ARCTIC TRANSPORTATION PROBLEMS

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Bibliography

Arctic Manual — Vilhjalmer Stefannson

Technical Manual 1-240, 17 Jan 44

The Quartermaster Review, July & Aug 46, Operation Muskox

Permafrost — Col G. W. Rathjine

The Quartermaster Review, Sept & Oct 46, Operation Muskox

The F. A. Journal, Sept 46, Operation Muskox

Within the Circle — Evelyn Stefannson

The O N I Review, Nov 46

Report of O P D Observer's Visit to Exercise Muskox, 17 Apr 46

Report on Motorized Surface Transportation in Antarctic

Catm, Dec 45

Canadian Report on Exercise Muskox 46 (Secret)

Microfilm #417 - Tractor Trains (Secret)

Letter, Hq Alaskan Dept, 461 (BTO-3) dated 15 Jan 47, Subject "Arctic Transportation Problems"

Army Transportation Journal, Dec 46 - Permafrost

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Subject: Arctic Transportation Problems

1. Problem.- To study arctic and subarctic transportation problems to include types of equipment, maintenance methods and limitations.

2. Discussion.- A. Arctic transportation presents many complex and difficult problems due primarily to the extreme climatic conditions and the terrain. When the weather is good, during the summer months, the terrain is practically impassible due to tundra, muskeg and swamps. When the weather is severe and almost beyond human and mechanical indurance during the winter months, the terrain is trafficable because of its frozen condition. (Appendix A, General Discussion of Arctic Regions) Altogether different types of equipment are used for summer and winter travel. B. All types of transportation, ground, sea and air are considered in this study:

(1) Appendix B, Tractor

(2) Appendix C, Dog Sledges

Appendix D, Truck

(3) Appendix E, Rail

(4) Appendix F, Pipeline

(5) Appendix G, Ships, Boats & Barges

(6) Appendix H, Air

3. Conclusions.- It is concluded that:

a. Track laying vehicles are best suited for Arctic overland transportation.

b. The Army cannot overlook the native modes of travel including shallow draft river boats and dog sleds.

c. Truck transportation is uneconimical and should be utilized only in built up installations where hard surface roads are provided.

d. Arctic Motor Maintenance and lubrication are major problems which are as yet unsolved.

e. Rail, ships and pipeline transportation are feasible in the Arctic and subarctic and are a necessary link in the lines of communication.

f. An extensive system of ice pack location and reporting is vital to Arctic shipping.

g. Air transportation is indispensible in Arctic operations and jet propulsion is well adapted for Arctic flying.

h. Barges are an important means of river and sea transportation in the Arctic.

4. Recommendations.- It is recommended that:

a. The Ordnance Department develope a front sprocket drive track laying vehicle combining the satisfactory features of the Canadian Snowmobile and the U. S. Weasel for extensive Arctic operation.

b. The tractor be so designed as to carry its payload rather than to tow it and to be a self contained unit with regard to sleeping, washing and cooking accommodations for crew.

c. A standard tracked chassis be adopted on which can be mounted different superstructures for different uses.

d. The above type tractors be tested in the next Arctic maneuvers.

e. The next experimental Arctic operation include the test of a tractor train, using a vehicle such as the D-8 tractor as prime mover, capable of hauling 150 troops or 75 tons of cargo.

f. The Army experiment with and standardize a shallow draft boat similiar to the "Umiak" capable of transporting a platoon of men with equipment or an equivalent amount of cargo for shallow river travel.

g. The Army train and maintain at least a cadre of dog team handlers, and standardize a cargo type dog sled capable of handling 1000 lbs.

h. Use of wheeled vehicles in the Arctic be discontinued except in built up areas.

i. Portable maintenance installations be experimented with and standardized capable of being quickly moved and assembled in strategic locations for support of Arctic operations.

j. The U S Navy sponsor a program for establishing ice pack locator and reporting system similiar to that used by the Russians to assist Arctic Navigation.

k. Jet propelled transport planes be developed and replace engine models now being used in the Arctic and that a cargo type heliocopter be developed for Arctic use.

l. The Quartermaster Corps experiment with and develop lubricants capable of withstanding extreme low temperatures.

m. The Signal Corps oil, HO-38, be field tested.

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Appendix A

GENERAL DISCUSSION OF THE ARCTIC

1. General Discussion.-

For the past 15 or 20 years the Arctic has been increasing in importance from a military point of view. This is readily understood when we see that the great circle routes from different Capitols of the world to Washington pass through or near to the Arctic circle (see annex 1).

The Russian military minds have been particularily active with regard to the north and in the late 20's were sending their fliers regularily over the north pole gathering Arctic weather and ice date. Their Navy has done more than any other in improving navigation through the Arctic sea. Since the time of the Czar they have been spending millions of dollars annually in forcing their merchants through the northern passage from Murmansk to Vladivastok.

The Canadians during the past two years have been pushing their operations in the north. Their recent operations "Eskimo", "Polar Bear" and "Muskox" were all designed to test Arctic transportation and equipment.

Our own Army Ground Force interest in the Arctic is indicated by recent operations "Williwaw" and "Frigid". Gen. Devers refused to cancel these operations even in the face of drastic budget cuts. In this connection, as contrasted to the Russians, our experience in the Arctic has been so limited that the Army Ground Force was able to find barely 100 men qualified to advise on polar matters incident to these operations.

2. Definition.-

There are three theories as to the definition of the Arctic region, all of which are recognized by the world's explorers, scientists and military men. The first concept is that the Arctic region should be defined on a temperature basis and is that region in which the mean temperature for the warmest summer months is less than 50°F.

The second concept is that the southern boundary of the Arctic region should coincide with the northern limit of the forest, known as the tree line. These two concepts coincide fairly well.

The third concept is that the Arctic region proper is bounded by the Arctic circle, which is lat. 66° 33'N.

The Arctic region includes the land masses of northern Alaska and Canada, the Canadian Archipelago, much of Labrador, Greenland, Northern Norway, Northern Sweden, Northern Finland and Northern Siberia. It also includes the Arctic Sea.

The Sub-Arctic region is a belt of variable width south of the Arctic region.

For the purpose of this study that portion of the sub-arctic is included which presents the same difficult problems to transportation due to terrain and climate as does the Arctic region.

3. Light and Climate.-

The climate in the Arctic is the most variable in the world and during any season the weather may change from clear and unlimited to zero-zero within a matter of minutes. The seasonal changes in temperatures are extreme. At Ft. Yukon, Alaska on the Arctic Circle the temperature variation is from 100° in the summer to-71° in the winter and at Verkhoyansk in Siberia a low of-94° has been recorded and a high of 96°.

In the summertime snow disappears from 80 to 90% of the land. High temperatures are found inland and in these inland areas the land is swampy, the atmosphere humid, and the mosquitos and other insects are unbearable. Soft mushy tundra covers the permanent frost which lies from 2 to 20 feet from the surface.

During the winter months 100% of the ground is covered with snow and all open water is solidly frozen. The lowest temperatures appear in the inland areas.

Fog is generally rare in the wintertime and increases during the spring becoming prevalent in July and August.

Generally speaking there are seven months of daylight and five of darkness. The presence of the northern lights prevents total darkness and usually at maximum darkness you can identify objects at 100 yards.

4. Sea Area.-

In the center of the polar region occupying the Arctic basin is the Arctic Sea covering some 5,000,000 square miles. (Annex 2)

In this respect the Arctic differs from the Antarctic, the polar region of which is a high continent rather than a basin. Surrounding the Arctic basin is a shallow shelf over which the ocean extends. It lies at a depth of several hundred feet and is of varying width. Off Siberia it is 450 miles wide, but off Point Barrow, Alaska it is only 60 miles. Most of the Canadian Archipelago lies on this shelf. From its edge, an abrupt slope leads down to a maximum depth of 18,000 feet.

There are two types of ice ever present in the Arctic Sea, the pack ice which is constantly moving and a generally immobile ice known as fast ice.

Fast ice remains immobile except during the summer breakup when it is set in very slow motion. It forms in bays and straits free of strong sea currents that otherwise would increase the movement. Generally this type ice is better suited for sledging and emergency landing than is pack ice.

Pack ice is ever in motion, not only the individual ice floes measuring from a few feet to a few hundred feet in diameter, but also great ice fields the limits of which reach 20 miles in diameter. During their movement fields and floes crack apart developing into narrow and broad lanes of open water known as leads. In the middle of winter, these leads soon freeze over forming smooth patches of ice suitable for air landings. Sometimes instead of pulling apart the floes and fields are crushed together by the wind and currents with a force strong enough to crush the strongest ship.

The thickness of pack ice varies from a normal of 7-12 feet to 200 feet. Thicknesses greater than 12 feet are almost always the result of piling up of floes.

Few icebergs are seen in the Arctic Sea, however, some are swept north by winds and currents and become part of the pack ice.

Currents (Annex 2) in the Arctic Sea strongly influences the Arctic Climate and also by controlling the direction of movement of sea ice controls the navigability of the waters. For example the current that flows southward along the east coast of Greenland brings ice that in some years blocks that coast summer and winter.

The tides in the Arctic Sea vary widely from place to place, but the ranges are usually smaller along straight portions of the coast than at heads of bays along the same coast. These tide ranges vary from 2 feet to 30 feet. In most areas small tides are more common than those of greater range and generally along the northern coast of Arctic land masses they vary from 2 to 4 feet.

The Sea adjacent land is generally shallow from 1 to 3 miles from shore necessitating in most ports liter operation for unloading. Except for the portion of the sea north of Greenland, the portion of the sea adjacent land masses is navigable from July to September with the aid of ice breakers. For Maximum and minimum Arctic Sea navigation see annex 2.

5. Land Areas.-

a. Permafrost.- Permanent ground frost is closely related to Arctic transportation problems with which this study deals and specifically with regard to railroad, road and airfield construction. It is commonly known as permafrost and is that portion of the soil, even bedrock, in which a temperature below freezing has existed for thousands of years. In Alaska it exists to a known depth of 900 feet. The permafrost table is generally rolling - dipping where the ground is bare and rising where the ground is insulated with moss and tundra. Above the permafrost table is a layer of ground which thaws in the summer and freezes in the winter. This layer varies from one to 20 feet thick. In some areas the permafrost lies deeper than the extent of the winter freezing of the top layer leaving a layer of unfrozen soil between the two frozen surfaces (Annex 3).

The basic troubles occur when any change in temperature caused by weather or pressure causes the various layers to contract or expand due to alternate freezing or thawing which sets up tremendous pressures which have been recorded up to 28,000 pounds per square inch. Also if the water within the unfrozen layer meets an impass and is forced to rise a like pressure is set up (Annex 4).

The troubles most frequently met are ground swelling, frostmounds, icings, frost blisters, ravines and sink holes caused by the melting of the ground ice known as "Thermokarst".

Ground swelling is caused by seasonal freezing and thawing and when it is irregular and not uniform it causes considerable damage to ground installations.

Frost mounds are caused by hydrostatic pressure and may reach a height of 300 feet and a perimeter of a mile. The force behind these mounds is irresistible and will erupt airfields and tilt entire forests (Annex 3).

Blisters are smaller frost mounds but are more widespread and just as destructive.

"Thermokarst" is caused by man removing the vegetation and active cover permitting the direct rays of the sun to act on the ground ice. This action is rapid and often spreads beyond control.

From the above, it is seen that permafrost causes Arctic roads, railroads and airfields to heave and slump and bridges to sag and topple.

b. Greenland.- Most of Greenland's 72,600 square miles is covered with a permanent ice cap and is the only Arctic land so covered (Annex 2). It's coastal regions consisting of about 15% of the entire area are free from the ice cap. The ice cap is creased with crevasses from one to one hundred feet wide making overland travel extremely difficult and hazardous and in most areas impassable. Successful plane landings have been made on the cap, but these usually consist of single rescue planes. The coast line is indented with deep fjords which provide good harbors which are generally ice free from July to September on the entire west coast and the southern half of the east coast, and the valleys leading inland from them are rich in vegetation and are of sufficient magnitude for airfield construction. The US constructed and used three such fields during the past war. Peary Land on the north tip of Greenland is also ice free and level and lends itself to airfield construction.

There are only local roads and no railroads in Greenland.

c. Lapland.- Lapland is the strip of Finland, Sweden and Norway lying within the Arctic Circle (Annex 2). The land is studded with lakes and streaked with rapidly flowing rivers, making the country rich in electric power. The city of Kiruna, north of the circle provides Stockholm, some 800 miles away with electric power. There are few roads in this area, however, the rich iron of Kiruna is taken to the port of Narvik 100 miles away on the Arctic ocean by rail. This rail line also extends to Lulea on the Baltic sea and connects with two North-South lines which extend to the southern tip of Sweden.

The terrain on the western shore is extremely rugged and impassible for cross country travel. That on the east in Sweden and Finland is flat and impassible in the summer because of the swampy condition of the land.

d. Soviet Far North.- The Soviet Far North constitutes almost one half of the land area surrounded by the Arctic Circle and the nature of its climate and terrain is much like Alaska and Canada (Annex 2). The area is lined with navigable rivers most of which flow north into the Arctic Sea. Russia's Arctic harbors far surpass those of other countries. Murmansk on the Barents Sea served as Russias end of her life line during the early days of lend lease in World War II. The great port of Archangel lies only 100 miles south of the circle. At the mouths of all the navigable rivers in Northern Siberia we find ports which can harbor ocean going vessels. Igarka at the mouth of the Yenisie River is a typical Arctic Port.

During the months from July to September the northeast passage along the northern coast of Siberia is a busy sea thoroughfare and the Russian's highly developed methods of ice reporting is responsible for the transformation of the formerly useless Arctic Sea into a highly usable seaway. This subject is further developed in Appendix G.

e. Alaska.- Only 1/3 of the entire territory of Alaska extends north of the circle but nearly all of its 586,400 square miles are similar to the Arctic region geographically and climatically (Annex 2).

Except for three great Mountain Ranges, the Alaska Range which reaches a height of 20,000 feet at Mt. McKinley, the Brooks and the Wrangell, the land is generally flat, covered with tundra and muskeg. During the summer months the tundra thaws to a spectacle that staggers the imagination - a quagmire exists 60% under rivers, lakes and stagnant bayous green with slime. The remaining 40% consists of clumps of sphagnum moss and tundra, which sucks a man to his ankles at every step and causes tractors to disappear (Annex 5). Out of the bog rise mosquitos by the millions. These bogs freeze solid in the wintertime and you have a tractor highway.

A fair road system has been developed in the subarctic area of Alaska, the Alaskan Highway from Edmonton, Canada to Fairbanks and the Richardson Highway from Fairbanks to Valdez and Anchorage (Annex 6).

A 600 mile standard guage railroad extends from the tidewater port of Seward to Fairbanks (Annex 6).

In Arctic Alaska there are no railroads and no Roads. The civilian modes of travel there are skin boats, dogsleds and airplanes, with the airplane playing the major role in recent years. There are more planes per capita in Alaska than anywhere else in the world.

The Yukon River is the largest river in Alaska and extends from Whitehorse in the Yukon Territory to the Bering Sea. This river is Navigable to flat bottom stern or side wheelers and tunnel shaft boats. There are no navigable rivers branching from the Yukon except the Tanana thereby limiting river boat travel to the courses of these two rivers.

There are no developed deep water ports or cities north of the circle. Point Barrow is the farthest north coastal village, but as in other far northern Alaskan ports such as Nome, Bethel and Teller its coastal waters are shallow and ships must anchor in open water and unload by means of liters.

An interesting strategic point is that the tip of the Seward Peninsula in Alaska is only forty miles across the Bering Sea from Russia's Siberia.

f. <u>Canada</u>.- Canada's Arctic territory is second to Russia's Siberia in size. Its Arctic region consists of a broad stretch of prairie and woods stretching from the Alaska border to Foxe Basin and from that point east to Greenland are arctic islands of every imaginable shape and size with irregular and intricate straits and passages seperating them. Some are mountainous, some low and grassy and some permanently covered with snow and ice (Annex 2).

Canada's mainland area is much similar to Alaska except its rivers are more plentiful and navigable. Many large navigable rivers connect large navigable lakes and during the summer months travel is extensively used. The equipment and supplies to develop the oil fields at Norman in the district of MacKenzie were taken in by barge from the Railhead at McMurry via the Athabaska River, Athabaska Lake, Slave River, Great Slave Lake, MacKenzie River to Norman (Annex 6).

There are no existing roads in Arctic Canada. However, a few miles south of the circle there is a usable road, excepting during the spring thaw, which parallels the pipeline from Norman to Whitehorse a distance of some 450 miles. This road and pipeline stretch over some of the roughest terrain in the northwest (Annex 6).

Aklivik near the mouth of the MacKenzie River is the main Arctic port of Northwest Canada and is also the Northern Terminus of the summer barge line outlined above.

Appendix B

TRACTOR

Complete motorization of transportation in the Arctic regions is highly desireable from a military point of view and to date the vehicle that is proving most adaptable is the full tracked vehicle.

There are certain fundamental principles which must be followed in theconstruction of such vehicles to properly meet Arctic conditions. These principles are:

1. They must be of the simplest mechanical construction. Complicated fuel, lubrication and track systems can be the cause of much undue suffering on the part of operating personnel in case of a breakdown.

2. Weight and size must be carefully considered for proper floatation. The width and length of the track must be in direct proportion to the weight of the vehicle. The weight per unit of running surface on the snow or mud must be kept to a minimum. Tests have proven that 5 lbs per square inch of bearing surface is the maximum. The track must be long enough to permit crossing of crevasses, but not of such length to interfere with steering.

3. Pressure-feed type engine lubrication is most desireable.

4. A system of preheating the crank case oil must be installed for starting in very low temperatures. The use of a blowtorch against the crank case has been used successfully in the past, but care must be taken not to overheat in that this tends to break the oil down.

5. The driving sprocket should be in front. On soft surfaces rear sprocket driven tractors tend to dig in. It has been proven in tests that heavier loads can be hauled over soft surfaces with less engine power by using front sprocket drive.

6. Vehicles must be winterized with a cab or caboose for the comfort and protection of driver, crew and passengers.

The use of tracked vehicles is greatly handicapped in the summer because of the extremely swampy and lake studded terrain of the Arctic. In autumn, however, the situation changes and every lake and sluggish stream gets a hard smooth surface which three or four weeks after the beginning of the freezeup will support vehicles of practically any weight, giving them boulevard conditions for travel. Rivers actually become excellent avenues of ingress from the sea into the hearts of northern countries.

The Canadian Operation "Muskox" conducted during Feb - May 1946 proved the adaptibility of track vehicles to Arctic travel. The operation covered some 2700 miles over all types of terrain and through all types of weather. (See Annex 7) The type of vehicle used on this expedition was the Canadian Snowmobile, and the force as it left Churchill consisted of 48 men in two divisions of ten vehicles each. The Snowmobile is a modification of the Canadian Armored tractor designed for the invasion of Norway. The principle modification consisted of the removal of some of the armor and the addition of a duraluminum cab to protect the crew. It is a full tracked 4 1/2 ton vehicle designed specially for oversnow travel. It is equiped with an eight cylinder Cadillac gasoline engine with a hydromatic transmission. One or two sleds were towed by each vehicle for carrying supplies. (Annex 8)

There were two types of sleds used, the American and the Canadian. The Canadian type consisted of a steel box 3 1/2' x 3' with a tubing framework forming sides 10" high and supporting a canvas cover 3 1/2' high. The runners were 6 feet long consisting of 3/16 inch steel 9 inches wide fitted on the bottom with a heavy oak keel with a 2 1/2" strip of 3/8" steel strapped on it. The runners were attached to the body by a suspension held in tension by heavy coil springs permitting the body to rock longitudinally and absorb some of the shock. The weight of the sled was 450 lbs and carried a pay load of 400 - 600 lbs.

The American type (M-29) was a rigid laminated solid wood sled with steel shod runners. The loading platform is 4 1/2' x 8'. The runners were 10" wide, an inch wider than the Canadian sled. It was capable of carrying a 1400 lb payload.

Both type sled performed satisfactorily, however, over rough country the runners did not stand up and required frequent replacement. The Canadian runner could be exchanged in 15 minutes on the trail where it took 1 1/2 hours to change an American runner. Both sleds sank in soft snow causing a great drag on the tractor and both were difficult to manage because of their rigid features. In this connection, at the present time the Transportation Corps is experimenting with a heavy duty, all purpose sled with four independent spring runners located generally where wheels on a vehicle are located. This type should facilitate towing and its flexibility should give it much more freedom of movement and maneuver.

One US M-29, "Weasel", started out with the expedition but failed mechanically during the first week and had to drop out. Its use, however, during the training period and in subsequent operations in the Arctic and Antarctic indicate that with proper maintenance, it can be used successfully under Arctic conditions and is at present the best vehicle that the US has for meeting the requirements of summer swamp and muskeg and winter snow.

The Snowmobiles were found to overheat excessively as a result of inadaquacy of the cooling system to dissipate the heat generated by the engine during normal operation.

The steel cleated 36" rubber tracks took the punishment fairly well although frequent replacement of individual cleats was necessary.

Lubricants froze at temperatures below - 30° and had to be thinned by alcohol which reduced the effectiveness of the lubricant.

When any vehicle stopped regardless of the reason, the maintenance Officer would immediately investigate. If the halt was for mechanical reasons, he would determine the extent and decide whether to repair it on the spot or to tolerate it until reaching the evening bivouac. In many cases it was found more satisfactory to drive a component to destruction rather than to waste traveling time. Such decision was based on length of the traveling day remaining and the number of man hours required for the repair. In many cases, engines were changed on the spot where they failed or as far ahead as they could limp after failure. In one instance, an engine change was made on the spot in 5 hours by two men.

Travel over sea ice was found to be much easier and faster than over frozen terrain and as much as 75 miles could be made in a single day.

Soft snow made the going extremely difficult and the engines labored unduly in pulling only one sled.

Cross country movement after the thaws almost caused the operation to be abandoned. Even these wide tracked vehicles bogged down almost hopelessly in the swamp and tundra.

In the lower temperatures of below zero degrees the maintenance was difficult and uncomfortable. Canvas windbreakers were used but still a man could not touch metal with his bare hand without it sticking to the part. It was proved that in this type operation maintenance camps must be set up at least every 100 miles so that vehicles can be serviced with some degree of comfort to the men.

Full tracked trailers were tried but proved difficult to tow and turned over easily. This type trailer was used during the war in Alaska behind D-8 tractors but were found unsatisfactory for the same reason.

The "Muskox" operation proved that track laying vehicles can operate in Arctic regions at least during the fall, early spring and winter seasons, but during the thaw, travel is greatly limited unless graded roads are provided.

The Canadian report on "Muskox" recommends that the tractor itself be so designed to carry its own payload and for each to be a self contained tractor unit. This means each tractor would contain sleeping, cooking and washing accommodations for its crew and its engine could be reached from the inside. Also a standard chassis of three weights heavy, medium and light should be adopted on which any type body could be mounted. It it were a passenger vehicle the body would include sleeping, washing and cooking accommodations for the passengers. The Canadians believe that such a vehicle is more economical than the tractor train described below. It appears that these recommendations deserve consideration in our development of Arctic Transportation.

In April of 1944 the Corps of Engineers in the Alaskan Department looked into the adoption of the "tractor train" to military use. Tractor trains have long been used by commercial lumber companies in Alaska and have proven satisfactory although expensive. The prime mover best suited is the Caterpiller D-8 diesel tractor. Bulldozer blades should be provided for breaking trail. It also is an effective protection for the radiator and engine and provides weight to the front of the tractor where it is needed in climbing.

There are two type trailers used, the skid type (Go Devil) and the bob sled type. Sled beds should not exceed 10 ft in width to 30 ft in length. The width of the runners or skids should not exceed the width of the tractor treads. Each cargo trailor unit is capable of carrying 75 tons and a D-8 tractor can tow 3 such trailors for a distance of about 10 miles in 24 hours. A 53 gallon drum of diesel is capable of fueling the tractor for 14 - 16 hours.

"Wannigans" or passenger trailers are usually 8 ft x 15 ft and 7 ft high. A kitchen "Wannigan" of this size is capable of cooking for 40 men and a bunking "Wannigan" of the same dimensions can bunk from 10 to 15 men.

Extreme difficulty lies in the fact that once a train stops in low temperatures it can freeze so solidly to the ice that nothing can tear the runners loose.

For breaking trail usually two D-8 tractors are used one towing a combination cooking and bunking "Wannigan" and the other acting independently. The best route is over level ground, avoiding dense woods and lakes where ever possible. If lake routes are used the trail breakers must test the ice at close intervals and mark the route with trees, poles or other devices.

A tractor train crew consists of a train master, "Cat" operators, assistant operators, mechanics, welders and blacksmiths, in addition to cooks and clerks.

The Alaskan Department recommends an Army Tractor Freighting Company be organized along the above lines to operate Army tractor trains.

Appendix C

DOG SLEDGES

The use of dog sledges as military transportation cannot be overlooked in any type winter over land and over frozen sea operation in the Arctic. This is probably the slowest means of transportation but to date is the surest.

The Nansen type sledge has been tried by the Army and has proved satisfactory for loads up to 1500 lbs.

For this size load a 70 lb sledge is necessary. It consists of ski runners with a light frame body added. It is most satisfactorly used over flat barren terrain and least satisfactory over rough sea ice and through thickly wooded areas.

Extremely low temperatures increase the hauling weight of loads. At-60° the snow reacts on runners as would sand on a beach. A drop from - 10° to - 50° will increase by at least three the strain on dogs pulling a given load.

The normal hitch of dogs for a sledge is six, usually in tandem. Such a hitch can pull approximately 1000 lbs for twenty miles a day over a sustained period of time. The load can be proportionately increased as the distance to be traveled is decreased. A load of 1500 lbs can be hauled up to ten miles a day.

It has been tested and proved that large heavy dogs weighing around 120 lbs are more satisfactory than the lighter breed of dog. Large dogs fit themselves better to harness and can be used for pack purposes when necessary. A one hundred and twenty pound dog can pack a 60 lb load and can carry it all day.

There are many problems involved in sledge operation. The drivers must be well trained specialists and the time required to train them is much longer than that required for a tractor driver. The weight of the sledge must be kept to a minimum in order to increase the pay load. This often causes a sacrifice in heavier sturdier construction causing the sledge to break up in heavy going. The harness is of necessity close to the ground

C

and tends to snag and become tangled in passing through wooded areas.

A properly conditioned dog of the weight described above can properly function at full capacity on two pounds of pemmican a day consisting of one pound of dried lean meat and a pound of fat.

There are several maladies in the Arctic shich can wipe out an entire stable of dogs before it is detected. "Piblokto", a type of convulsion, wiped out Peary's entire group back in 1909 and no prevention or cure for it is known to date. Another disease the nature and origin of which are obscure is a type of lockjaw which is prevalent and fatal. Peary in his expeditions allowed an average of 60% for death by disease and accident.

Dog sledges have a definite place in military transportation and are especially valuable over ice too thin to support track vehicles, in very deep soft snow which necessitates a trail breaker on snowshoes, and for transporting supplies forward of the tractor head. When the weather is too bad for air and the ground not suited for tractor, the sledges can take forward emergency supplies.

Recently in Labrador, a dog sled travelled 20 miles over the most difficult terrain and effected an air crash rescue while a heliocopter was being serviced and standing by for suitable take off weather.

Appendix D

TRUCK

In all parts of the world trucks are more or less road bound, but in the Arctic they are entirely such.

Any standard type Army truck is adaptible to their limited Arctic use by winterizing the cab for the protection of the drivers and if the vehicle is to be used as a troop carrier some method of heating the bed must be provided. Charcoal burners have been used successfully but are a constant fire hazard.

In extreme cold, the moving parts of a motor wear out much quicker than in a temperate climate. The lubricants which become stiffened by the cold are unable to cover the entire surface of the part or penetrate into the close fitting areas. The Signal Corps has recently developed an oil, HO 38 which will withstand temperatures down to - 60°. It has not been field tested. As explained in Appendix "A", Tractor Operation, any condensation within the motor will cause freezing.

Recently in Alaska during operation Frigid the temperature reached a low of - 52°. At this temperature practically all motors failed to start and the few that did would operate only a short while due to crankcase oil and other lubricants freezing. Also, for some unaccountable reason tires went down and would freeze in the deflated state making inflation impossible. Men were unable to change them necessitating running on flats thereby ruining the tire. Such conditions increases the maintenance factor many times over the normal. Also as outlined in the discussion of the tractor, provisions must be made for inside maintenance. This necessitates maintenance camps to be spaced at least every one hundred miles along any highway in operation. Along the Alaskan Highway these camps were spaced at about this distance (Annex 9) and in addition small cabins and caches were placed every ten to twenty miles where drivers could find refuge in case of a blizzard or a breakdown.

Road maintenance is a difficult problem because of permafrost, deep snow and the spring thaws. A method used on the Alaskan Highway was to divide it into one hundred mile sections and assign a maintenance crew with all necessary equipment the responsibility for each section. This included snow removal, grading and drainage. District Engineers were responsible for the bridges in their districts.

During the winter months in some areas heavy snow removal equipment (Annex 10) was on the road twenty-four hours a day for weeks on end. When it was'nt actually snowing, the wind drifted snow across the road. D-8 Tractors, airfield snow blowers, worm type snow removal vehicles, and road patrols were extensively used.

During the thaws the road became a quagmire although many sections were never completely closed. Muskeg areas over which the road passed caused most trouble. The Muskeg in some places was "bottomless". These areas were avoided whenever possible even to the extent of detouring many miles or taking on the difficult task of grading along a granite mountain side. Upheavals in the earth during thaws created cracks and craters along the entire road.

Bridges are a constant problem during the spring and unless permanent bridges with extremely heavy abuttments and piers are put in they will be required to be replaced each year due to the terrific shock and damage they undergo by the gushing ice and the permafrost action. Single spans are most desireable. Arctic streams also have a habit of changing their courses during a single season which proves an additional obstacle to road operation.

In the Canadian operation "Eskimo" in 1945 light lories were used entirely for supply. This was a winter operation in Central Canada over an area where there were no existing roads. D-8 tractors cleared the way with their blades followed closely by the lories. It was mostly over level ground, but the lories were constantly under tow over slight grades and were constantly sliding off of the trail provided by the tractor.

During the winter of 1944-45 our own Ordnance conducted motor vehicle tests at Dawson Creek, Canada for the purpose of developing a truck that could operate in snow. It was found that by placing a wide reinforced rubber track over the two pair of double rear wheels of a 2 1/2 ton 6 x 6 truck and by attaching a similar tread over the front wheels the truck could negotiate 14" of snow over level ground.

Truck operation at its best it not economical in the Arctic and due to conditions is most uneconomical. The mission of the Alaskan Highway was to supply the airfields along the North Ferry Route. However, more often than not during winter and spring months it was necessary to supply the fields by air and often the North West Service Command installations that operated the highway were kept alive through air supply.

Appendix E

RAILROADS

Rolling stock and engines used in Arctic operations are the same as those used in other climates with some minor modification. For winter operation all engines must be provided with a snow plow (Annex 11) and during heavy snow storms a separate snow plow engine should precede each train to clear the track.

Track maintenance presents the greatest problem and entire stretches of track must be relaid each summer after the upheavals and eruptions which are caused by permafrost action and the thaws. During World War II the 716th Railway Operating Battalion operated the Alaska Railroad from Seward to Fairbanks and instead of the one Maintenance of Way Company called for in the T/O and E, it was authorized three in order to properly maintain and rebuild the track. Engineers have recently discovered that the best way to reduce track dislocation and deformation is to float the ties over a gravel base 10 feet deep and 25 feet wide. Even then continuous dumping of gravel is necessary to keep the tracks from sinking or being upheaved.

Snowslides are a constant threat to continuous operation through the mountains (Annex 12) and schedules on both the White pass and Yukon Railroad and the Alaska Railroad were constantly interrupted by them.

The long winding trestles on both of these railroads were an ever present threat to their operation. Any serious damage to them would render the rail lines useless for months.

Both of the railroads were vital links in our lines of communication in Alaska and Canada. (Annex 6)

The Alaska Railroad supplies Ft. Richardson and Elmendorf Field at Anchorage, Ladd Field at Fairbanks. Fairbanks also served as a railhead for barge supply to airfields on the Yukon River.

The White Pass and Yukon Railroad was also operated by the Army and ran between the Port of Skagway, Alaska and Whitehorse. It supplied the Northwest Service Command and the Alaskan Highway in the Whitehorse area.

Appendix F

PIPELINE

Pipeline operation lends itself readily to Arctic use in the summer season, but winter operation involves many problems the main one being that oil will not flow in extreme low temperatures.

The Canol Project (Annex 6) carried crude oil from the oil fields at Norman Wells, MacKenzie Territory to the refinery at Whitehorse in the Yukon Territory. At Whitehorse the crude oil was converted into motor oil, motor gas, and aviation gasoline and these products were pumped to the air and ground installations north of Fairbanks a distance of 500 miles and south to Watson Lake approximately 1/2 that distance. There were five major ATC fields between Fairbanks and Ft. Nelson and many satilite fields.

In addition to the above pipeline there was one from the tidewater port of Skagway to Whitehorse where it was connected into the Canol system.

In low temperatures, the crude oil from Norman Wells could not be pumped even after large booster stations were placed at close intervals along the line. It became necessary to pump gasoline from Whitehorse back to Norman Wells to decrease the viscousity of the crude oil. This is obviously not an economical operation.

Construction is also a serious problem, in that graded roads must be built along the entire stretch of line in order to transport the pipe in and to maintain it. This in itself is a major problem. The many rivers also add to construction problems.

Appendix G

SHIPS, BOATS AND BARGES

As much as the great Arctic rivers and overland travel in the winter season they hinder it in the summertime and help to make over-land travel nearly an impossibility. These rivers are generally shallow and those that are at all navigable to large craft, such as the Yukon, the Tanana and Kuskikwin in Alaska, the MacKenzie and Slave in Canada, and the Yenisei, the Ob and the Lena in Siberia can be plied only by flat bottom side or stern wheelers, tunnel shaft boats and shallow draft tugs and barges. The maximum length for any of these vessels is 60' - 100' feet, depending on the depth, width and degree of curves on the river where they are operating. As mentioned above only a few Arctic rivers can take heavier vessels, the rest being too shallow.

Twin screw, twin rudder, tunnel shaft shallow draft river boats have been most successful in river operation in Alaska. The twin screws and rudders tend toward maximum maneuverability and the tunnel shaft protects the propellers from the bottom.

River barging is extensively used in the Arctic. The most successful means is by pushing rather tan towing. A shallow draft tug with an experienced skipper could maneuver two loaded barges through the most difficult channels.

G

The river barge is of necessity shallow draft and contains a molded bow. River barges up to 500 ton pay load were used both on the Yukon and on the MacKenzie barge operation.

The greatest problems to barge operation are the maneuvering of them in the winding rivers, the availability of trained skippers, and the shortness of the season.

For navigating the shallow rivers, 1 to 4 feet deep, the native Arctic boats have proven themselves superior to any commercial or other patented type. The Alaskan "Umiak" which consists of a spruce ribbed frame, over which seal, walrus or white whale skins are stretched has been tried by the military and found highly successful. A 40 foot "Umiak" can carry 30

Infantrymen with full field equipment or 4 tons of cargo. Being flat bottomed this type boat draws only two to four inches of water and are readily paddled up or down stream. It is so light that it can be carried across country by four men with ease. Another good feature, it has been found to provide excellent shelter by turning it over on land to provide a combination shelter and windbreak. The hide is extremely tough and normal scraping over rocks will not puncture it. If a few ribbs are caved in it is a mere matter of minutes to repair it.

The boat should not remain in the water over two days at a time in hot weather in that the seams will decay. They should be unloaded and pulled out of the water during overnight stops and be allowed to dry out and oiled with tallow or grease. With proper care and oiling the life of an "Umiak" is about three years.

It is not too humorous to say that skin boats can be eaten, because Stefannson says that they have saved the lives of numerable people. The skin is palatible either raw or cooked and is of considerable food value.

The greatest threat to sea navigation is the ice pack which is in motion during all seasons of the year. Experience has proved that ships being caught in the pack above Greenland and Spitzenberger are likely to get loose because the ice in those regions flows in a southernly direction and warm waters are encountered. However, above Alaska and Siberia a ship that gets in the ice and starts moving with it is not likely to get out, unless quickly freed by an ice breaker in that the pack moves northward and gets thicker and tighter as it spirals towards the pole.

To a ship's Captain operating in the Arctic Sea a report of ice location means what a weather report means to a flyer. The Soviets have developed a technique of ice reconnaissance and reporting that is rivalled by no other nation. They have established many polar stations and a fleet of scouting planes which report ice locations, thickness, speed and direction of flow. Such information is broadcast periodically throughout the day and night and special reports are given to any Soviet ship upon request. These reports are plotted on charts by ships navigators and after several plots they have a clear picture of the ice movement in their vicinity and navigate to avoid it. Also all ice stations and planes report to a control station where an accurate overall report is forecasted periodically. In 1939 the forecasts of the East Siberian Sea were 83% accurate and that was when the system was in its infancy.

The ideal ship for Arctic operation should be about 350' long with a 50 to 55 foot beam. It should have a fully riveted blade, a bottom with no welding, and a cruiser type spoon bow. The hull should be reenforced forward with a 4 inch sheath of wood extending from 4 feet under the waterline to 4 feet above it and far enough aft for about one-third of the length of the ship. It should have a twin screw with small four blade propellers. The draft should not exceed 24 feet and its propellers should be at least 8 feet below the surface of the water. It should contain extra water tanks and should carry about 5000 tons of cargo. Liberty ships were found not satisfactory for Arctic use. It is too long and its hull is thin and weak. Several Russian and American Liberties split in half in the Bering Sea during the past war. Also, the Liberty is a single screw ship which together with its length makes it difficult to navigate through the narrow and crooked channels and its thin hull renders it vulnerable to ice damage. Vessels with rounded hulls can withstand ice pressure if closed in by being forced up on the ice and then breaks through by virtue of its weight. Liberties, on the other hand, have double disadvantage of straight sides and weak hulls.

The ice breaker is a trouble shooter in Polar navigation. The Russians also lead in this field. They permanently station ice breakers along their Arctic sea lanes to keep the lanes open and to await calls to assist ships in distress. In addition to the permanently stationed vessels, ice breakers are included in convoy, usually one for four ships. A typical ice breaker is the J. Stalin commissioned in 1938. This ship is an 11,000 ton vessel, 345 ft long, 75 feet wide with 3 steam turbine engines with a total of 10,000 hp. Its bunkers hold 3000 tons of coal; has nine boilers and 3 furnaces; and a 25 KW steam driven dynamo. It is all welded and contains double hulls which extend completely around the ship. Its pumps have a capacity of 3500 tons per hour. In its equipment are included 3 catapult planes for ice observation.

Ocean barging was used extensively in our step by step movement out the Aleutian Chain. Landing craft were not available and the next best method of moving heavy equipment from one island to another was by barge. All of the heavy engineering equipment used on Adak Island for airfield construction was moved from Umnak Island, a distance of almost 200 miles, by barge. Both the towed type, up to one thousand tons, and the barge, self propelled, up to 50 tons (Annex 13) were used in this operation. This operation took place in August 1942 and although extremely heavy seas were encountered, the barge convoy made the trip in less than two days without losing a single tow. The towed barges were squared bow and flat bottomed.

The problem in ocean barging is in beaching the barges and unloading. This is very difficult in heavy seas which are prevalent in that area.

The island of Shemga in the Aleutians is a 2 mile by 3 mile flat island and is the site of a B-29 field. This island is 30 miles east of Attu and has no harbor or docking facilities. All equipment and supplies had to be barged from Attu. Difficulty was encountered in that when the sea was calm at Attu a waging storm was raginf at Skenya and vice versa. Often barges leaving Attu would get halfway between the two islands and would be caught between storms and have to remain off shore for as long as three days at a time and oftentime the thirty foot waves would require the tug pilot to cut loose his tow.

Securing heavy barges during storms was almost impossible. 500 ton barges anchored or moored off shore were thrown ashore in the extremely heavy seas during storms like matchwood. If the barges were tied to the docks during storms, extensive damage to the docks resulted. (Annex 14 - 15)

Appendix H

AIRPLANE

The civilians in the Arctic regions have in a great part deserted their snowshoes and dog sleds in the winter and their "Umiaks" in the summer for the small commercial type airplane. This has proven a very successful mode of travel. By using skis in the winter season and wheels or pontoons in the summer, the plane has been an all season method of travel with one limitation -- fliers must wait for good weather whether it be 60° below zero or 90° above.

The Army Air Force has successfully operated in the Arctic as proven by the operation during World War II of the Alaskan Division of the ATC which operated a transport service from Great Falls, Montana and Seattle, Washington to Alaska and also ferried lend-lease planes to Fairbanks, Alaska where they were turned over to the Russians for delivery to the battle field.

There are certain features of such operation in the Arctic which prove considerable problems. As stated before a mechanics hand cannot touch a piece of metal in - 50° temperature without his hand sticking to the part. This necessitates facilities for inside maintenance in the form of hangars. Also, if a plane is not kept warm in a hangar, and there never will be enough hangars to support a large operation, it takes one hour to warm up a plane which has been standing outdoors in temperatures 20° to 30° below zero, one hour and a half for temperatures - 40° and if the temperature is less than - 50° two to three hours is required. In these extreme temperatures a plane will use up a great percentage of its flying gas in the warm-up operation. Also, as in other engines any condensation will cause it to freeze.

Winter operation requires complete winterization of the plane including de-icing equipment. The weight of such equipment materially decreases the pay load.

Another difficulty is the rapidly changing weather which necessitates many auxiliary and satellite airfields. For example in Alaska when the

Nome airfield is closed a field not twenty miles away, Moonlight Springs is usually open and vice cersa. However, this is not always the case. A flight might take off from Fairbanks to Nome, a distance of 500 miles with clear and unlimited conditions at both fields. At half way it would receive a report that all fields in the Nome area were closed and all fields along the route were closed in also. The flight would then receive reports from Fairbanks that it too was weathered in and the flight would be forced to go to Anchorage some 300 miles to the south.

In addition to sudden storms and fog which blot out everything within a period of a few minutes, visibility is tricky even in the finest weather. There are practically no shadows in the vast expance of white; objects which appear far away are frequently close at hand and those which the pilot feels he could almost touch are really distant hundreds of yards. Such being the case it would be entirely possible for a pilot to touch an outcropping of ice with his wings without having seen the danger.

During all recent Arctic operations C-47's have been used successfully in supplying the expeditions by air drop and by landing on the ice pack in the sea or on frozen lakes. Portable homing devices mounted in Snowmobiles were used to guide planes in during Muskox and they worked very well.

Extreme difficulty has been experienced in airfield construction because of permafrost. The slightest swelling or sag in the soil causes breaks which are extremely dangerous.

All methods have been tried from laying the field on top of the tundra to laying on the permafrost but all have developed flaws. A short while ago the Engineers began an experiment using thick insulated mats under the runway. On a field near Fairbanks 20 runway sections have been insulated from permafrost by layers of foam glass, cellular concrete, asphalt, gravel, spruce boughs and moss. Results have not yet been obtained.

Another cause for great damage is the oozing of water up through the field caused by great pressures on areas of high water content.

Snow removal is also a major undertaking and requires heavy snow removal equipment in twenty four hour a day operation to keep the fields open.

Out of necessity for supply it is necessary to locate inland fields on or near rivers. With spring, comes the ice break up which often results in an ice jam causing a dam and the flooding of the river and adjacent areas. In the spring of 1944 this occurred at Gelena on the Yukon River. The Army airfield there was flooded and great damage resulted. This field was an important auxiliary field in the Nome-Fairbanks route and was out of operation for months.

In the Operation Frigid held in Alaska during the winter of 1946-47, a jet propelled P-80 was started and made airborne in weather - 43° without a moments delay for warm-up or other purposes. It was done by starting the plane with gasoline, then shifting to kerosene which is the normal fuel.

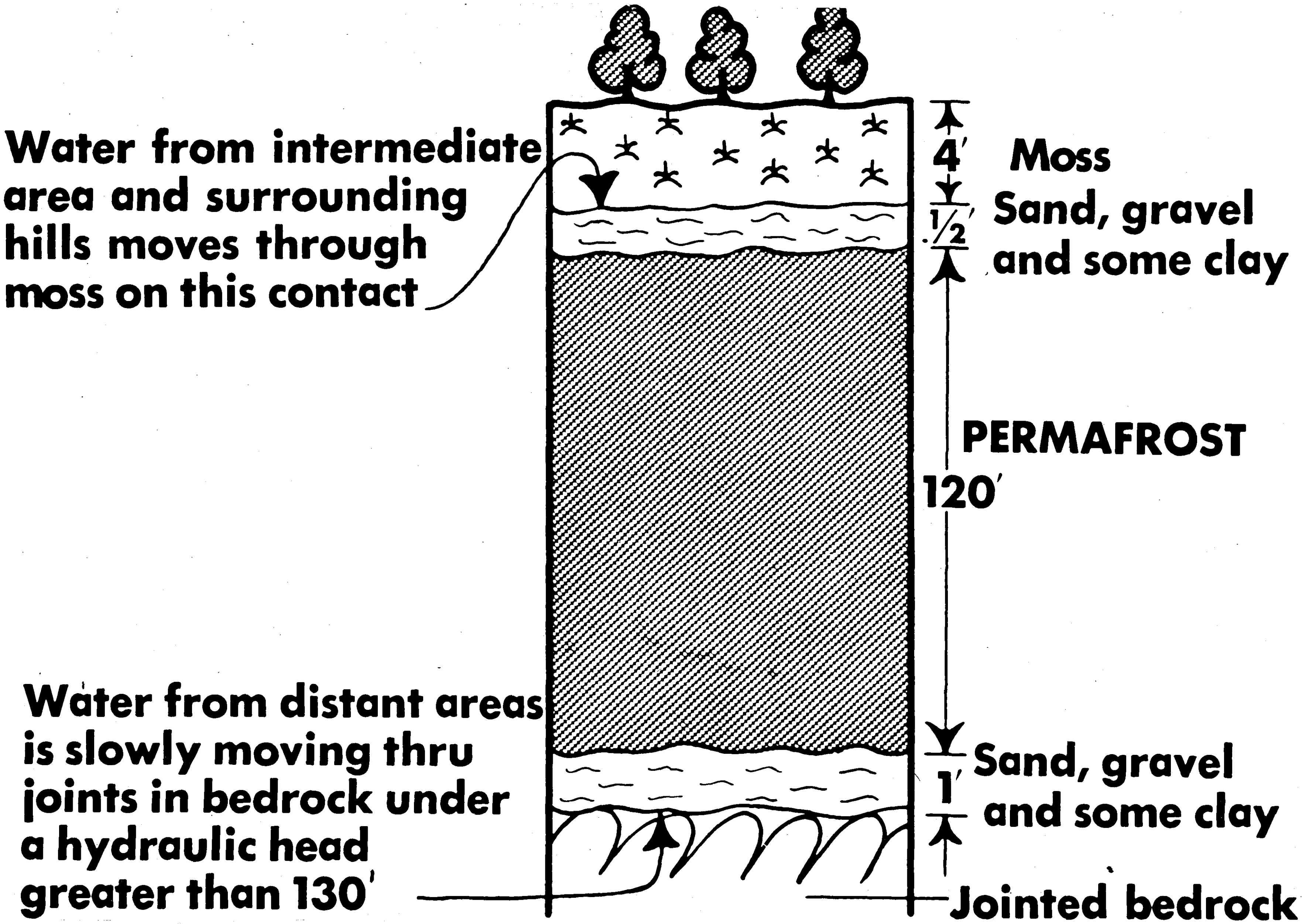
Because of its need for limited landing facilities, the heliocopter is very suitable for the Arctic. This type plane has been instrumental in recent Arctic rescue missions.


To Calcutta
To Singapore
8150
Cairo
9200
Moscow
6630
Tokyo
N
Pole
5100
London
6700
3460
Fairbanks

ANNEX 2

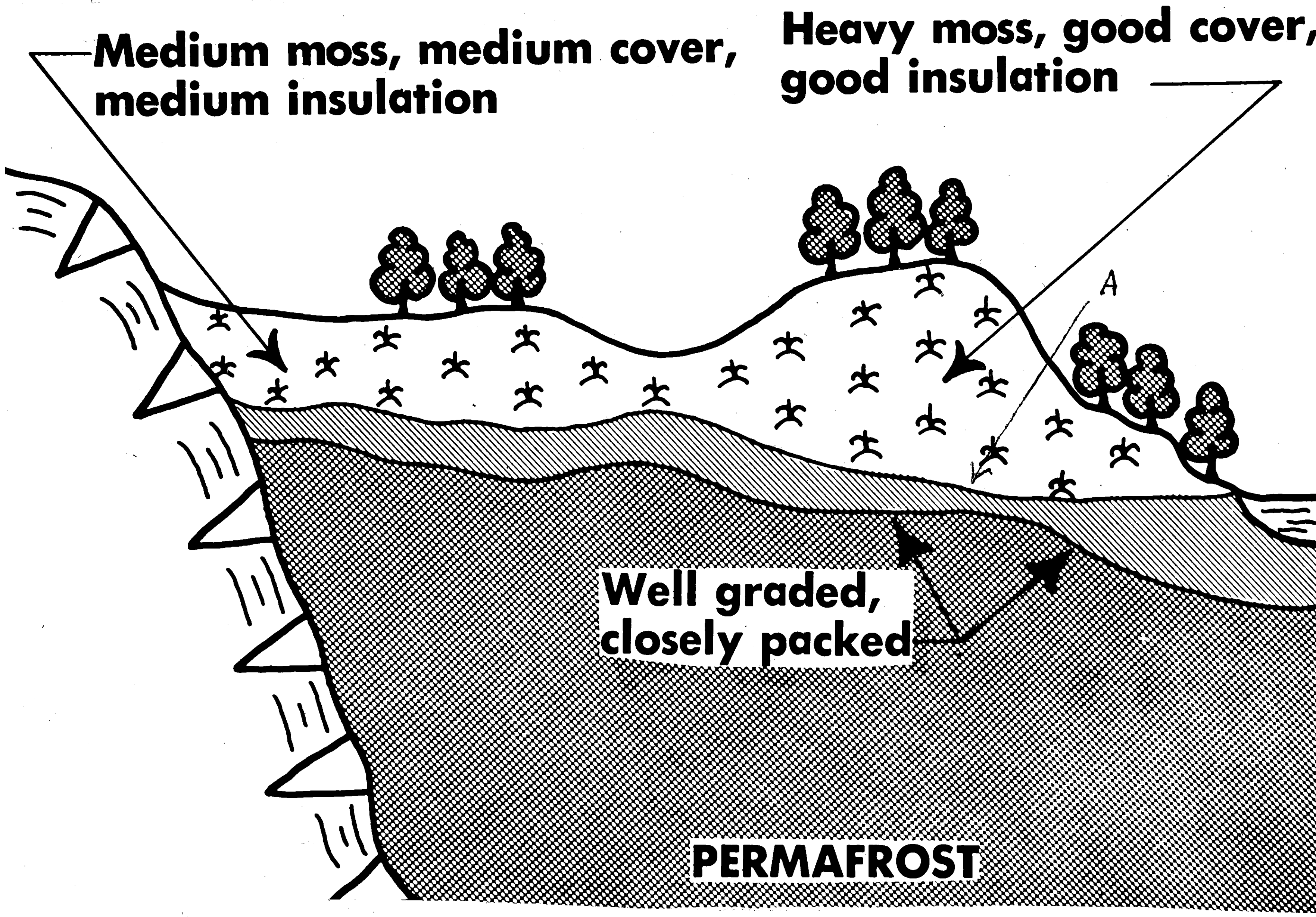
ANNEX 2

THE ARCTIC REGIONS
PREPARED IN THE MAP DEPARTMENT OF THE
NATIONAL GEOGRAPHIC SOCIETY FOR THE
NATIONAL GEOGRAPHIC MAGAZINE
GILBERT GROSVENOR, EDITOR
Scale 1:14,673,400 or 231.6 miles to 1 inch
STATUTE MILES
KILOMETERS
Azimuthal Equidistant Projection - Pole of Projection at North Pole
COPYRIGHT, 1925, BY THE NATIONAL GEOGRAPHIC SOCIETY, WASHINGTON, D.C.
Reprinted 1943
EXPLANATION
Angles of Variation of the Magnetic Compass from the True North shown by Red Arrows
Routes of Explorers
Warm Ocean Currents
Cold Ocean Currents
Glaciers and Ice Caps
Course of Icebergs
Railways
H.B.Co. Hudson's Bay Co. Stations
The approximate elevation of the land is indicated by color, viz:
Over 6000 feet
2000 to 6000 feet
600 to 2000 feet
Sea level to 600 feet
SPITSBERGEN AND FRANZ JOSEF LAND
Conical Projection Standard parallels 78 and 81
ELLESMERE ISLAND REGION
Conical Projection Standard parallels 77 and 82
ARCTIC OCEAN
NORTH POLE
BARENTS SEA
GREENLAND SEA
FRANZ JOSEF LAND
SPITSBERGEN
GREENLAND (To Denmark)
The interior of Greenland, with an elevation of from 5,000 to 10,000 feet, is covered with glacial ice of great thickness
ICELAND
ATLANTIC OCEAN
BAFFIN BAY
BAFFIN ISLAND
BEAUFORT SEA
LINCOLN SEA
BERING SEA
GULF OF ALASKA
ALASKA
DOMINION OF CANADA
HUDSON BAY
HUDSON STRAIT
LABRADOR
NEWFOUNDLAND
NORTH AMERICA
ASIA
SIBERIA
RUSSIA
KARA SEA
TAIMYR PENINSULA
NEW SIBERIAN ISLANDS
WRANGELL I.
SCOTLAND
BALTIC SEA
GULF OF BOTHNIA
Approximate limit of pack ice



Cross Section Of Permafrost

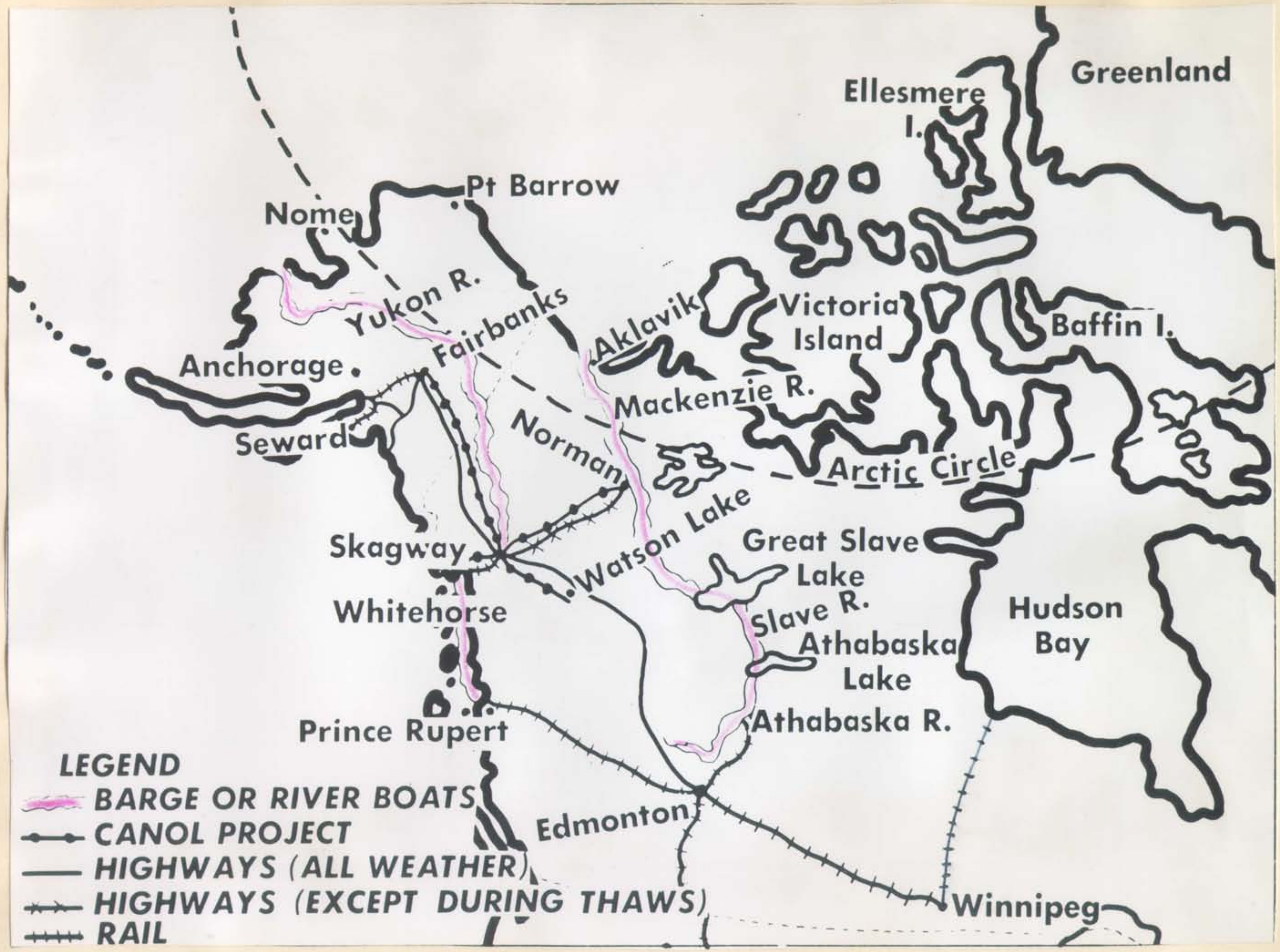
ANNEX 3



Cross Section Of Arctic Land Area

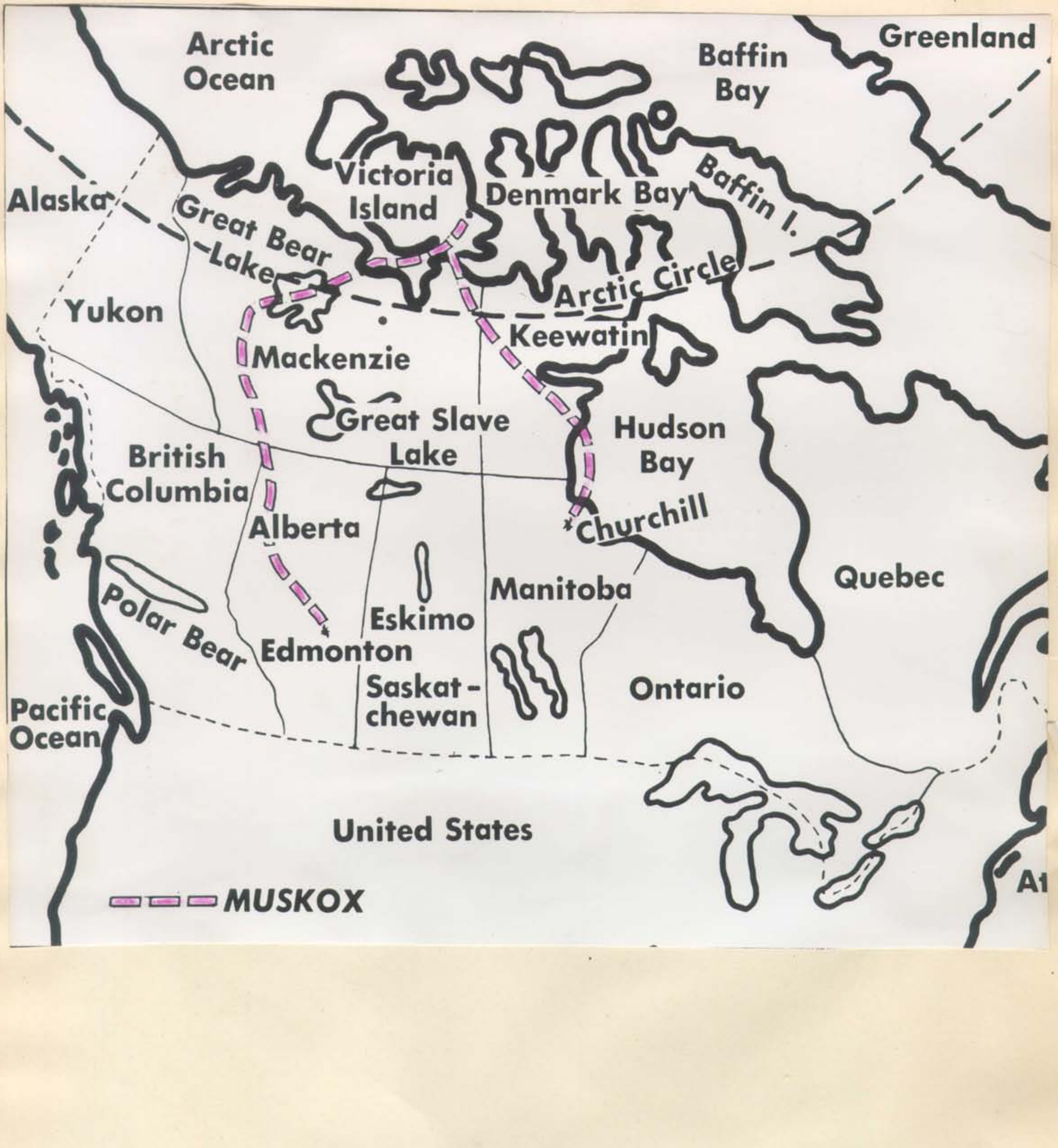
Point"A" is impass thereby forcing water to boil through areas of low insulation

ANNEX 5


Greenland
Ellesmere I.
Pt Barrow
Nome
Yukon R.
Fairbanks
Aklavik
Victoria Island
Baffin I.
Anchorage
Mackenzie R.
Seward
Norman
Arctic Circle
Watson Lake
Great Slave Lake
Skagway
Whitehorse
Slave R.
Hudson Bay
Athabaska Lake
Prince Rupert
Athabaska R.
Edmonton
Winnipeg
LEGEND
BARGE OR RIVER BOATS
CANOL PROJECT
HIGHWAYS (ALL WEATHER)
HIGHWAYS (EXCEPT DURING THAWS)
RAIL

ANNEX 6

6



Arctic
Ocean
Baffin
Bay
Greenland
Victoria
Island
Denmark Bay
Baffin I.
Alaska
Great Bear
Lake
Arctic Circle
Yukon
Keewatin
Mackenzie
Great Slave
Lake
Hudson
Bay
British
Columbia
Alberta
Churchill
Quebec
Manitoba
Eskimo
Polar Bear
Edmonton
Saskat-
chewan
Ontario
Pacific
Ocean
United States
MUSKOX

ANNEX 8

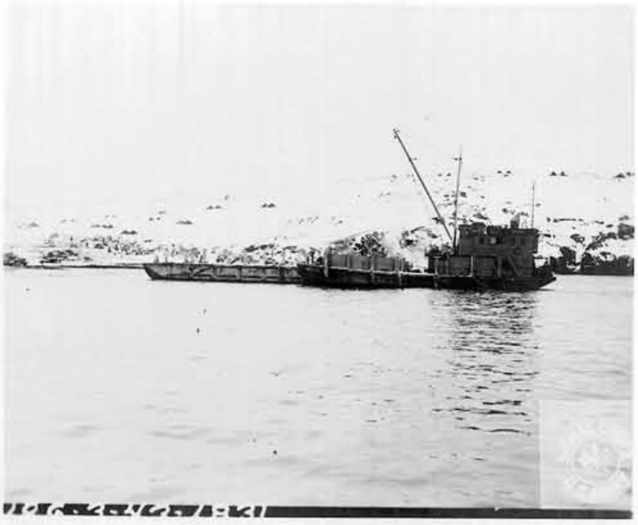
ANNEX 8

ANNEX 9

ANNEX 10

ANNEX 11

ANNEX 12



ANNEX 13

ANNEX 14

14