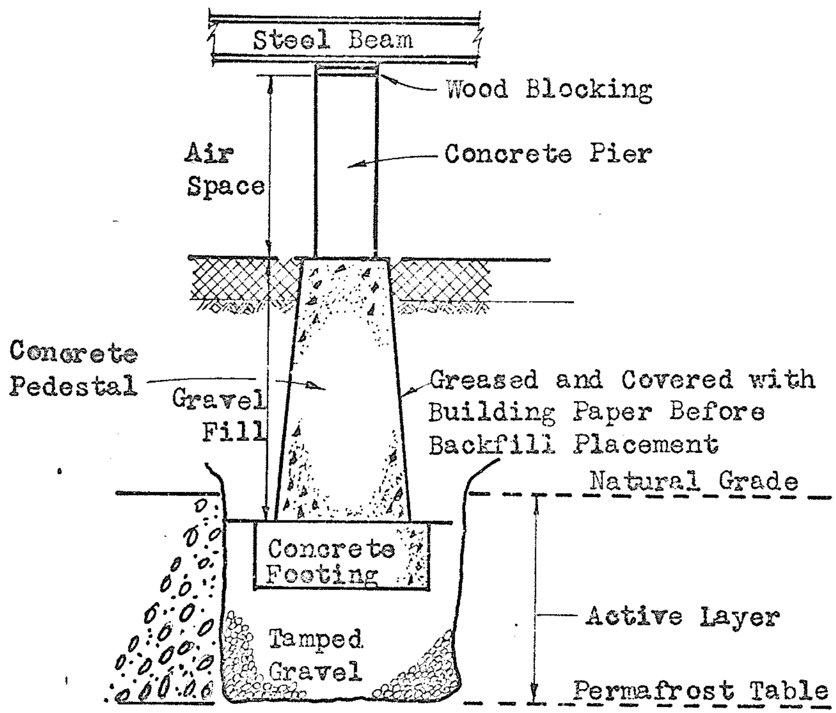


Figure 20

PEDESTAL AND FOOTING FOUNDATION

Source:

Frederick J. Sanger, Foundations of Structures in Cold Regions, U.S. Army Corps of Engineers, Hanover, N.H., June, 1969, p.14.

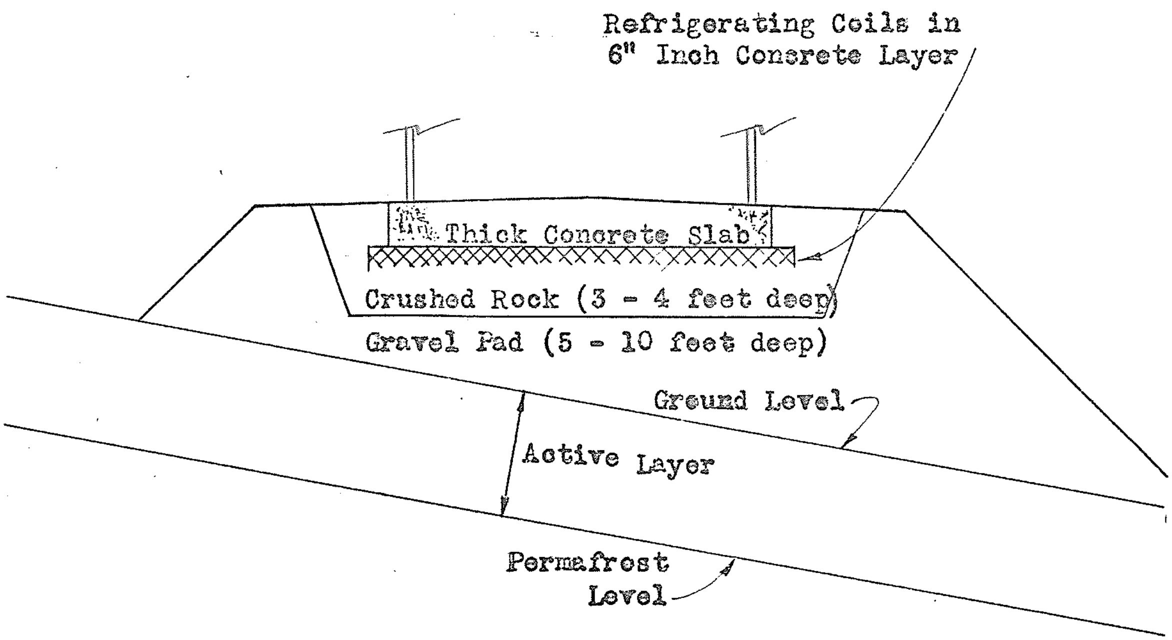


Figure 21

REFRIGERATED FOUNDATION

Source:

Frederick J. Sanger, Foundations of Structures in Cold Region, U.S. Army Corps of Engineers, Hanover, N.H., June, 1969, p. 10.

radar structure subject to large dynamic loads. This type of foundation could also be used under such structures as central heating and power generation plants.

Other underground cooling devices such as ventilating pipes and ducts can be used in buildings with a large load on the floor of the first storey when it is impossible to provide for a crawl space. In such cases silty soil subject to heaving must be replaced to the depth of summer thawing by soil that is not subject to heaving to avoid deformation of the cooling ducts and the floor of the first storey. The cooling ducts are located near the foundation of the building and can be single or in groups.

Undergound cooling devices should have the following requirements; accessibility for inspection, cleaning and repair, for which the diameter of underground ventilation ducts should not be less than two feet; unconditional reliable waterproofing; and they should be located above the foundation footing. Ventilation of the underground cooling pipes is either by draft ducts with deflectors or by mechanical ventilation. Inlets must be designed in such a manner that they are kept free from snow in the winter and water in the summer.

Ducted foundations, illustrated by Figure 22, have been successfully used for many heated structures that require the floor slab at the natural grade elevation, such as aircraft hangars. The circulating cold air acts as heat barrier between the heated floor and the permafrost table. Constant monitoring and maintenance is required for this type of foundation as any malfunctions in the ventilating system can cause irrepairable damage such as differential settlement. This type of foundation was used on several aircraft hangars at Thule, Greenland.

From the foregoing description of various types of foundations that can be used in permafrost regions it is evident that no one type is an ubiquitous solution. Only careful and detailed site and soil investigation of each construction site will provide the data necessary to select the most suitable foundation type and then the actual detailed design of that foundation type.

The provision of potable water presents some serious difficulties in Arctic regions due to the restricted sources of supply and distribution problems created by permafrost and climate. The abundant surface water in the Arctic does not generally provide an adequate water supply as most lakes and ponds are shallow and

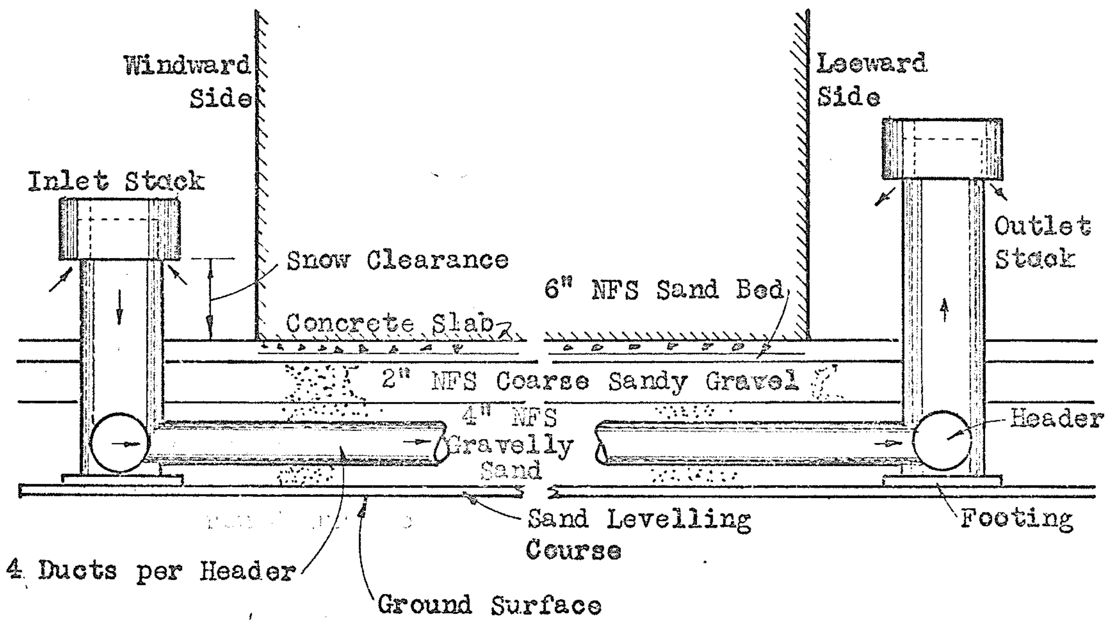


Figure 22

DUCTED FOUNDATION

<u>Source:</u>

Frederick J. Sangar, <u>Foundations of Structures in Cold Regions</u>, U.S. Army Corps of Engineers, Hanover, N.H., June, 1969, p. 16.

therefore freeze to the bottom in winter and adequate ground water supplies are uncommon due to the permafrost. An adequate source of potable water can be supplied from a flowing river or deep lake with a treatment process differing little from southerly locations. In most situations simple settling, filtration, and chlorination are sufficient.

Sewage disposal in the Arctic region requires special attention. The harsh environment severely retards the natural biological processes to such an extent that the natural decomposition that normally renders sewage to a harmless state in more southerly locations does not even begin to occur in the Arctic. The current practices of discharging directly into watercourses or large bodies of water must cease. This method of disposal is only a form of dilution and grave pollution problems will occur in the future as the result of this short-sighted practice.

Sewage lagoons have met with some limited success in the Arctic. The required size of the lagoon cells is several times that of southern installations due to the very slow rate of organic decomposition during the cool and short Arctic summer. Also the problem of altering the ground thermal regime by placing this body of water on the permafrost can cause significant settlement and ground shifting problems. Thus lagoons appear to be suitable only where specific ground and topography conditions will permit their construction and where a small population is involved.

A more positive solution to sewage disposal but also more expensive, is a packaged sewage treatment unit. The unit is compact, efficient, and is available in various capacities. It is basically a tank with several chambers for settling, aerating, filtering, and chlorinating which could be installed in a heated building. Units of this nature could be centralized to service the entire settlement or decentralized to service smaller areas within the settlement.

Some research has been conducted into methods of conserving water through recirculation and multi-use systems. Figure 23 illustrates a partial recycling system which re-uses waste water for flushing toilets. Colour in the flushing water has been found objectionable by some users, however, this simple recycling principle greatly reduces water demand and is most advantageous in regions where water is scarce. Figure 24 shows a more

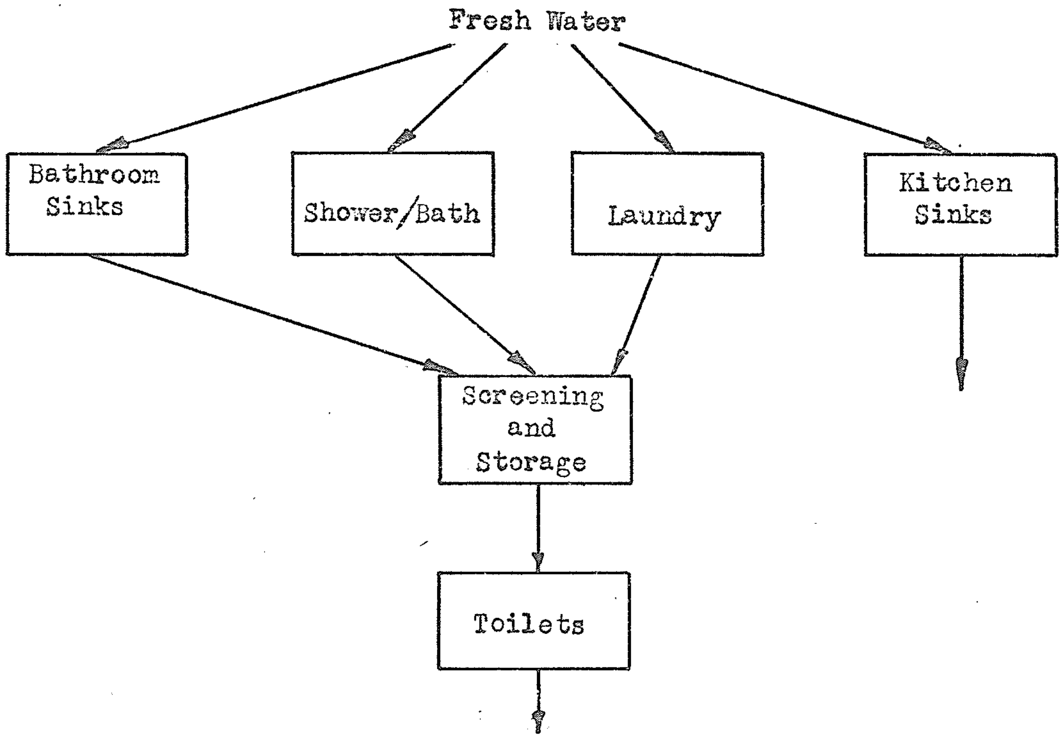


Figure 23

PARTIAL WASTE WATER RECYCLING SYSTEM

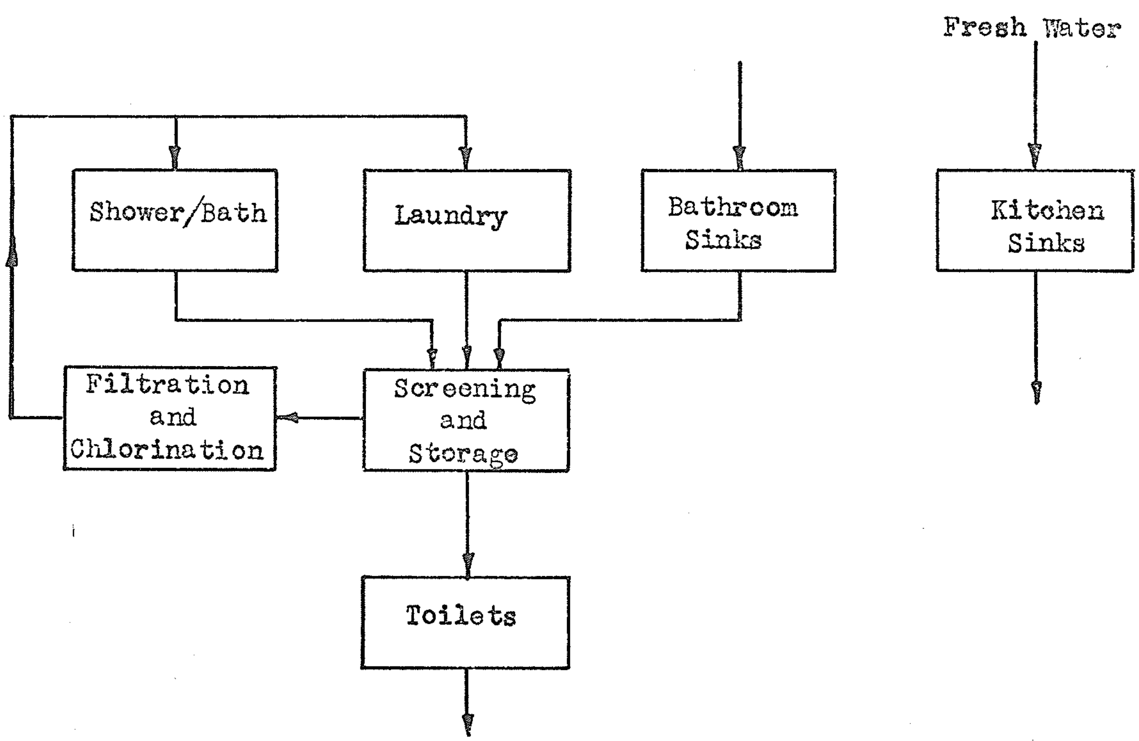


Figure 24

ADVANCED WASTE WATER RECYCLING SYSTEM

advanced recycling system which re-uses waste water for all functions except kitchen use. The waste water is recycled directly for toilet flushing but for other uses the waste is filtered and chlorinated. This principle of recycling can be projected to include total re-use. A system of this nature would simply treat all sewage to the tertiary[21] stage and then use this effluent as the raw water for a complete water treatment process. In this manner complete buildings or complexes could be self-contained internally in respect to water supply and sewage disposal. Figure 25 illustrates a complete recycling system of this nature. Figure 26 illustrates two packaged treatment units that are capable of sewage treatment to the tertiary stage and complete water treatment. These two units coupled together would be capable of providing sewage and water treatment for a residential complex containing 1,000 persons. The units are compact, requiring a floor area of approximately 1,000 square feet

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[21] Tertiary sewage treatment is the third and final stage of current treatment methods. Primary and secondary treatment remove solids and neutralize the wastes; however, they do not remove the excess nutrients which cause excessive algae and plant growth in the receiving water course. Tertiary treatment removes these excess nutrients thus producing a completely stable effluent.

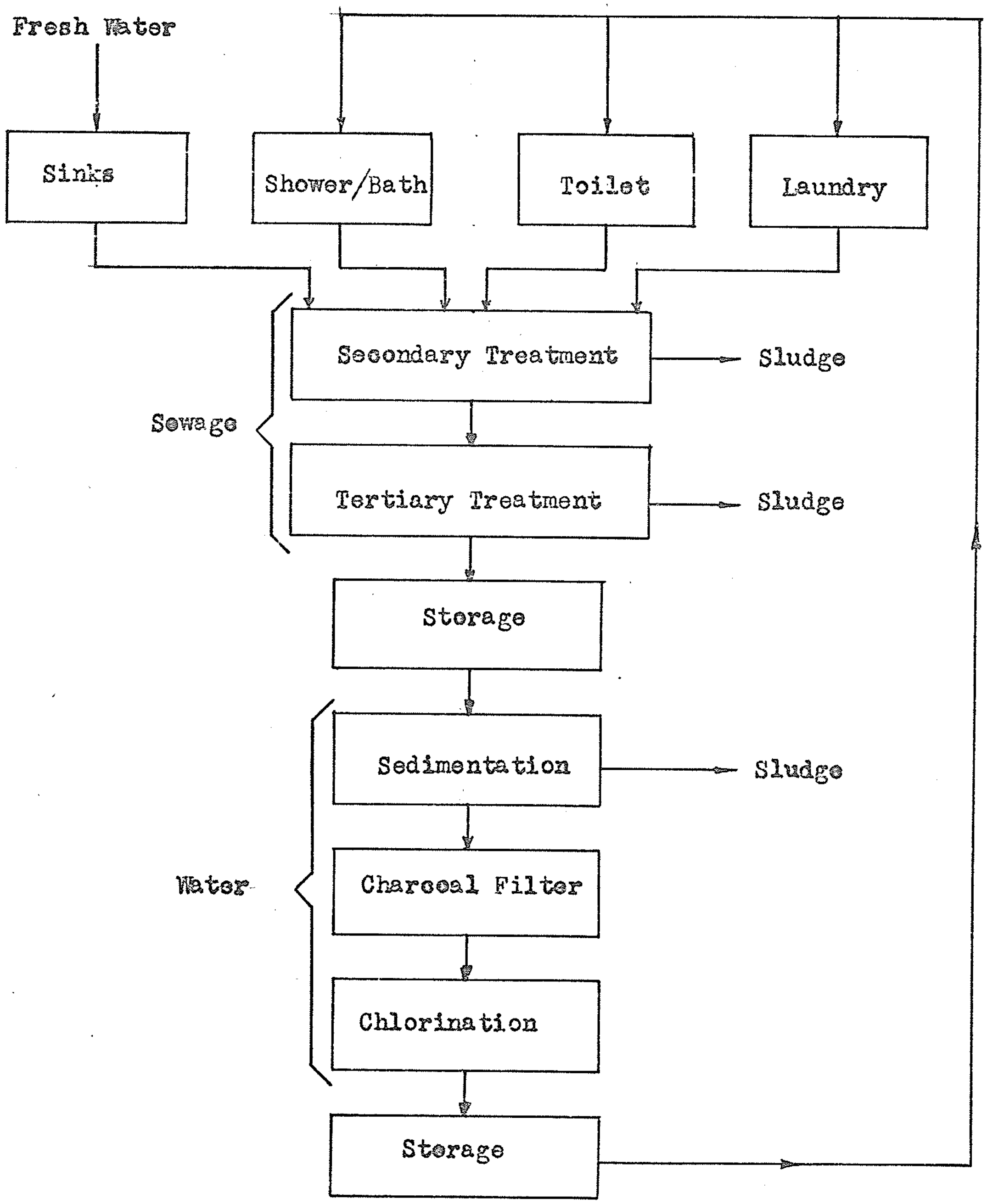

Figure 25

COMPLETE WATER RECYCLING SYSTEM

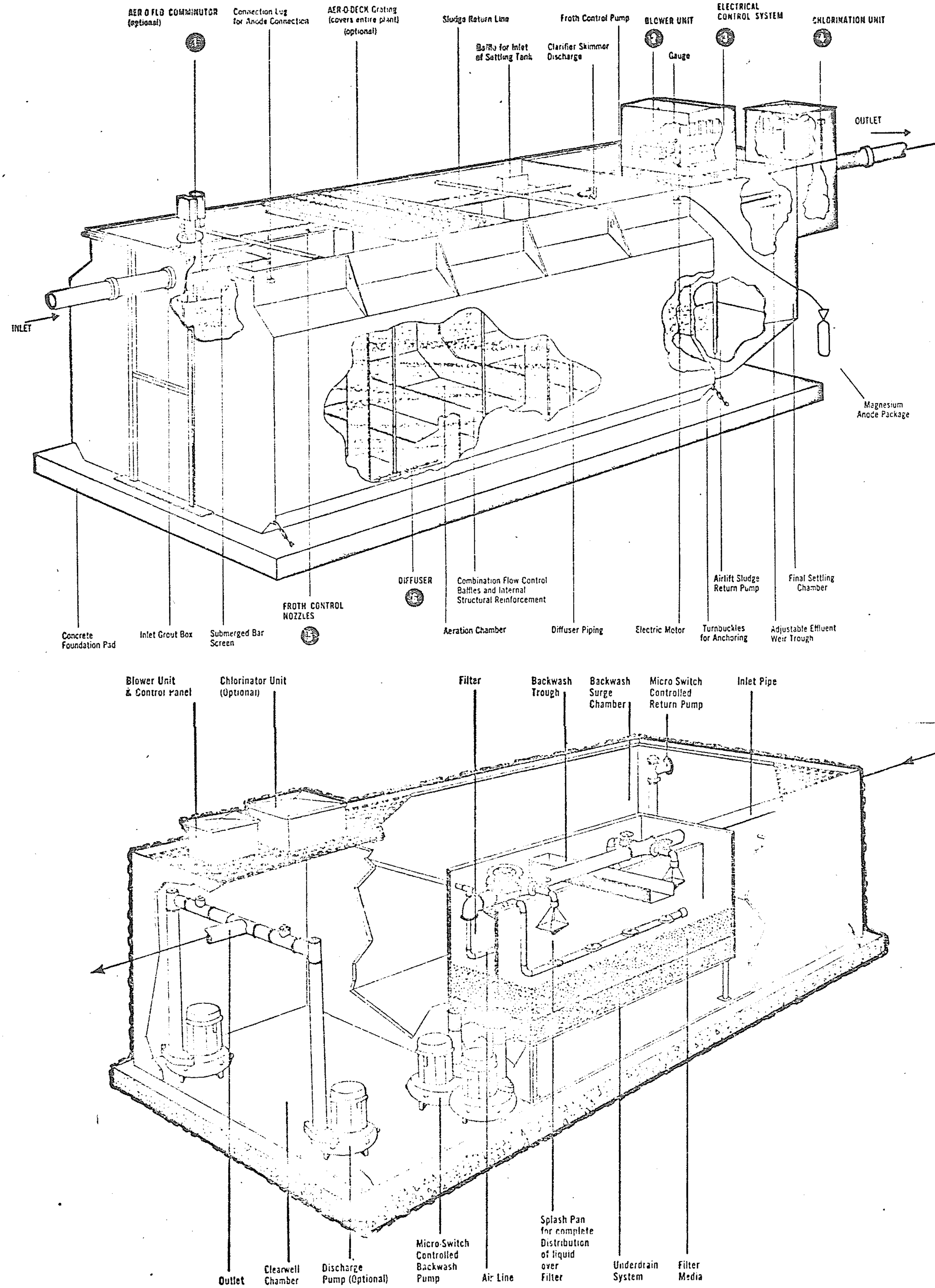

Figure 26

TERTIARY TREATMENT SYSTEM

Source:
Aero-o-flo Corporation, Technical Literature, Head Office Florence, Kentucky.

with a ceiling height of eight feet.

Waste water recycling is not common at present; however in areas where potable water is scarce and as the demand for water increases, more settlements will have to consider recycling as one means to meet this demand. Recycling is a more expensive initial installation in that additional piping and storage tanks are required. Probably the greatest objection to recycling is a psychological one as people are reluctant to accept re-using water which only hours before was sewage. This psychological barrier can be overcome by education and the increased number of applications. In the not too distant future complete waste water recycling could be a common practice especially in Arctic regions where water supplies are not adequate.

The generation of electrical power in the Arctic region is currently provided primarily by diesel engine generators. These generators are available in a wide range of capacities and have the added advantage of being portable. Their main disadvantages are the noise they constantly produce, the need for skilled tradesmen for maintenance and repair, the requirement for fuel which must be obtained from distant locations, and the requirement of a large number of units if any significant quantity of electrical power is required.

With the recent discoveries of oil and natural gas within the Canadian Arctic the possibility of obtaining fuel at a lower cost is possible if a refinery is established in the Arctic region. By utilizing these energy sources, future requirements for electrical power could be met by larger thermal plants utilizing steam turbines.

Nuclear energy to produce electrical power appears to be feasible as a result of recent research conducted by the US Army. Several small nuclear plants of 1600 kilowatt capacity have been installed and operated in Alaska, Greenland, and the Antarctic.[22] The components are airportable and total weight is about 300 tons. A valuable by-product of nuclear power is waste heat with a 1600 KW unit producing approximately one million BTU's of heat per hour which can be utilized for domestic heating. In addition, nuclear plants do not present the continual fuel supply and storage problems associated with diesel power generation, nor do they create the vast amounts of pollutants that fossil fuels produce.

Solid waste (dry garbage) would require very

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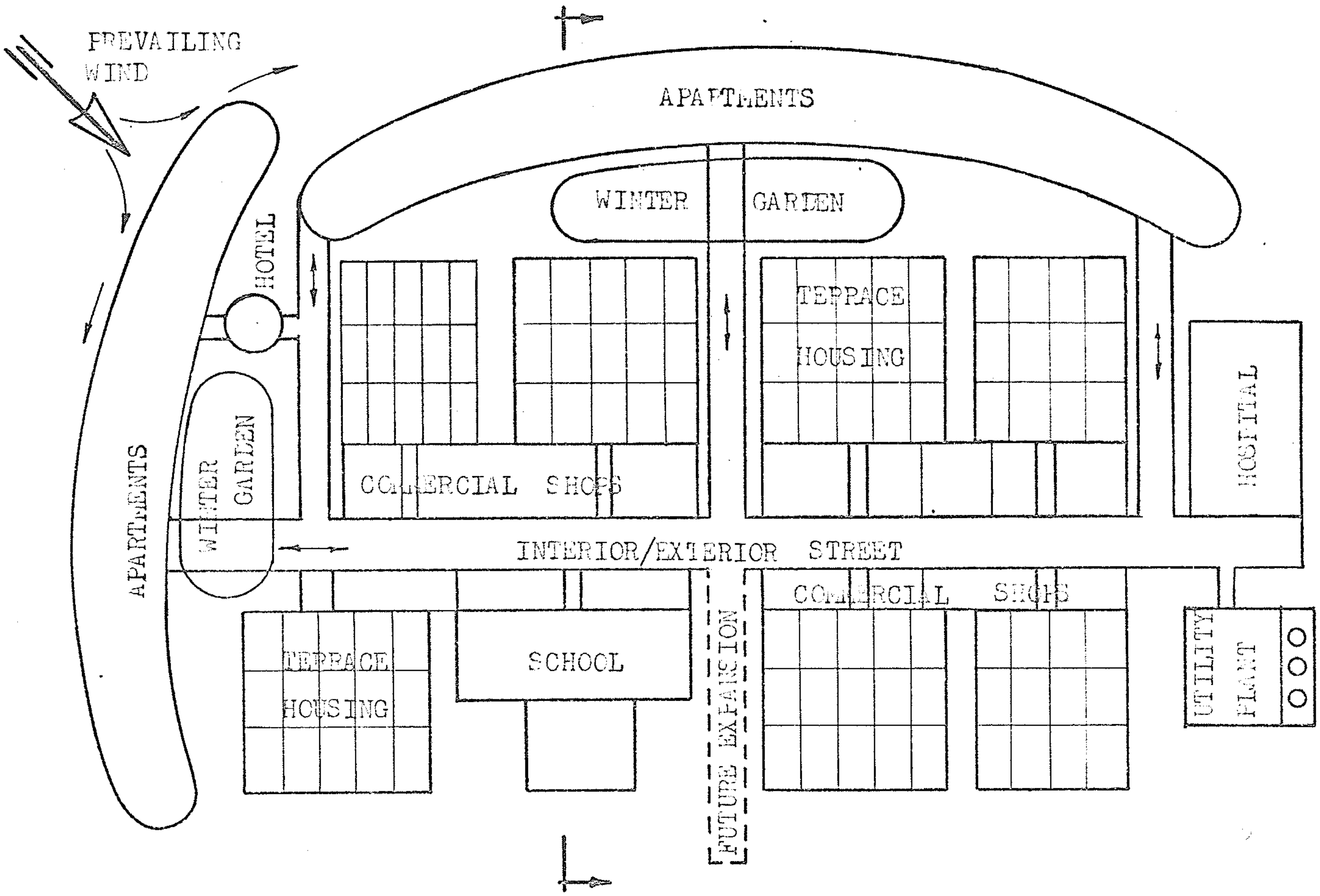
[22] Karol Bogdan, "Nuclear Plants for Northern Power", North, Volume VIII, No. 2, March-April, 1961, pp. 40-41.

stringent controls in order to control the bulk which could accumulate. Due to the dry and cold atmosphere plus the lack of appreciable quantities of organic soil, little decomposition occurs in the Arctic region and as a result solid waste cannot be disposed of by conventional methods such as sanitary landfills. In order to reduce the bulk of solid waste produced by an Arctic settlement strict controls over the use of disposable containers would be required. This could be accomplished by allowing into the settlement only containers that are capable of reuse or multiple use. For example, beverage cans would not be allowed but reusable bottles would be encouraged and current canned foods would be required to be packaged in reusable glass jars. This second example can be illustrated by the recent change from tins to reusable glass jars by the manufacturers of baby foods. Beverage bottles could be refilled and redistributed within an Arctic settlement and as such would form part of the settlement's industrial infrastructure. A portion of the jars could be reused within each individual household and the bulk of the remainder could be returned intact to the manufacturer for reuse or melted into glass ingots within the Arctic settlement and then transported south for reuse. By judicious control over the production of solid waste by Arctic residents the problem of bulk and the disposal of this bulk waste could be held within manageable proportions thus preserving the Arctic from this common form of pollution which invariably accompanies growth developments.

The physical form and layout of a settlement that contains all or most of these characteristics could take many different forms. The final form that is eventually chosen will depend on many physical factors in addition to the primary functions and tasks that the settlement must fulfill.

One conceptual diagram for a permanent Arctic settlement is illustrated at Figure 27. This diagram contains a mix of dwelling types but is heavily biased to multiple and apartment units for economic reasons and to obtain a high density settlement. The commercial and service areas are centralized and within a short walking distance of all dwelling units. The diagram also gives the pedestrian the choice of walking outdoors or within a two storey climate controlled passageway. The location and shape of the two large apartment structures serve as a shield to break and deflect the prevailing wind thus creating a moderated microclimate for the remainder of the settlement. Within this area of microclimate the



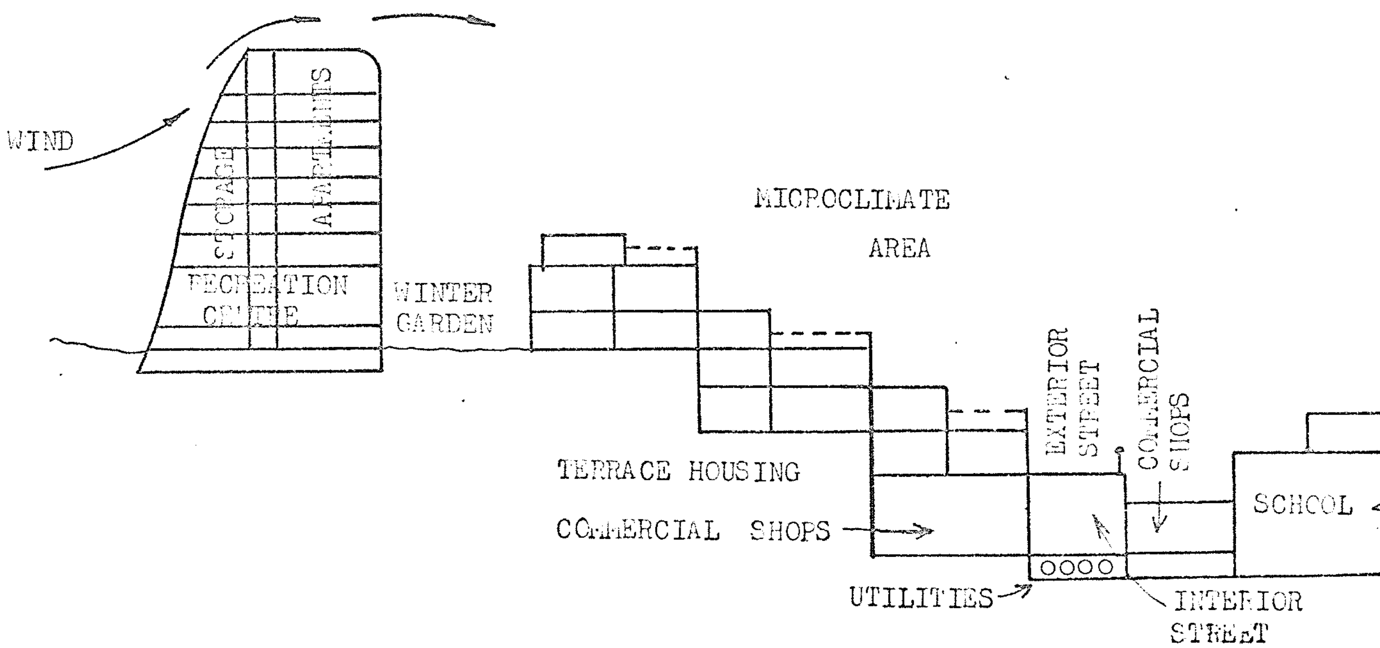


Figure 27

CONCEPTUAL PERMANENT ARCTIC SETTLEMENT

commercial and service facilities are found along with dwelling units of the terrace and row types. The utilities plant is located on the downwind edge of the settlement to eliminate any noise, odours, or pollutants that may eminate from such an installation. Future expansion could be accomplished by extension of the existing main spine or by constructing a new spine parallel to the existing one but located behind the school.

Based on a design population of 5,000 residents a permanent Arctic settlement of this nature would require approximately 1,400 dwelling units ranging in size from bachelor apartments to four bedroom units. At current construction costs[23] for southern portions of Canada a complex of this nature would cost an estimated $25 million derived as follows:

Apartment Blocks (1,000 units accommodating 3,000 residents)	$ 10.0 million
Terrace Housing (400 units accommodating 2,000 residents)	6.0
Commercial Centre	2.0
Recreational Centre	1.0
Hospital (50 beds)	1.0
Schools	1.0
Utilities	3.0
Miscellaneous	1.0
	$ 25.0 million

[23] Heavy Construction News, September 13, 1971, p. 61.

The cost of constructing a complex of this nature in the Arctic region would double due to material transportation costs, increased labour costs, and the improved design to withstand the Arctic environment. This estimated cost of $50 million to establish a permanent Arctic settlement of 5,000 residents averages out to approximately $10,000 per capita. This per capita cost is not much more than an average family of four pays for a typical suburban single family detached dwelling in many southern regions which does not include the cost of neighbourhood facilities such as; schools, shopping facilities, and recreation centres. Therefore a high density complex of this nature appears economically feasible for the Arctic region.

This conceptual diagram is one of many that architects, engineers, and planners could design to meet the requirements of the permanent Arctic settlement. The final settlement form for any particular location will be influenced by many factors such as the physical surroundings and the function of the settlement.

The purpose of presenting these conceptual ideas is to illustrate that the current Arctic settlement forms are not adequately meeting the needs of Arctic residents and that there are new forms and designs which could better fulfill their requirements. In order to further refine these conceptual designs more experimentation and research is required in this neglected area.

CHAPTER VI

CONCLUSION

The purpose of this study has been to examine in some detail, the Arctic environment and how this environment can be tempered by intelligent settlement planning. Assuming that the Arctic region is currently on the verge of an era of rapid growth due mainly from a pending influx of southerners associated with natural resource exploitation, administration, and service industries. In addition, improved medical facilities have significantly reduced the infant mortality rate and raised the life expectancy of native peoples to the point where more than one-half the residents of the Northwest Territories (most of which is Arctic) were under 20 years of age in 1966. If most of these young people remain within the Northwest Territories they will be forming the families of the future and could significantly contribute to an expanding population in the North over the next two decades.

The provision of economical transportation holds the key to improvement in Arctic living conditions.

Greater communication is required between Arctic residents and the more southerly population if they are to share equally in the benefits of the country. This could be accomplished through an active program of improving land, sea, and air transportation facilities. New forms of personnel and cargo transportation methods could be developed and their implementation coordinated with policies and programs for settlement, economic, cultural, and social development of the Arctic region.

Future Arctic settlements will require architectural and engineering innovations to successfully modify the harsh effects of Arctic environment. From the preceding discussion the multi-storey, high density, and multi-dwelling complex appears to be the best suited type of settlement to adequately accommodate Arctic residents. Complexes of this nature require the investment of large sums of financial capital and therefore should be constructed only in regional centres or at sites of long term resource exploitation.

A regional centre in the Arctic could fulfill the function of servicing the vast surrounding area. It would provide a greater variety and number of services and facilities than could possibly be made available at the smaller and more remote settlements. For example, a small remote settlement could not support a department store, whereas the regional centre could support one department store supplemented by a number of smaller specialty shops. Regional centres could be located at natural transportation nodes, such as where good harbour and airport facilities exist or could be developed. Many commercial and governmental activities could be established at regional centres and the extensions of these activities that affect the smaller surrounding settlements could be administered by a form of commuting or trips of short duration. This could negate the requirement of a sub-office in the smaller settlements, thus effecting financial economies.

The exact size of Arctic regional centres would depend largely upon the commercial, industrial, and administrative requirements of the particular area. However, it is unlikely that any Arctic settlement would exceed a total population of 5,000 in the foreseeable future. This growth limitation would largely be determined by the logistic efforts required to support this settlement which would be almost wholly dependent upon the provision of basic goods from more southerly latitudes.

The Arctic landscape and climate is not at all conducive to the growth of food products of a magnitude or variety required to adequately provide for a concentrated population of this order. Thus settlements upon the Arctic tundra will necessarily not be urban in size but nevertheless must be planned and designed upon the most modern principles and techniques to ensure a high standard of settlement habitability and amenity for it's residents.

Regional centres could be designated on the basis of a comprehensive analysis of the education, medical, social, economic, and administrative needs of the region. Permanent settlements developed near the site of natural resource exploitation activities would be predicated on the magnitude of the resource and long term demand for its products which would probably be in excess of 25 years to economically justify the financial investment.

Settlements which cannot be delineated as future service centres, due to natural resource wealth or for administrative requirements, could be designated as non-permanent settlements and be developed further with mobile components which could be relocated later when necessary without serious financial loss to the residents or the developing agency. This does not imply that existing structures should be completely demolished and the settlement established anew from mobile components but that any future growth or replacement of existing structures should be of the mobile type. Through this method of replacement and expansion over a period of several years the standard of living and the amenity of life could be substantially improved in smaller Arctic settlements.

Through this system of designated regional centres, which could be highly developed along distinctive Arctic designs, it is envisaged that a sense of pride and enthusiasm could be created that would attract and hold new Arctic residents. The life style of these new northerners could be similar to that of southern communities but the activities would occur in specially designed structures and facilities more suited to the Arctic environment. The special plans and designs required for such distinctive settlements can only be developed if the many varied factors, limitations, and consequences are considered. A comprehensive planning approach with its careful structuring of information, analysis, and integration of related dimensions and aspects, could provide the basis upon which sound policy and program decisions could be made. This planning process should not terminate once the initial plan is determined but should be a continuing process. It is planning as an on-going process that should be instituted, not a rigid and inflexible planned settlement or society.

The comprehensive planning approach is concerned with effecting change for the better as a result of understanding the context wherein the change process is to be bettered. This is accomplished by employing a range of planning, design, and management skills appropriate to achieving a betterment on a continuing basis over time. Only through this process can plans and designs be derived that will establish and provide a more satisfactory place in which the expanding population of the Arctic can more comfortably live and work.

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