PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

FACILITIES DEVELOPMENT, CONSTRUCTION AND OPERATION PROBLEMS AND RELATED ENVIRONMENTAL CONFLICTS AND PROBLEMS OF THE ICE STRESSED COASTAL AREAS OF ALASKA*

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INTRODUCTION

This paper represents a cursory survey of the problems associated with the potential activities of man in the ice stressed coastal areas of Alaska and the corresponding effects on the environment, and some inference on the ecological aspects. Figure I shows the State of Alaska, and the points of interest of the present study. Figure II shows more details of the study area.

The primary purpose of the study was: a) to identify facilities development problems in the ice stressed coastal water; b) to identify construction and operational environmental conflicts; and c) to use imagination and experience in coastal engineering and the Arctic environment to postulate ideas to avoid problems of engineering and construction conflicts with the ecology of the areas involved. Ideas in this area were considered to be the most important objectives of the project. A detailed report was prepared as a result of this investigation. The present paper summarizes the pertinent points of the report. (Reference 1)

APPROACH TO THE PROBLEM

The approach to the assigned problem consisted of the following three steps: first, interviews with people (who were available at the time) who had first-hand knowledge of the ice and coastal zone problems of Alaska; second, a bibliographical survey of previous work in the world Arctic on the subject matter and a review of selected reference material, as applicable to the present study;

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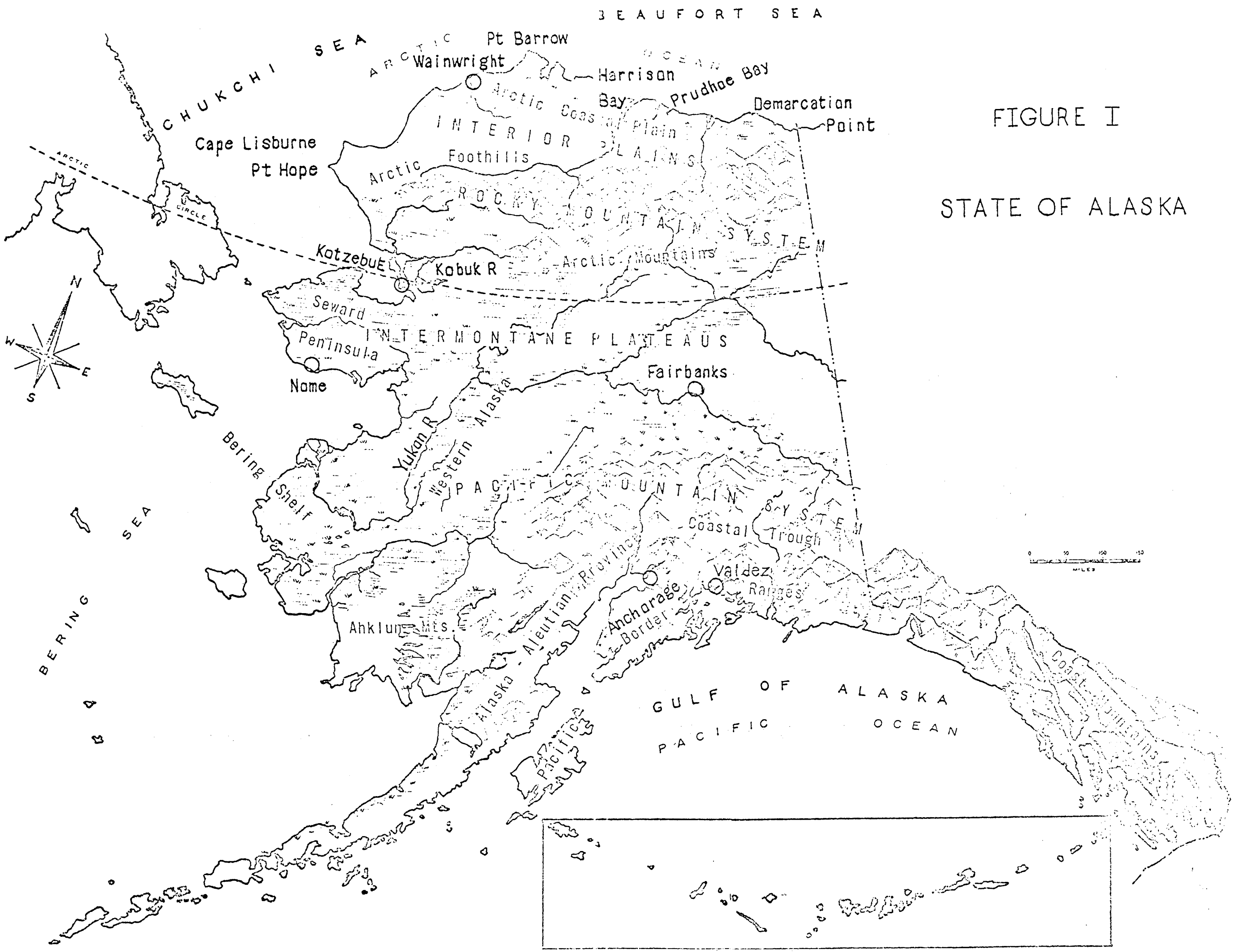

FIGURE I

STATE OF ALASKA

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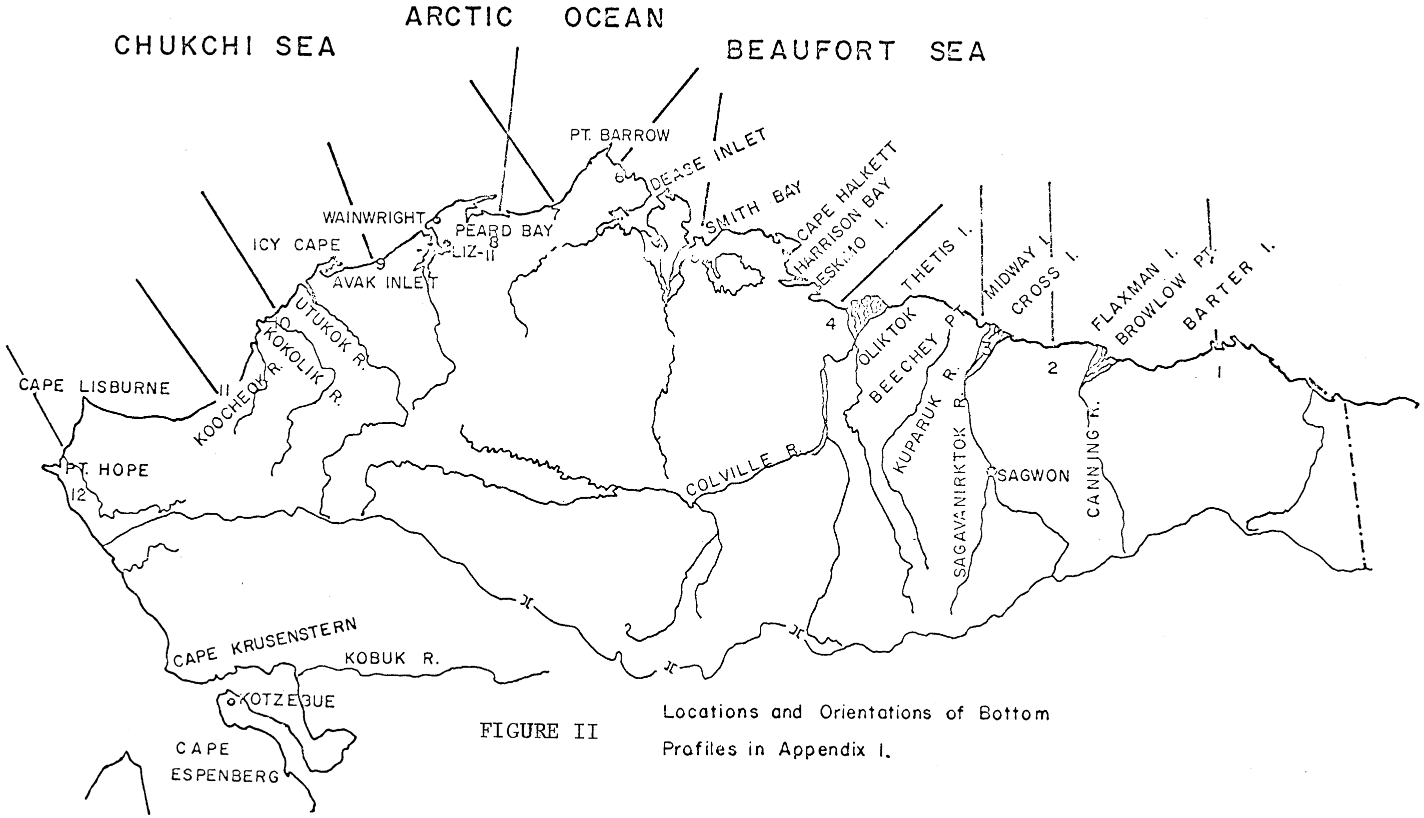

FIGURE II Locations and Orientations of Bottom Profiles in Appendix I.

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and third, a reconnaissance field trip to the particular areas of interest -- Beaufort Sea and Chukchi Sea coasts. The field trip was planned on the basis of the knowledge obtained above.

Based upon the findings of this study, recommendations are made within the members' respective fields of expertise, and the group also makes suggestions for additional work in allied fields that might otherwise effect the ecological systems of the ice stressed areas of Alaska.

SCHEDULE OF FIELD TRIP

The schedule of the field trip is given in Table I.

TABLE I

July 10	Anchorage - Prudhoe Bay
July 11	Prudhoe - Colville - Sagwon - Canning River
July 12	Prudhoe - Colville - Barrow
July 13	Barrow - Pt. Barrow and North 82 n. miles
July 14	Barrow - Wainwright
July 15	Wainwright - Icy Cape - Beaufort - Cape Lisburne
July 16	Cape Lisburne - Pt. Hope - Cape Thompson - Kotzebue - Kobuk
July 17	Kotzebue
July 18	Kotzebue - Fairbanks

ARCTIC COASTAL CLASSIFICATION

There are three major areas: 1) the Beaufort Sea; 2) the northeastern Chukchi Sea; and 3) the southern Chukchi Sea. There is a definite demarcation between each of these regions. A north-south line through Point Barrow separates the Beaufort Sea from the Chukchi Sea. An east-west line through Point Hope separates the northeast part of the Chukchi Sea from the southern Chukchi Sea.

The Arctic coastal zone consists of various definite features, including: a) barrier islands; b) offshore islands; c) open flat coastal plain; d) cliffed coasts with no coastal islands; e) spits and points; and f) river deltas. In combination with the above are: a) open bays; b) lagoons; c) estuaries; d) lakes; e) permafrost; f) ice; and g) sand dunes.

The Arctic coast can be discussed in terms of geographical considerations, taking into account coastal morphology. For the sake of convenience, we will use the term geo-coastal morphological divisions, realizing that in some instances we do not have adequate information to be completely exact in our divisions and subdivisions.

Geo-coastal morphological divisions and subdivisions are shown in Figure II. This breakdown was made by use of detailed hydrographic and geologic survey charts, photographs, a literature survey, and interviews prior to the field trip.

The coastal region of the Beaufort and Chukchi Seas is broken down into five physiographic classifications. They are: 1) the large river complex; 2) lagoons and bays; 3) protected coasts; 4) offshore bars, islands and spits; and 5) unprotected coastal areas. Only recently have any definitive studies of the biota of this region been introduced. No attempt is made here to describe the biota of the region. Papers of particular interest are Brooks, et al. [1970] (Reference 2) and Roguski [1970] (Reference 3). The separate seas are quite different in their physiographic coastal makeup.

ECOLOGICAL IMPORTANCE

Beaufort Sea Area

The coastal zone of the Beaufort Sea between Point Barrow and the mouth of the MacKenzie is primarily depositional. This is due, in large part, to the major river systems which enter the Arctic Ocean west of Point Barrow including the Canning, the Sagavanirktok and the Colville in Alaska and the MacKenzie, in Northwest Territories. Each of the three Alaskan streams hold valuable resources which are in short supply on Alaska's North Slope. They have a different biological makeup. An increase in knowledge of the biology of the area and the construction materials needs is paramount to planning. It should be possible to retrieve both the living resources and the construction materials with a little interference.

The Canning River. — Biological information on the Canning River is extremely limited. The Canning is obviously a good source of gravel. It is probable that under controlled conditions the gravel can be removed from the Canning with little or no damage to the fishery resource. It is, however, a considerable ways to the east of the present development, thereby lowering the value of the material available.

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The Sagavanirktok River.— The Sagavanirktok is one of the largest north coast rivers, second only to the Colville. It is an unstable river in the geological sense. The lower reaches of the Sagavanirktok are widely braided. The bottom composition is primarily gravel near the mouth. The lower 40 miles of the stream show evidence of high instability as exemplified by the multiple channels and recent channel changes. The gravel in the lower end of the Sagavanirktok River are very highly sorted and poorly graded from a construction standpoint. This grading situation presents problems in utilization for roads and airport runways. Most important fish of the area is the Arctic char. There are apparently few whitefish. The char is subject to a commercial fishery outside of the mouth of the river, principally on the barrier islands and, while the commercial harvest is small, the recreation potential for this species is high. The area of the North Slope is very short in natural recreation resources. In this harsh remote area it is mandatory that we give primary consideration to local recreational possibilities for the crews which are developing the area. A potentially damaging conflict exists between the taking of gravel from the Sagavanirktok River and its charfish population. The problem is in the method and time which the gravel is taken rather than the physical removal of the gravel itself. Because of the unstable nature of the river the scars from gravel removal will soon be obliterated. The char migrate through the lower regions of the river in late summer and fall. Stock-piling of gravel in the river, which has been common, blocks off the migration routes and physical activity during migration time can disrupt the spawning migration. Careful planning as to time, method and area of removal is required.

The Colville River.— The Colville is the largest river on the North Slope, draining most of the western half of the North Slope of the Brooks Range and empties into the Beaufort Sea about 50 miles west of Prudhoe Bay. Its lower 40 miles are principally sand and sandy mud. It is the most mature river on the North Slope in a geological sense. Colville is the site of the only commercial fishery on the North Slope. This fishery has been pursued for about 20 years. At the present time there is an annual catch of about 40,000 pounds. The primary fishery is for several species of whitefish. There are limited numbers of char and salmon. Three distinct species of whitefish are taken. These are the broad whitefish, the humpbacked whitefish, and the cisko. All three spend some time in salt water feeding and return to fresh water to spawn. It is evident from the commercial fishery that the three types of whitefish enter the mouth of the Colville at distinctly different times. There is some overlap in harvest, however, this is probably due to milling in the river. All three of these whitefish normally spawn by broadcasting eggs and sperm on the fine gravel and sand bars. Because of the wide disparity in migration times it is possible that eggs and larva may be present in the lower river during a considerable part of the year. This industry, while not large by other standards, is important to the local areas and to Point Barrow. It could also provide an inexpensive fresh source of food for the camps at Prudhoe Bay. Because of our lack of knowledge of the spawning times and required habitat of the whitefish in this area, it would be a poor practice to remove material or disturb the actual streambed. It is probable that material could be removed from exposed sand bars during winter time with little or no damage to the fishery resource. However, this may have a dynamic effect on the coastline during the summer as it may upset the relative stability of the Colville.

Special Feature

The Spit, Island, Bay, Lagoon.—One of the most prominent figures of the Alaskan coast of the Beaufort Sea is the vast amount of mainland shoreland protected by offshore islands, spits, and bars. These geographical features are ecologically one of the most important of the Arctic coast of Alaska. The islands are depositional in nature, and roughly parallel to the coast in a northwesterly-southeasterly direction, with the east end of the islands being turned to the south or southwest. Some islands have been permanent features of the coast for centuries as evidenced by grass and tundra cover. They provide nesting sites for large numbers of migratory water fowl. More important, the islands provide the first open water along the north coast. As breakup approaches, open leads are found on the leeward side of these islands. The shallow seas adjacent to the islands, particularly on the inshore side, provide rich feeding area for migratory water fowl. Any activities which would disturb these islands would have an adverse effect on migratory water fowl population. The topography and flora of these islands suggest that the northwest end is older, more consolidated and more poorly sorted than the southwest end of the island. The areas that are covered with beach grasses and tundra provide nesting sites for the eider and other migratory water fowl. The only safe area for gravel removal would be the southeast end of each island. This material is much more highly sorted, therefore it would be poorly graded construction materials. From an ecological standpoint, the more suitable source for gravel, albeit more expensive, would be from dredging the channels between the islands and the main shore. Such channels are undoubtedly to become more important as shipping lanes in the future.

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Arctic Dunes. — In the area immediately to the east of the Sagavanirktok River there is a unique coastal feature, wind-formed dunes. As compared to tundra, these dunes have a relatively deep active zone. There are important ecological considerations: They provide denning areas for foxes and are areas of high biological activity. It is common practice in such areas to utilize dunes for burying solid waste and as staging areas. As suggested by the definition "dunes", these features are highly unstable once the covering flora has been removed. Dunes offer relatively high and dry ground suitable for staging areas, yet they should be protected. Disturbance should be held to a minimum. They are yet another example of the fragile environment encountered in the Arctic.

Chukchi Sea Area

The rivers to the west of Point Barrow are those of the Kuk and the Ugokok. There is no information available of the biological aspects of these two streams, pointing out the dearth of knowledge on the North Slope of Alaska. Both contain quantities of well-graded gravel. It is probable that this material would be utilized in any development. It would be desirable to do at least a cursory biological survey of the systems prior to any development.

There are three important river systems which drain into the Chukchi Sea on the south side of the Brooks Range. These are the Wulik, the Kobuk and the Noatak. The latter two systems are under continual management of fisheries resources. They constitute the farthest north commercial salmon fishery, State of Alaska. The biological systems are well-known compared to those of previously discussed rivers. Any industrial development would be a potential conflict to this important fishery resource. To prevent the potential damage it is extremely important to integrate the activities of engineering with biology. The Wulik River is also an important stream from a subsistence fishery purpose. The native population in the adjacent village of Kivalina is highly dependent upon this system and take from 20,000 to 40,000 pounds of char a year.

The Coastal Regimen - Point Barrow to Cape Lisburne. — The northwest coast of Alaska facing the Chukchi Sea has relatively few islands. The general regimen is one of interspersed erosional and depositional beaches. The problems encountered on the coast from Cape Lisburne to Point Barrow are considerably different than we find to the east of Point Barrow. In certain locations abundant sources of well-graded gravel are available. These include not only the rivers but also the beaches and spits. The spits protect lagoons and provide an active biological area. These areas are the primary nesting grounds for migratory water fowl. In mid-summer the

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caribou utilize these spits to escape to the seaward of many of the insect pests. In choosing sources for gravel removal, accessibility cannot be the only criterion. From present knowledge it would be more desirable to utilize river gravels than to disturb these spits.

The communities of the northwest coast are principally built in areas of erosional beaches. There are problems facing villages such as Wainwright which are built along the erosional coast which should receive some attention. Prior to the establishment of permanent settlements, in the modern sense, the erosional problem did not have the impact on a mobile population as they do today when the population remains static. This is true of such communities as Point Hope, Kotzebue and Wainwright. The problem of sewage disposal, both domestic waste and solid waste, is a relatively new one to native communities in north and western Alaska. Prior to the establishment of relatively permanent communities, seminomadic populations moved often enough to allow the grounds to become healed and the waste to decompose. Villages no longer have this option. The villages on the north and west coast of Alaska need the direct technical assistance on an immediate and local basis. Planning these projects on a regular consulting basis is a service which none of these villages can afford.

<u>Cape Lisburne, Sheshalik</u>. — During prehistoric and early historic times this stretch of the coastline has been heavily populated with Eskimos. At the present time the only permanent villages are Point Hope and Kivalina. There are a number of temporary seasonal settlements along the coast, particularly from Kivalina southward through Cape Krusenstern.

Characteristic of the coast is the lagoon and open tundra-covered barrier beaches. Cape Thompson is a single high promontory rocky cliff which serves as a rookery for massive bird colonies. The area of Point Hope is one of the historically important archeological village sites with the Eskimo culture being traced back several thousand years. As a native village it is almost entirely dependent on a marine mammal subsistence economy. Ruins and burial sites cover a large portion of the land at Point Hope. Similar conditions are evident on the beaches from Kivalina through to Sheshalik. In certain areas the barrier beach between the ocean and the lagoon are totally covered with ruins of old houses, old graves, and graves which are marked to indicate recent usage. Any development along this coast with the exception of the Chariot site a few miles to the east of Cape Thompson would have to take into consideration these old sites. Development in the modern sense could not help but desecrate areas which are held sacred to the

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native peoples. With the exception of excavations at Point Hope and Cape Krusenstern, this entire area is poorly known in an archeological sense and would be of very significant scientific value. The one place where development could proceed with very little ecological damage or destroy no valuable archeological material would be at the Chariot site. The east coastline from Point Hope through to Cape Prince of Wales should be zoned, taking into consideration the scientific value, the needs and the desires of the indigenous population.

BACKGROUND INFORMATION ON BARRIERS TO CONSTRUCTION OF FACILITIES ON THE ARCTIC COAST OF ALASKA

Climate

The extremely cold winters in the north is a major problem. Most people would not like to live in the Arctic and very few go there to become permanent residents.

High income and adventure (sometimes a nebulous thing) are about the only inducements that will bring people to the Arctic. Because of the climate, it is doubtful that even the extreme population pressures of the lower latitude areas will cause very much of a population shift to the Arctic.

Permafrost

Almost implied in the definition of the Arctic region is permanently frozen ground. All engineers and builders have been intrigued with this phenomenon and a great deal has been done to solve the resulting construction problems. Some successful methods for building are now known.

It might be wise to reiterate that in any permafrost situation, the thermal regime of the ground must be maintained if foundation stability is to be achieved.

Water Supply and Waste Disposal

When observing the Arctic terrain in the summer, one would think that water supply would never be a problem; the entire landscape appears to be water -- either lakes and rivers, or an almost flooded tundra.

It is a fact, however, that a permanent supply of potable water is a rarity and one of the major problems is to provide adequate water. With the exception of the summer months, nearly all of the water is frozen and only a few of the lakes and streams will have water under the ice. It is possible to melt ice or snow to provide water, but the energy requirements make such a system impractical.

There is little likelihood of ground water, due to the permafrost (1,000 or more feet in depth), so a surface source is mandatory. Similarly, sewage disposal is a problem. The ground is either saturated or frozen, and no septic tank-drain field system can operate in frozen ground. Also, since streams are solidly frozen in the winter, disposal into the rivers is not practical.

Some construction locations would be useless, due to lack of water and sewage capability, and indicate that a sophisticated water-sewage system is needed. It is not impractical to suggest a system which converts sewage back to potable water, or one which desalinates the sea water. Research on these ideas has been going on for a long time. While the systems may not be economical in a temperate zone, they might be found feasible in the Arctic, since fossil fuels are plentiful in much of the area.

If a re-use of sewage for water were to be used, plants could be designed to dehydrate the sludge which could then be used as a fuel to reduce the total energy requirement. (Three papers by Amos J. Alter [1969] give many citations and contain extensive bibliography -- References 4, 5 and 6)

Construction Materials

Except for gravel and sand, there are no practical materials for construction in the Arctic; all such materials must be imported. It would seem that considerable effort should be devoted to making suitable structures from ice, or mixtures of ice, gravel, and tundra grass.

The requirement for materials only increases the problems of transportation. Materials used for Arctic construction should be of low weight, and particularly of low volume. In this respect, the technique of building with plastics that can be imported as liquids, and later foamed or expanded, could be very useful. This procedure, however, will have to undergo much further experiment before proven applicable.

Ice-Crete.— It was demonstrated during World War II, and later at the University of Alaska, that a saturated wood pulp or sawdust, when frozen, made a very tough material -- even a reinforceable one.

It would seem that certain structures could be built in the Arctic by freezing a well-graded saturated gravel -- a material having considerable strength.

The material could be insulated by using either a manufactured insulation, sawdust and ice, ground tundra moss or grass and ice, etc.

Laboratory experiments to develop criteria for such material should not be expensive and could prove quite fruitful for development of roads, landing strips, and other structures.

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Transportation

First and foremost, the greatest problem facing builders in the Arctic is the logistic problem of transportation. There is no economical way to transport materials and supplies to the Arctic Coast.

Air transportation can serve practically the entire area during most of the year and is effectively doing so now; however, air transport is, and probably will continue to be, predominantly passenger and mail carrier service. Only high-priority freight can be flown. The likelihood of air freight for the products of any conceivable industry is remote, except for extremely high value-low volume products.

The least expensive transportation in the major portion of the world is by sea. However, the Arctic Coast of North America has the extreme disadvantage of being ice-bound most of the year, resulting in next-to-impossible navigation. In addition to being ice-bound, the sea is very shallow, with many shoals and barrier islands, on most approaches to the land. It is unlikely that a vessel can be built powerful enough to negotiate the ice pack and still have shallow enough draft to negotiate the waters. Perhaps the present system of using ships and sea-going barges in great numbers, during the few short weeks when the ice is out, is the only practical method of hauling into the Arctic. The lightering problem could possibly be improved upon by giving special consideration to the engineering of the equipment.

Highway or railroad transportation to the Arctic from the south is a possibility and will someday, no doubt, be done. It should be pointed out, however, that overland routes can only serve a narrow corridor and therefore, only a small amount of the country can be made available in this way -- and at a very high cost. The terminal of an overland system must be a long-lived resource of great value before it can be built economically.

Labor Force

The permanent population of the Arctic area of Alaska is small and scattered. Nome, Kotzebue, and Barrow are the largest villages, and are inhabited by those of mostly native origin. The natives (especially the young) are, or can be, trained in most of the construction skills; also, they are acclimated to all conditions of life in the region. Industrial development in the form of extractive resources may provide jobs necessary to keep these people in their home environment.

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Energy Source

The Arctic abounds with fossil fuel deposits; e.g., gas, oil and coal. The extent of these deposits are only beginning to become known. It is paradoxical that the most prevalent item of pollution in the area is the 55 gallon drum, and the most frequent freight load to new sites is fuel. Any future development should ideally be preceded by the development of local fuel sources, which would save greatly on the expense of exploitation.

The development of other than fossil fuel energy sources is not likely; there is no timber; hydro power would be impossible due to the long period of freeze-up; nuclear power does not seem practical.

RECOMMENDATIONS

1. Increase the effort to become more knowledgeable of the Arctic Seas:
   a) What are the indicators for the behavior of the ice pack and the time of break-up?
   b) How can the methods of taking freight from ship to shore be improved, from the economical standpoint?
   c) Where are the most suitable locations of off-load materials, causing the least damage to the coastal regions?
2. Do not use beach gravel, or gravel from the seaward side of islands or barriers, for construction.
   a) Protect shores from wave and ice action.
   b) Protect river mouths from developing bars.
   c) Protect bird nesting grounds (islands with grasses).
3. Develop criteria for taking gravel from offshore islands and from streams. Do not remove material from islands except under urgent and well-controlled conditions.
4. At all times, maintain open channels of running water to protect anadromous fish (when taking gravel from streams).
5. Investigate lightering methods with the idea of reducing labor and hastening the unloading of ships. Perhaps self-propelled, amphibious vehicles with powered gear could be developed especially for the Arctic. An efficient craft might be one that could crawl out onto the ice or onto the shore, and yet be large enough to take a fair sea and carry a reasonable pay load.
6. Onshore storage should be organized and kept to a minimum area.

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7. All refuse (organic) should be burned where possible; ash and residue should be placed in a sanitary fill. (Dune areas could be used for this.)

8. Oil drums, in particular, should be gathered up and stacked for future use. A good use for the drums would be for construction of revetments, dams, and quays, if they are filled with gravel and properly anchored.

9. It would appear that any industry developed in the Arctic would be extractive in nature (fishing excepted), meaning that ultimately facilities would be abandoned. With this in mind, the designer should keep cognizant that structures should be semi-portable or disposable. They should not be left as junk on the landscape.

    a) It should be remembered that cuts and fills require careful layout to prevent damage to the drainage systems after their abandonment.

10. To prevent hazards to the migration of animals on the tundra, wires, cables, etc., should always be picked up after use.

11. A variety of reasons constitute the requirement for keeping the size of camps to an economic minimum:

    a) A large camp or city would have difficulty maintaining proper sanitary discipline for water supply and waste disposal.

    b) Large camps could create disasterous fire hazards, particularly in the winter months.

    c) Small camps could be useful later for native villages or government stations; large ones would need a greater area to support the population "living off the land."

    d) Small camps would keep men close to their work; hence, cut down the cost of daily transportation.

    e) Small camps would require less fuel, thus reducing the winter ice fog conditions.

    f) Small camps can be completely encapsulated to produce a more desirable environment.

    g) Small camps could provide a more manageable social structure, from a morale and law enforcement standpoint. They would not be the attractive nuisance as that of a large camp.

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12. Due to the temporary nature of probable camps, they should remain as "company" towns. The operator should be responsible, under state license, for legal and sanitary operations of the camp. If service centers are to develop (such as small cities), controlled development and siting should precede the growth. In other words, proper water supply, sanitation, fire protection, transportation systems, and zoning should be developed prior to construction.

SUGGESTIONS

If the resources of the upper Kobuk prove exploitable, there remains the problem of land transportation and port facilities to be developed:

1. Dredge the Kobuk River channel to provide a harbor near Kotzebue; develop the Kobuk for barging, or construct a road to the harbor.
2. It looks feasible to build a road from the upper Kobuk region, through the Lockwood and Zane Hills (N66° 30' - W156° 10'), to the Koyukuk River; use barges on the Koyukuk and Yukon Rivers to the nearest point of the Kuskokwim River; develop a portage, or canal, to the Kuskokwim and construct a harbor at the most applicable point below the village of Bethel.

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