US Army Corps of Engineers
Alaska District

COMMUNITY IMPROVEMENT FEASIBILITY REPORT

Kivalina, Alaska

Cold Region Center of Expertise

April 1998

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, ALASKA
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COMMUNITY IMPROVEMENT FEASIBILITY REPORT

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PREFACE

The preliminary draft version of this report was published for review and comment by residents of the city of Kivalina and officials of the Northwest Arctic Borough and other regional, State, and Federal agencies with an interest in community improvements at Kivalina. The technical information in this April 1998 final version is essentially the same as in the preliminary draft, though the presentations of some analyses are refined. The preliminary draft was distributed to every household in Kivalina and became the primary documentation of the three community improvement options offered in a special election. The special election, documented in appendix M of this report, presented three options to voters: remaining at the present village site, moving to a site on the Wulik River, or moving to a site on the Kivalina River. Permanent Kivalina residents 18 years of age or more were eligible to vote for one of these options. Voting took place on February 26, 1998, and the results were certified on March 6, 1998. This report includes discussion of the voting and the results. This final report also includes accounts of recent community discussions, and additions and corrections provided by reviewers.

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SUMMARY

The U.S. Army Corps of Engineers conducted these studies to define problems of sanitation and other living conditions at Kivalina, Alaska, and to propose solutions under the authority of Section 22 of the Water Resources Development Act of 1974 (P.L. 93-251), as amended. A cost-sharing agreement between the Northwest Arctic Borough and the Corps of Engineers, executed on June 3, 1997, called for investigation of three basic options: improvements at the existing village site and relocation to either the lower Kivalina River, 8 miles to the north, or the lower Wulik River, about 3 miles east.

Kivalina, a Native Alaskan community of about 400 residents, is located about 80 miles north of the Arctic Circle on the Chukchi Sea coast of northwestern Alaska. The village is on a low-lying barrier island that separates Kivalina Lagoon, a shallow estuary, from the Chukchi Sea. Kivalina is 74 miles northwest of Kotzebue, the region's transportation hub and seat of the Northwest Arctic Borough.

Field investigations and intensive interaction with residents from June through August, 1997, led to development of an improvement plan at each of the three alternative sites. Improvements proposed at the existing site included flood and erosion protection in the form of a beach fill and dike. Landfill with erosion protection on the Kivalina Lagoon side of the village was proposed for expansion of housing and community facilities. The existing runway would have to be moved to the northwest along the narrow barrier island to allow this expansion of community buildings and roads. Part of the landfill would be developed for disposal of wastewater collected from a new sewer system in the village.

The Kivalina River option included complete relocation of all community facilities and residences to the north bank of the river at a site known locally as Imnakuk. A well-water supply system and sewage treatment lagoon would be developed to provide year-round running water and flush toilets. A new road from the Imnakuk site to the open coast would allow transport of heavy and bulky cargoes delivered by barge. A new airport would be constructed north of the new village.

The Wulik River plan included complete relocation of all community facilities and residences to a site on the south bank of the river known locally as Igrugaivik. A well-water supply system and sewage treatment lagoon would be developed to provide year-round running water and flush toilets. A new road from the Igrugaivik site to the end of the spit at Singauk Entrance, the narrow inlet by the existing village, would allow transport of heavy and bulky cargoes delivered by barge. A new airport would be constructed east of the new village. The road and the relatively easy crossing of Singauk Entrance would allow a gradual shift of residences and facilities.

Residents of Kivalina at least 18 years of age voted on February 26, 1998, to indicate a preference among the three basic options for community improvement. A majority of those voting preferred relocation to the Wulik River at Igrugaivik.

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CONVERSION TABLE FOR SI (METRIC) UNITS

This table is provided to help in the conversion of Standard International (metric) units of measurement to inch-pound units. Many measurements in this report are given in both types of units.

Multiply	By:	To obtain
Celsius degrees	*	Fahrenheit degrees
centimeters	0.3937	inches
kilograms	2.2046	pounds
kilometers	0.5399	miles (nautical)
kilometers	0.6214	miles (U.S. statute)
meters	3.281	feet
meters	1.0936	yards

* To obtain degrees Fahrenheit (°F) temperature readings from degrees Celsius (°C) readings, use the following formula: °F = (9/5)(°C + 32).

GLOSSARY
Abbreviations, Acronyms, and Technical Terms

ADCRA = Alaska Department of Community and Regional Affairs
ADEC = Alaska Department of Environmental Conservation
ADF&G = Alaska Department of Fish and Game
ADOT&PF = Alaska Department of Transportation and Public Facilities
BIA = (U.S.) Bureau of Indian Affairs
cm = centimeter(s)
CHL = (U.S. Army Corps of Engineers) Coastal Hydraulics Laboratory
CRREL = (U.S. Army) Cold Regions Research and Engineering Laboratory
EPA = (U.S.) Environmental Protection Agency
ER = Engineering Regulation
ft = foot, feet
ft^3 = cubic foot, feet
ft^3/s = cubic feet per second (flow rate
gal = gallon(s)
GPS = Global (satellite-based) Positioning System
H = horizontal
h = hour(s)
ha = hectare(s); 1 hectare = 2.47 acres
HDPE = high-density polyethylene (pipe)
IRA = Indian Reorganization Act
kt = knots (nautical miles per hour) = 1.1 statute miles per hour
lb = pound(s)
km = kilometer(s)
km^2 = square kilometer(s)
m = meter(s)
m^2 = square meter(s)
m^3 = cubic meter(s)
m^3/s = cubic meters per second (flow rate)
mi = mile(s)
mi^2 = square mile(s)
mi/h = miles per hour
mo = month(s)
nm = nautical mile(s) = 1.1 statute mile
NEPA = National Environmental Policy Act of 1969
NHS = (Alaska Area) Native Health Service
NMFS = National Marine Fisheries Service
NWAB = Northwest Arctic Borough, Alaska
O&M = operation and maintenance
P.L. = Public Law
PAS = Planning Assistance to States
USCG = U.S. Coast Guard
USFWS = U.S. Fish and Wildlife Service
USGS = U.S. Geological Survey
V = vertical
VSW = Village Safe Water, a part of ADEC that also receives funds from EPA
WES = Waterways Experiment Station (of the U.S. Army Corps of Engineers)

ACKNOWLEDGMENTS

The investigations summarized in this report were accomplished through a cost-sharing agreement between the Federal Government and the Northwest Arctic Borough, executed on June3, 1997. During this study, Mr. Chuck Greene was mayor of the Northwest Arctic Borough. The city of Kivalina supported and participated in all aspects of the study. Mr. Oscar Sage Sr. was mayor of Kivalina and Ms. Betty Swan was city administrator in 1997. Members of the City of Kivalina Relocation Committee, who helped guide field investigations and plan formulation, included Austin Swan, Caleb Adams, Andrew Koenig, Fred Swan, David Swan, Enoch Adams Jr., and Joseph Swan Sr.

The investigations were conducted by the Alaska District, U.S. Army Corps of Engineers, and through contracts administered by the District in Anchorage, Alaska. The project manager was Dr. Orson P. Smith, of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Anchorage office. The headquarters and primary facilities of CRREL are located in Hanover, New Hampshire. Dr. Smith acted as project manager under the auspices of the U.S. Army Cold Regions Center of Expertise (CRCX), which is a cooperative venture between the Alaska District and CRREL. Dennis Hardy, Alaska District CRCX Advocate, helped arrange assistance by both District and CRREL specialists and provided his personal expert advice throughout the project.

The Alaska Area Native Health Service, Anchorage, conducted a concurrent investigation of water supply improvement options for Kivalina, funded through the Village Safe Water program of the Alaska Department of Environmental Conservation. LCDR Mark Anderson was project engineer for the Native Health Service. The principal product of this investigation was a geophysical survey of prospective village relocation sites, accomplished through a contract with the Anchorage office of Golder Associates. The Corps of Engineers provided logistical support for geophysical field measurements in conjunction with other fieldwork under way at the same time.

Mr. Ron Cothren of the Geomatics Department, University of Alaska Anchorage, accomplished plans and overall supervision of survey and mapping aspects of the study during a summer Inter-Government Personnel Act assignment to the Alaska District. Topographic and hydrographic geophysical surveys were accomplished through a contract with Terra Surveys of Palmer, Alaska, under the leadership of Mr. Tom Newman, RLS. AeroMap US, of Anchorage, Alaska, accomplished aerial photography and photogrammetric maps through a subcontract with Terra Surveys.

Alternative community layouts and cost estimates were accomplished by contract with DOWL Engineers of Anchorage, who subcontracted portions of the work to USKH, Inc. and HMS, Inc., also of Anchorage. Dr. Greg Carpenter and Mr. Stewart Osgood of DOWL Engineers alternated as project engineers for this contract and were assisted by Mr. Howard Holton of USKH and Mr. Cliff Hitchins of HMS.

Mr. Guy McConnell and Mr. Johnny Duplantis of the Environmental Resources Section, Civil Works Branch, Alaska District, prepared the overview of environmental and cultural issues and concerns presented here. Mr. James Sauceda, Chief of the Soils and Geology Section, Geotechnical Branch, Alaska District, performed field investigations and coordinated geotechnical aspects of the project. Mr. Steve Walls, of the Civil/Sanitary Section of the Technical Engineering Branch, Alaska District, designed a road from the coast to alternative relocation sites on the Wulik and Kivalina Rivers and performed computations for maintainable building foundations on the permafrost conditions of these sites. Mr. Steve Geppert of the Civil/Sanitary Section prepared preliminary designs for water supply systems at alternative relocation sites and improved water supply to the existing village site.

Dr. Jim Martel of the Geochemical Science Division and Ms. Rosa Affleck of the Civil Engineering Research Division, CRREL, Hanover, conducted field investigations and collaborated with the Native Health Service to develop alternative plans for improved human waste disposal. These investigators also visited the Cree Indian village of Ouje-Bougoumou in Quebec, Canada, which is internationally recognized as an outstanding example of a modern rural development with features designed to fit a Native culture and lifestyle.

Mr. Andy Tuthill of the Ice Engineering Division, CRREL, Hanover, and Mr. Ed Chacho of the Fairbanks office of CRREL performed field investigations and hydrological analyses to establish flood plain elevations at alternative relocation sites.

These investigations were conducted under the general direction of Mr. Claude V. Vining, Chief, Engineering Division; Mr. Kenneth E. Hitch, Chief, Civil Works Branch; and Mr. Carl Stormer, Chief, Project Formulation Section. Commander of the Alaska District during this study was Colonel Sheldon L. Jahn, Corps of Engineers. Dr. George Ashton, Chief, Research and Engineering Directorate, and LTC Mark Nelson, Commander and Director of CRREL, provided general direction of CRREL investigators.

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1. INTRODUCTION

1.1 Corps of Engineers Study Authority

The investigations documented in this report were conducted as part of the Planning Assistance to States (PAS) program of the U.S. Army Corps of Engineers under the authority of Section 22 of the Water Resources Development Act of 1974 (Public Law 93-251), as amended. This law authorizes the Chief of Engineers to cooperate with States to prepare plans for the development, utilization, and conservation of water and related land resources of drainage basins located within the boundaries of the State. Section 319 of the Water Resources Development Act of 1990 (Public Law 101-460) directs the Secretary of the Army to collect 50 percent of the cost of PAS projects from non-federal entities. Guidelines for PAS work are provided by Engineer Regulation 1105-2-100.

1.2 Cost-Sharing Agreement

An "Agreement between the United States of America and the Northwest Arctic Borough (NWAB), Alaska, for a Feasibility Study of Community Improvements for the City of Kivalina, Alaska," was executed on June 3, 1997. This agreement established a total project budget of $400,000 and specified increments of the scope of work, to include:

- Public and agency involvement
- Investigation of problems and solutions at the existing village site
- Investigation of problems and solutions at two relocation sites, one on the lower Wulik River and another on the lower Kivalina River
- Comparison of alternative solutions

- Development of an implementation plan for recommended improvements
- Preparation of a project report

1.3 Native Health Service Water Supply Study

The Alaska Area Native Health Service (NHS) began a study of water supply options for Kivalina in July 1997. This study was funded through the Alaska Department of Environmental Conservation, Village Safe Water Program. The Native Health Service effort consisted primarily of a geophysical survey aimed at location of prospective well sites that could provide a year-round source of clean water to the existing village or two alternative village relocation sites. The Corps of Engineers provided logistical support in August 1997 for geophysical measurements contracted by the city of Kivalina under the NHS project, in conjunction with other field investigations documented in this report.

1.4 Previous Studies

The most significant previous study was completed by DOWL Engineers in 1994, resulting in a report titled "City of Kivalina, Alaska, Relocation Study" (DOWL Engineers 1994). This project was authorized and funded through the Alaska Department of Community and Regional Affairs' Community Development Block Grant Program and was directed by the Kivalina City Council. Findings and conclusions of this report were applied directly toward this investigation and are summarized later in this report.

The University of Alaska Anchorage senior engineering class of 1996 investigated relocation of Kivalina to the lower Wulik River as part of their undergraduate course of studies. A report was not published, but the materials produced by the class are on file at the UAA School of Engineering.

1.5 Community Involvement

Leaders of the city of Kivalina participated in various meetings and negotiations of the scope of work, budget, and schedule for this project, which led to the aforementioned cost-sharing agreement between the Federal Government and the Northwest Arctic Borough. An initial public meeting took place in Kivalina on June 23, 1997, at which representatives of the study team introduced the objectives of the project to attendees and gathered practical advice related to pending field measurements. Following a reconnaissance of fieldwork sites at Kivalina, technical team members visited the borough offices in Kotzebue on June 25, 1997, to coordinate future work with borough staff members.

A second public meeting took place at Kivalina on August 5, 1997, at the start of an 8-day program of intensive field measurements. Members of the technical team described their planned measurements and analyses and heard the suggestions and concerns of Kivalina residents. Leaders of the technical team continued to meet with community leaders, in particular the Kivalina Relocation Committee, during the August field measurement program. The technical team enlisted Kivalina residents during this period to act as guides, river pilots, survey team members, and cooks. Food for the technical team was purchased at the Kivalina Store, and the Kivalina School provided housing. Additional documentation of the August fieldwork is presented in appendix K of this report. A special meeting was held with the technical team in Kivalina on August 7, 1997, at which elders of the community shared recollections of Kivalina history, severe weather events, and related difficulties.

Meetings took place on July 8 and October 20, 1997, at the offices of the NANA Corporation in Anchorage. At these meetings, representatives of the city, borough, and various public agencies heard study progress reports from the technical team and discussed related efforts. The draft version of this report was presented at a public meeting in Kivalina on December 11, 1997, and copies were provided to residents and interested agencies. A number of other meetings subsequently took place among residents, borough representatives, and others to discuss information in the draft report. Written comments on the draft report are published here in Appendix M, Correspondence.

2. COMMUNITY SETTING

2.1 Physical Setting

2.1.1 Location of Study Area.

Kivalina is located at latitude 67° 44' N., longitude 164° 33' W., which is approximately 80 miles north of the Arctic Circle on the Chukchi Sea coast of northwestern Alaska (figure 1). Kivalina is 119 kilometers (km) or 74 miles (mi) northwest of Kotzebue. The village is located at the southeastern tip of a barrier island that separates Kivalina Lagoon from the Chukchi Sea. Two tidal inlets define the island: Singauk Entrance, by the village, and Kivalik Inlet, 8.8 km (5.5 mi) to the northwest. The Kivalina River empties into Kivalina Lagoon at its northern extreme, and the Wulik River empties into the lagoon at its southern extreme. Travel to Kivalina is accomplished by sea or by small plane from Kotzebue.

2.1.2 Climate.

Long, cold winters and cool summers characterize the climate at Kivalina. The coastal location of Kivalina is responsible for generally breezy conditions, summer and winter. Temperatures range from 60 °F in summer to –17 °F in winter. About 8.6 inches of total precipitation falls each year, but this includes about 57 inches of snow. Winds averaging 10 knots cause deep snowdrifts at Kivalina in winter.

2.1.3 Geology and Soils.

Kivalina is located in a coastal area of low topographic relief, consisting of gently sloping, rubble-covered hills separated by broad expenses of tundra. Elevations range from sea level to a few hundred feet. Bedrock of limestone and dolomite is found in outcrops along river-cut bluffs of the Kivalina River. Marine deposits lie over bedrock near the mouth of the Kivalina River. Pleistocene glaciers originating in the mountains of the western Brooks Range covered the upper reaches of the Wulik and Kivalina Rivers, but did not advance into the study area. Low-lying portions of the study area are covered with unconsolidated Quaternary deposits of unknown thickness, ranging in size from clay to gravel. The flood plains of both rivers are broad and braided. The region has continuous permafrost, which may be encountered within a few feet of the ground surface. Permafrost may be as deep as 600 feet in the

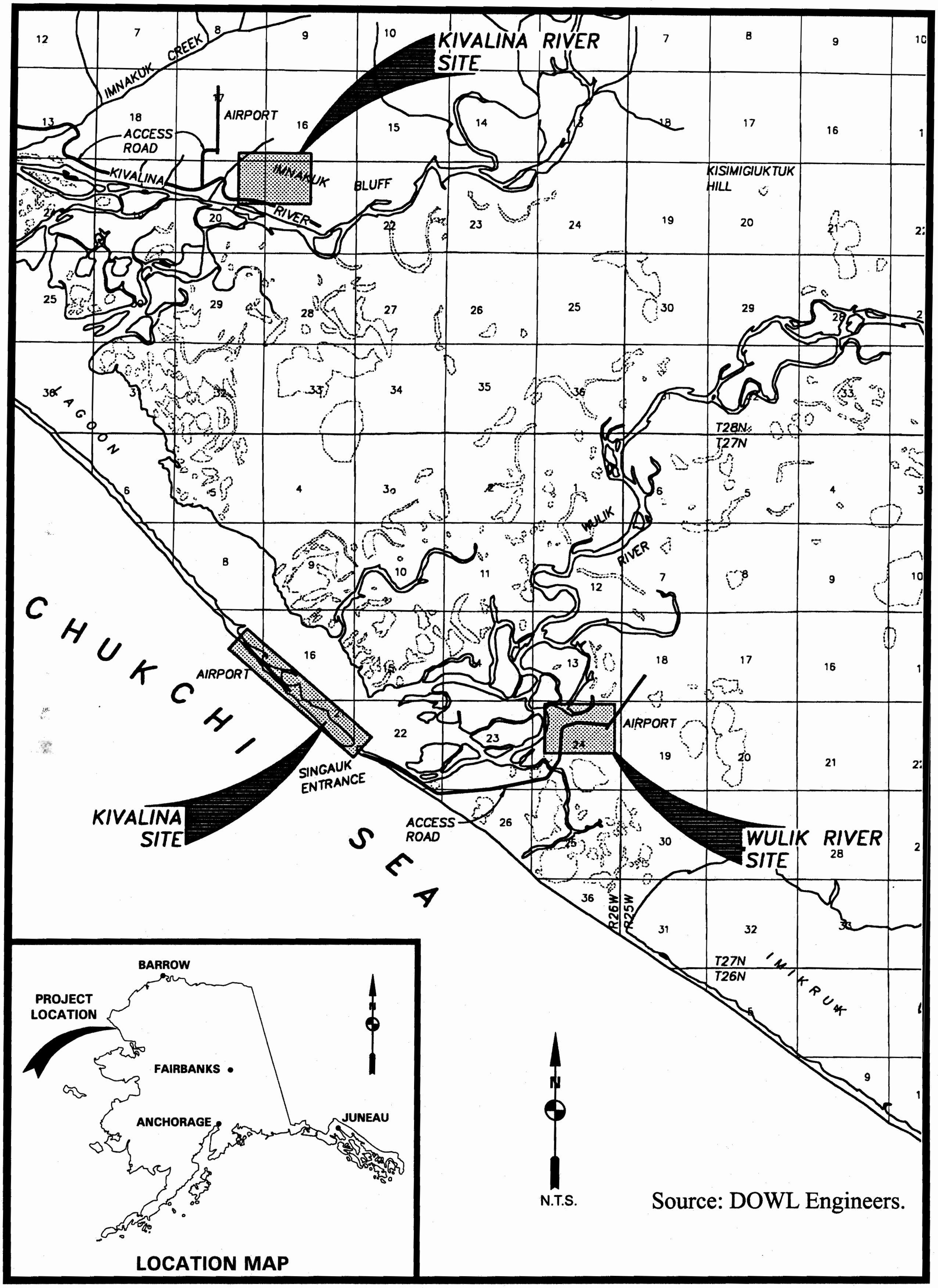

FIGURE 1.--Location and vicinity of Kivalina, Alaska.

study area, but thaw bulbs may exist in the vicinity of the Wulik and Kivalina River channels. The report of Golder Associates (1997, appendix B) provides additional background geology and results of a geophysical survey at prospective village relocation sites.

2.1.4 The Wulik River.

A program of field measurements, analysis of data on file, and numerical modeling were conducted as a part of this project to estimate flood elevations on the lower Wulik River. The Wulik River flood analysis is documented in appendix E of this report. The following paragraphs summarize the methods and results.

The U.S. Geological Survey has operated a discharge gauging station on the Wulik River below Tutak Creek from September 1984 to the present. The gauging station is located approximately 35 km upstream of the proposed new town site (Igrugaivik). The flood of record occurred on August 17, 1994, with an instantaneous peak of 1,090 cubic meters per second (m^3/s). A large flood event also occurred on July 26, 1996, with an instantaneous peak of 878 m^3/s. Flood peaks in the intervening years were relatively low. Based on the 12-year record from the Tutak Creek gauge, the estimated 100-year discharge is 1,780 m^3/s (63,000 ft^3/s). The drainage area at the gauging station is 1,830 square kilometers (km^2), resulting in a runoff of 0.60 and 0.48 m^3/s per km^2 for the August 1994 and July 1996 flood events. The drainage area at the proposed new town sites is 2,330 km^2. Flood peaks of 1,390 and 1,120 m^3/s are estimated at Igrugaivik for the August 1994 and July 1996 flood events.

The analysis used the HEC-2 numerical riverflow model to estimate the 100-year flood water surface elevation at Igrugaivik. Simulations assumed a concurrent wind-induced coastal storm surge elevation in the Kivalina Lagoon of 3.4 m. The results of the coastal storm surge analysis (appendix D) found this elevation to be slightly conservative, but quite close to a more precise surge estimate of 3.2 m. The water surface elevation in the lagoon had a much greater effect on flood elevations at Igrugaivik than river discharge. The 100-year water surface elevation at Igrugaivik due to these combined effects was estimated to be 3.6 m. The huge storage area of the wide tidal marsh north of the lower Wulik River prevents increases in river discharge in excess of the 100-year flow from causing substantial increases in water surface elevation. Therefore, land in the vicinity of Igrugaivik with elevations above 4 m is not very likely to be inundated by floods of the Wulik River.

2.1.5 The Kivalina River.

An analysis of flood flows and elevations for the lower Kivalina River was not accomplished for this project. The riverbanks are steep, and the land contemplated for village development is more than 10 m above the normal water surface of the river. There appears to be no danger of flooding at this proposed village relocation site. A flood frequency analysis should be accomplished, if this site is chosen for development, to establish design criteria for boat launch facilities and other riverbank developments.

2.1.6 Oceanography.

The Chukchi Sea is bounded to the north by the shelf break of the Arctic Ocean and to the south by the Bering Strait, a distance of more than 800 km. Its lateral extent varies from a minimum of 85 km at the Bering Strait to a maximum of about 900 km along the shelf break west of Point Barrow to Siberia. The basin has a relatively flat bottom, with depths increasing gradually from 30 m in the east to 55 m in the west. The major features of circulation in the Chukchi are influenced by bathymetric features, seasonal wind stress, sea ice, fresh water inflow from rivers, and influx of Pacific water through the Bering Strait. Weingartner (1994) summarized the bathymetric and oceanographic features of the northeast Chukchi, north of Point Hope. Aside from the gross features of weather patterns and flow volumes through the Bering Strait, little of the information pertains to the southern Chukchi and the region of Kivalina.

The southeastern Chukchi Sea, south of Point Hope, is characterized by shallow water that nowhere exceeds 50 m. The village of Kivalina lies on the open Chukchi Sea coast north of Kotzebue Sound, about halfway between Cape Krusenstern and Point Hope. Kotzebue Sound, between Cape Espenberg and Cape Krusenstern at the southeastern portion of this region, is a large, shallow estuary surrounded by smaller bays and inlets. The City of Kotzebue, seat of the Northwest Arctic Borough, lies on a sandy peninsula on the eastern side of the sound.

The Chukchi Sea is characterized as a microtidal environment. At Shishmaref, on the south shore of the Chukchi Sea, mean high tides reach +0.76 m above mean sea level (MSL) while the highest tidal debris is only + 0.975 m above MSL (Mason *et al.* 1997). Though tidal measurements have not been made at Kivalina, the range is expected to be similar. Because the tides are minor, water surface elevations due to atmospheric changes and wind stress can be quite significant. The presence of sea ice offshore tends to reduce the occurrence of storm surges throughout the area from November to June. There have been occurrences of storm surge flooding on top of shorefast ice in the Kotzebue area, but an ice cover generally dampens the transfer of energy from the atmosphere to the ocean. Most storm surges along this coast occur in August and September. In late October and early November, shorefast ice appears along the entire coast, including eastern Kotzebue Sound. By late November, the region is generally covered with pack ice (Wise *et al.* 1981).

Major storms generally enter the Chukchi from the southwest at the Bering Strait (Mason *et al.* 1997). High intensity storms, most common during fall, may cause winds of 40 to 70 knots. Waves generated by these winds have been observed at Shishmaref to be as high as 5 m, and 3-m storm surge elevations have been recorded at Kotzebue. In the initial phases of the storms, southwesterly winds may generate large waves toward the northeast directly into Kivalina. In later phases, winds may shift to the west, northwest, or north. Once the wind shift to the west and northwest has occurred, Kivalina is relatively protected from extremely large waves. Strong winds from these latter sectors may cause shifts in the predominantly northerly coastal current, however. Bathymetric soundings show that the sea bottom off Kivalina is relatively shallow and broad, with shore-parallel sand or gravel bars at a depth of approximately 1.5 to 2 m. This condition protects the village from extremely large waves, which are limited in height to about 0.8 of the water depth. The effects of breaking waves and runup are discussed in appendix D of this report.

2.2 Living Resources

The importance of biological resources is related, in this discussion, to their role in local and regional ecosystems and their value to humans. Human values may be related to consumption (*i.e.,* subsistence or recreational taking) and to cultural values (*e.g.,* esthetic, traditional, religious, educational, and status as threatened or endangered). The following discussion focuses on the biological resources in the Kivalina area that: (1) are important in local subsistence use, or (2) are otherwise identified as important by regulation. Examples of the second category are endangered species and wetlands, both of which are given special consideration under Federal law. The focus is further narrowed to address important resources that might be affected, either adversely or beneficially, by a decision to move the village or to alter land use around the village.

2.2.1 Subsistence Resources.

General. Subsistence uses of natural resources are extensive and essential in this remote village. The most comprehensive survey of subsistence uses (Burch 1985) is 12 years old. That survey and more recently the ADF&G 1992 survey identify the principal subsistence food sources and the variations in their use. Use patterns may have changed in the years between the two surveys, but the relative importance of subsistence resources remains.

Two hunting and fishing periods are crucial to the production of staple foods. The first is early summer, when most of the dried fish (early to mid-June) and all of the dried bearded seal meat and oil (mid-June to early July) are harvested. The second is early fall (mid-September to early October). It is during the latter period that most of the fish later consumed frozen as *quaq* are caught. The major harvest of caribou is in early fall.

Despite the many changes that have come to Kivalina in the last 30 years, residents still depend on traditional Native foods. The people of Kivalina tend to view the subsistence year as a continuous flow of activities ordered by the migratory habits of fish and game species (ADF&G 1985). Table 2-1 presents the estimated harvests during four different subsistence years.

TABLE 2-1.--*Kivalina total harvest of major food resources by species*[a]

Species	1964-65	1965-66	1982-83	1983-84
Bear, grizzly	280 (0.1 %)	730 (0.2%)	0 (0.0%)	862 (0.2%)
Bear, polar	0 (0.0%)	800 (0.2%)	0 (0.0%)	1,325 (0.3%)
Beluga	15,250 (4.1%)	31,150 (7.0%)	71,750 (16.4%)	74,850 (15.1%)
Caribou	60,563 (16.4%)	240,724 (54.1%)	80,337 (18.4%)	127,753 (25.9%)
Char	93,995 (25.5%)	28,140 (6.3%)	69,059 (15.8%)	68,467 (13.9%)
Cod	0 (0.0%)	6,955 (1.6%)	9 (--)	4,299 (0.9%)
Moose	0 (0.0%)	3,400 (0.8%)	5,100 (1.2%)	4,950 (1.0%)
Salmon[b]	1,425 (0.4%)	116 (--)	464 (0.1%)	2,107 (0.4%)
Seal, bearded	85,592 (23.2%)	68,406 (15.4%)	76,266 (17.5%)	33,103 (6.7%)
Seal, ringed	109,547 (29.6%)	59,078 (13.2%)	21,784 (5.0%)	11,776 (2.4%)
Walrus	0 (0.0%)	5,450 (1.2%)	111,800(25.6%)	6,000 (1.2%)
Whale, bowhead	0 (0.0%)	0 (0.0%)	0 (0.0%)	157,080 (31.7%)
Whitefish	2,500 (0.7%)	13 (--)	100 (--)	1,608 (0.3%)
Totals	369,152 (100%)	444,962 (100%)	436,669 (100%)	494,180 (100%)

[a] Figures are for estimated whole body weights, not just edible pounds.
[b] All species included.
Source: Burch 1985.

Subsistence patterns reported 12 years ago apparently continue today. The people of Kivalina harvested about 262,000 edible pounds of wild foods in 1992. This is the equivalent of about 3,600 pounds per household or 760 pounds per capita. Kivalina's 1992 per-capita subsistence harvest was approximately 25 percent greater than that reported for 1991 by the more populated and diverse regional center of Kotzebue, but was similar to the per-capita harvests of several other small northern Alaska communities with a marine mammal orientation (Magdanz *et al.* 1995).

Variability in annual harvest of different species is probably a function of several factors, which were addressed by Burch (1985), but have been altered by recent changes in the village (Magdanz *et al.* 1993). Those factors include relative abundance of the resources near the village; availability of preferred subsistence resources and other foods; non-biological conditions (sea ice, weather, snow cover, and other weather-related conditions) that affect the villagers' ability to reach subsistence resources; changes in regulations that affect use of animal products; and changes in technology that affect transportation, food storage, and other aspects of life in the village.

Subsistence Resources That Could Be Affected. Most marine mammals would not be directly affected by land use changes at Kivalina or by a decision to move the village. The marine mammals in the Kivalina subsistence harvest are from large populations that do not depend upon habitat at the village or at a site where the village might be relocated. Other species that use the Wulik and Kivalina Rivers, Kivalina Lagoon, and the lands around them are more likely to be affected by decisions about land use around Kivalina. Potentially affected subsistence species, based on the Burch (1985) report, include moose, caribou, grizzly bear, polar bear, salmon, Arctic char, whitefish, cod, and other fish.

The fish categorized as "char," "salmon," and "whitefish" in table 2-1 may represent several species. Char are a group of fish species that include Arctic char, Dolly Varden, lake trout, brook trout, and others. Char in the Wulik and Kivalina River have been identified, by different professionals using various characteristics, as either arctic char (*Salvelinus alpinus)* or Dolly Varden (*Salvelinus malma)*. The species are similar, and the characteristics separating the two have been debated for many years. A generally accepted taxonomy lists the char of the Kivalina River as Dolly Varden (Morrow 1980). Others (Alt 1978, DeCicco 1983, 1984) refer to them as arctic char. The Alaska Department of Fish and Game, which for years listed the State record arctic char as a Wulik River fish, now lists the species in the Wulik River as Dolly

Varden (Ott and Scannell 1996). The Wulik and Kivalina char are locally referred to as "trout."

Salmon includes chum, pink, coho, chinook, and sockeye salmon, all of which are reported to occur in the Wulik River (NWAB 1996). The Alaska Department of Fish and Game (1978) identifies spawning populations of pink and chum salmon in both the Wulik and Kivalina Rivers. Burch (1985) and Magdanz *et al.* (1993) both report that most of the salmon reported in the subsistence catch were chums.

Whitefish includes at least four species in the freshwater systems around Kivalina: humpback whitefish (*Coregonus pidschain*), round whitefish (*C. cylindriceum*), Bering cisco (*C. laurettae*), and least cisco (*C. sardinella*) (Burch 1985). Burch (1985) reports that humpback and Bering cisco represent almost all the catch, either targeted or taken incidentally in the char and salmon fisheries.

Cod include two species, arctic cod (*Boreogadus saidi*) and saffron cod (*Eleginus gracilis*), that are taken through the ice from the lagoon (Burch 1985). Other fish reported in subsistence catches include grayling, burbot, sculpin, and smelt.

Burch (1985) reported that berry picking is an important summer activity for both the food obtained and for the variety in activity it offers. He reported that blackberries (crowberries, *Empetrum nigrum*), blueberries, low-bush cranberries, and salmonberries were the most important species. Sourdock also is harvested and may still be important in some diets.

2.2.2 Important Wildlife and Their Habitats.

Moose range through most of western Alaska, including the area around Kivalina. No critical habitats for moose have been identified in the area of the lower Wulik and Kivalina Rivers. ADF&G (1973) did not note any moose habitat of special importance in the area, and the relatively low numbers killed locally indicate relatively sparse populations. Moose generally prefer willow as food, but the dense willow stands along both the Kivalina and Wulik Rivers showed very little indication of moose browsing. Tracks were seen only occasionally in August 1997, and little of the willow showed "brooming" that indicates winter browsing.

The region of the lower Wulik and Kivalina Rivers is listed as caribou winter range (ADF&G 1973), but no critical habitats for caribou have been identified in the area. Caribou use is apparent in the extensive trails, antlers and bone fragments at kill sites, and the harvest recorded in subsistence records. Burch (1985) reported that caribou were a major part of the subsistence diet, with 500 to more than 1,000 taken in the years he recorded. Magdanz *et al.* (1993) indicate that a kill of 500 caribou is considered a poor year. The area around Kivalina is certainly important winter habitat to the vast Western Arctic caribou herd, but the herd also occupies a huge area of northern and western Alaska. None of the area around Kivalina is identified as important calving habitat or is in a restricted migratory pathway required by the herd, so none of the area is listed as "critical habitat."

Grizzly bear range throughout the area. They are not of particular importance in local uses, and no specific denning or other critical habitats have been identified in the area. Polar bear occasionally drift south with ice floes, but do not den or use other critical habitat in the area.

Musk oxen were reestablished in the Cape Thompson area in 1970 and 1977. The population in the area between Cape Thompson and the Noatak River has grown to about 200. People from Kivalina harvest a small number of musk oxen (Ayres 1995). Parts of the herd have ranged through the Kivalina area since soon after the herd was reestablished. ADF&G (1973) reports summer and winter ranges in relatively small areas south of the village. Those areas may deserve recognition as important habitats.

Waterfowl, including sea ducks, diving ducks, dabblers, swans, geese, and cranes migrate through and nest in the area. ADF&G (1973) lists the entire area as migratory and nesting habitat for waterfowl. Northwest Arctic Borough (1996) lists the flats around the Kivalina and Wulik Rivers as important migratory waterfowl staging and nesting areas.

Occurrence of marine mammals within this area is closely associated with the presence of shorefast ice along the coast during the winter and the recurring polynya (area of open water) between Kivalina and Point Hope. During the winter, ringed seals use the shorefast ice for pupping. Densities of 2.3 ringed seals per nautical square mile have been reported for this area. Bearded seals are present during the winter in association with flaws, leads, polynyas, and open-water areas. Beluga whales may be in the open leads along the coast as early as January and February due to the presence of a persistent polynya. During the summer, gray whales feed in the shallow water adjacent to the coast in this area. Spotted seals use the barrier island beaches and coastline as haul-out locations during the summer and fall; specific high-use locations have not been identified. (Northwest Arctic Borough 1996).

Critical habitats associated with the marine mammals of the Bering Sea near Kivalina appear to be associated with migratory routes used by gray and bowhead whales and with leads, cracks, or other openings that form in the sea ice and are vital to survival of all the marine mammals. Both habitats are extremely important to the marine mammals and to the people of Kivalina. However, neither habitat is particularly vulnerable to the types of impact that might be associated with the alternative actions considered in this report.

2.2.3 Endangered Species.

Several whale species that might occur in the Chukchi Sea near Kivalina are listed as endangered species. Several other listed species might be found in the Kivalina area. Spectacled eider (*Somateria fischeri*) is not known to nest near the Kivalina area, but may move through the area. Steller's eider (*Polysticta stelleri*) nests in various sites in western Alaska; none are known to nest in the immediate vicinity of Kivalina, but they may move through the area.

2.2.4 Wetlands.

Most of the vegetated lands around Kivalina are wetlands, which are given special consideration in accordance with the Clean Water Act of 1977. Wetlands near the lower Wulik and lower Kivalina Rivers have been mapped by the National Wetlands Inventory.

2.2.5 Critical Fish Habitats.

Char. Northwest Arctic Borough *et al.* (1996) reported that 60,000 to 140,000 char overwinter in the Wulik River each year. Historically, the variation may have been even greater (DeCicco 1984). A smaller but regionally important number of char overwinter in the Kivalina River. These overwintering char are largely stocks from other river systems of the region, so protection of this resource is important to the freshwater fisheries in the entire region. These fish spend the winter in deeper pools of the rivers where there is enough dissolved oxygen to maintain them and enough water depth to protect them from freezing. The overwintering areas have been defined as the mainstream of the lower reaches of both rivers, starting about 3 or 4 miles upstream from the mouth and continuing another 15 or 20 miles (Alt 1978, DiCicco 1983, Ott and Scannell 1994). These areas are essential to the char stocks of the Wulik and Kivalina Rivers and to the stocks of the region. The wintering areas are critical habitats.

Most overwintering char migrate out from the Wulik and Kivalina Rivers after breakup, during June in most years, to continue their complex migratory pattern that may take them into various other freshwater systems of the region. A thousand or so overwintering fish apparently stay in the Wulik, and a smaller number remain in the Kivalina to spawn in the late summer or early autumn. Alt (1978) and DiCicco (1983) identified principal spawning areas in the Wulik and Kivalina Rivers. They reported the spawning in the middle and upper reaches of the Wulik River, more than 15 miles upstream from its mouth, and in tributaries to the middle and upper river. Principal spawning areas for the Kivalina River were reported in Grayling Creek, the river above Grayling Creek, and in tributaries above Grayling Creek.

The spawning population varies considerably each year, but is roughly 1,000 char in the Wulik. Spawning habitat for this species typically is gravel one-fourth inch to 2 inches in diameter near the center of the stream, in water at least 1 foot deep (Morrow 1980). Spawning depths in the Wulik River would be appreciably deeper to protect eggs from desiccation and freezing. Char eggs hatch over the winter. The newly hatched young remain in the gravel of the spawning bed until the yolk sac is absorbed, and emerge as fry about 1 inch long. The young typically remain in the river of their origin for 3 or 4 years, then begin their cycle of migration to salt water and possibly other streams. During their residence in the rivers, these char require riffles and other feeding habitat, and most critically, spring-fed pools for wintering habitat. The young may winter in smaller pools than those used by larger char. Char reach maturity at about 7-9 years. In northern Alaska, they spawn only every second or third year (Morrow 1980).

Critical habitat for char in the Wulik and Kivalina Rivers can be expected to include:

1. Any pools that do not freeze during the winter and that receive sufficient flows to maintain dissolved oxygen. These pools are essential to overwintering char and to the well-being of the entire char population in these rivers.

2. Spawning gravels that are acceptable to spawning char, that do not freeze, and that receive enough flow to maintain dissolved oxygen levels all winter.

Char also require riffles and other feeding habitat, adequate passage for their seasonal migrations, and good water quality, but wintering and spawning habitat probably are the most limiting.

Other Fish. Most other fish in the Wulik River require habitat about like that required by char. Grayling need pools or spring-fed areas for overwintering, gravel for spawning where it will not freeze, and shallow riffles for food production. All the salmon require spawning gravels in areas that do not freeze. Pink salmon spawn in the lower 6 miles of the Wulik River, downstream from Simik Hill to the mouth of the river. Chum salmon spawn in the lower 15 miles of the river and in the upper Kivalina River and its tributaries from Kitingirak Gap downstream to Simik Hill. A few sockeye spawn below the forks of the Wulik (Northwest Arctic Borough 1996).

Young of chums and pinks migrate out to the lagoon and, presumably, to the Bering Sea during their first summer. Juveniles of the other salmon species have about the same requirements as the young char. Whitefish, too, require wintering habitat, spawning gravels, and shallows that produce aquatic invertebrates for food.

The two species of cod that regularly appear in the subsistence fishery are species that commonly use brackish water or make excursions into fresh water. Both use the lagoon for a period just after freezeup and are taken in the local fishery. Habitat requirements are not known, but it might be assumed that the fish are in the lagoon to feed. They feed on a variety of invertebrates and small fish.

Planning Measures To Avoid or Minimize Impacts. The Northwest Arctic Borough (1996) Coastal Zone Management Plan lists the following activities or results from development that could cause significant adverse impacts:

a. Surface runoff from disturbed areas or erodible soils,

b. Removal of streamside vegetative cover,

c. Alteration of water flow, temperature, or water quality,

d. Increased turbidity or sedimentation above seasonal ambient levels,

e. Interference with free movement and timely migration of adult or juvenile fish within or between seasonal use areas,

f. Alteration of the physical integrity of spawning, rearing, or overwintering areas,

g. Induced thickening of ice cover on overwintering areas by ice roads, snow removal, or vehicular traffic compaction,

h. Reduction in abundance of preferred food organisms,

i. Disturbance of the hydrologic equilibrium of watercourses,

j. Blasting in or adjacent to aquatic habitats,

k. Thermal degradation of permafrost from vegetation clearing or stripping of the insulating organic mat,

l. Disturbance of streambanks, flood plains, or adjacent uplands which induces hydraulic or thermal erosion,

m. Disposal of overburden within stream flood plains, and

n. Discharge of effluents from sewage treatment facilities, mining operations, or processing facilities.

To avoid impacts and to minimize unavoidable impacts, the coastal zone management plan defines areawide policies that restrict or place special limitations on activities in the coastal zone. The plan also identifies Important Resource Areas and specific limitations to protect those areas. The North Kivalina Coast, which includes the coast along Kivalina Lagoon and the lower Wulik and Kivalina Rivers, is one of the Important Resource Areas. Specific limitations are identified to protect subsistence uses, marine mammals, and nesting waterfowl between June 1 and July 15.

A more restrictive category is established for Sensitive Use Areas, one of which is the Wulik River Dolly Varden Overwintering Area. The restrictions are related to mining and gravel extraction in the active flood plain, wastewater discharge, and flow maintenance.

2.3 Community Profile

2.3.1 History.

The vicinity of Kivalina has long been a stopping-off place for seasonal travelers between the arctic coastal areas and Kotzebue Sound communities. Kivalina was founded in 1905, when a school was built on an island opposite the mouth of the Wulik River. The original population consisted of a number of survivors of the aboriginal Kivalinarmiut Society, as well as refugees from Shishmaref. Archaeological and cultural resources are present in Kivalina and the surrounding areas (Northwest Arctic Borough 1996), but a search of the Alaska Heritage Resource Survey data base did not identify any historical or archaeological sites in the village of Kivalina or in any of the alternative location sites.

2.3.2 Native Culture.

The culture of Kivalina residents is Inupiaq Eskimo, whose values are expressed in this pledge:

With guidance and support from Elders, I teach my children these Inupiaq values: respect for Elders, sharing, love for children, cooperation, respect for others, hard work, respect for nature, avoid conflict, hunter success, spirituality, domestic skills, family roles, humility, humor, knowledge of language, knowledge of family tree, and responsibility to tribe.

Most Kivalina residents are devout Episcopalians, and Protestant Christian teachings are now intertwined with more ancient Inupiaq traditions and values. All living residents of Kivalina have had educational opportunities, and most have traveled to urban areas within and outside Alaska. Kivalina has for at least two decades had regular access to radio and television. A significant number of residents have college-level education. The democratic values of the rest of the United States and the ubiquitous culture transmitted by modern media are also strong influences among Kivalina residents.

2.3.3 Demography.

Kivalina had 421 residents according to a housing survey conducted in August 1997, which is 72 residents (21 percent) more than the population certified in December 1996 by the Alaska Department of Community and Regional Affairs (appendix A). The 1990 census indicates that 97 percent of residents are (Inupiaq) Eskimo. A projection of the growth rate from 1970 to 1996 by the U.S. Census predicts a population of 562 residents in 20 years. Significant community improvements, as discussed in this report, will probably draw about 10 percent more residents to the community. A target population of 600 residents is accordingly applied for facility design in subsequent chapters of this report.

2.3.4 Local Government.

City of Kivalina. The city of Kivalina was incorporated in 1969 under the laws of the State of Alaska as a second class city with an elected mayor, elected city council, and appointed city administrator. The city operates a variety of public services, funded in part by a 2-percent local sales tax.

Native Village of Kivalina. The Corporate Charter of the Native Village of Kivalina was ratified under the auspices of the U.S. Department of Interior, Office (now Bureau) of Indian Affairs. The charter designates the village as a "Federal Corporation chartered under the Act of June 18, 1934, as amended by the Act of

May 1, 1936." The Indian Reorganization Act (IRA) of 1934 was amended in 1936 to include Alaska. The charter declares the corporation to have the following powers:

- To own, hold, manage and dispose of all village property;
- To make contracts;
- To sue and be sued;
- To borrow money from the revolving Indian credit fund and to use it under a loan contract;
- To enter into any business or activity that will better the condition of the village and its members; and,
- To do such other things as may be necessary to carry on the business and activities of the Village.

The constitution and bylaws of the village, ratified February 7, 1940, begin with the following preamble:

> *"...We, a group of Eskimos having the common bond of living together in the Village of Kivalina, Territory of Alaska, in order to have better life and greater security, make for ourselves this Constitution and By-Laws, by Authority of the act of Congress June 18, 1934, as amended by the acts of June 15, 1935, and May 1, 1936..."*

The Constitution specifies members of the village as "all persons whose names are on the list of native residents, made according to the Instruction of the Secretary of the Interior for organization in Alaska," and all children of any members.

An administrator and a council of seven, known as the IRA Council, manage the village corporate affairs. The IRA Council has influence essentially equal to that of the city of Kivalina government with regard to major decisions affecting the community.

2.3.5 Regional Government - Northwest Arctic Borough.

The Northwest Arctic Borough (NWAB) was incorporated as a home rule borough under the laws of the State of Alaska. Kivalina and 10 other communities distributed over a land area of 39,000 square miles are represented by the NWAB. It is the second-largest borough in Alaska, extending roughly 175 miles north to south and 250 miles east to west. The borough includes a coastline of more than 300 miles and a number of significant river drainages. The borough has 641 residents, more than 90 percent of which are Inupiaq Eskimo (NWAB, undated brochure). Subsistence lifestyles dominate all borough communities except Kotzebue, which has become a transportation hub and business center for the surrounding region. Borough offices are located in Kotzebue.

2.3.6 Native Corporations.

NANA. The NANA Regional Corporation, formed in 1971, is a merger of the original Alaska Native Claims Settlement Act (ANSCA) Regional Corporation for the area with 10 of the 11 original village corporations (all except Kotzebue). Under ANCSA, regional and village corporations received settlements of cash and land. NANA has 8,500 Inupiaq Eskimo shareholders.

Maniilaq Association. Maniilaq Association is a nonprofit entity that provides health, social, and planning services to the region. Maniilaq oversees services including hospital and dental care, counseling, substance abuse treatment, emergency shelter, village government assistance, vocational training, and housing assistance. With headquarters in Kotzebue, Maniilaq serves the region through a network of community clinics, adult education programs, and tribal operations.

2.3.7 Public Facilities.

The Wulik River provides water through a surface transmission line, which is treated and stored in a 600,000-gallon and a new (1997) 750,000-gallon tank. Water is hauled from this point for most purposes. One third of Kivalina homes have running water for the kitchen. Four honeybucket disposal bunkers are located in the city. A new landfill and an adjacent honeybucket dumpsite were completed in 1996, which are intended to allow abandonment of the bunkers in the city proper.

2.3.8 Housing.

An August 1997 housing survey indicates a total of 80 residences exist in Kivalina. these houses have 1 to 3 bedrooms and as many as 15 occupants. Most homes have more than 5 occupants. Appendix A presents housing statistics based on the 1990 census.

2.3.9 Kivalina School.

The Northwest Arctic Borough School District provides public education in all 11 borough communities. The McQueen School at Kivalina serves approximately 109 students from pre-kindergarten to 12th grade. The school employs one principal (currently Mr. Tom Hanifan), 7 teachers, and 13 staff. The school has nine classrooms, a wood shop, darkroom, gymnasium, library, and modern computer and video equipment. The Chukchi Campus of the University of Alaska Fairbanks, through its Kotzebue facilities, offers post-secondary courses at Kivalina.

2.3.10 Transportation.

The major means of transportation are plane, barge, small boat, all-terrain vehicles, motorcycles, and snowmachines. There are no roads outside the village. A State-owned 914-m (3,000-ft) airstrip serves daily flights of small planes from Kotzebue. Fuel and bulk cargoes are delivered by barge each summer. Coastal barges in many years have been able to navigate Singauk Entrance and offload cargo in Kivalina Lagoon at the village. Barges must occasionally land on the open coast at the village, when the inlet is shallow. Strong onshore winds preclude navigation of the inlet or landing on the open coast, sometimes causing delays in cargo deliveries.

2.3.11 Economy and Employment.

Subsistence fishing and hunting dominate the activities of most Kivalina residents, and high levels of unemployment and poverty are chronic. The Native craft industry has recently expanded. Carvings and jewelry are produced from ivory, whalebone, and caribou hooves. The major employers are the school, city government, Maniilaq Association, the village council, local airlines, and local stores. Six residents hold commercial fishing permits. The 1990 census indicated a median household income of $28,000 and 32 percent of household incomes below the poverty level. Of 168 potential workers, 56 percent were unemployed in 1990.

The single most significant economic impact on the region has been the development of the Red Dog Mine, whose port site is only 18 miles down the coast from Kivalina. The mine began operations in 1991, mining lead and zinc ore at the headwaters of the Wulik River. The mine is owned and operated by Cominco, a Canadian-owned corporation. The Alaska Industrial Development and Export Authority, a State-owned corporation, has participated in financing, building, and operating a haul road to the coast and a port facility for lightering ore to large ships anchored offshore. The construction, operation, and recent expansion of the Red Dog Mine have provided employment opportunities for Kivalina residents, whose transportation by air to the mine's private airstrip is provided by Cominco. Few Kivalina residents are actually employed at the mine at any one time, however, and periods of employment tend to be measured in weeks.

The arctic char of the Wulik River are noted in sport fishing literature for world-class fishing, and records have been set with Wulik River catches. The Kivalina River also has a notable run of these prized sport fish. One camp on the Wulik River now provides guide services to small groups of fishermen who fish both rivers. Tourism focused on sport fishing may prove to be a profitable enterprise at Kivalina in coming years, perhaps worthy of advertised guide services and one or more riverside lodges.

2.3.12 Land Ownership.

Land ownership in the study area is either by NANA Corporation, the State of Alaska, or individuals in the form of ANCSA Native allotments. The State of Alaska owns the island land at the site of the airstrip for a distance of 6,700 feet from the edge of the village. This and Federal Aviation Administration clearance rules are presently the primary constraints to expansion of housing at Kivalina. Native allotments are scattered along Kivalina Lagoon and the Wulik and Kivalina River banks. Maps excerpted from Bureau of Land Management files, presented in appendix C, show allotments affecting choices for village relocation.

3. PROBLEMS AND OPPORTUNITIES

3.1 Summary of DOWL 1994 Report

The city of Kivalina contracted with DOWL Engineers of Anchorage, Alaska, using funding from the Alaska Department of Community and Regional Affairs, to determine solutions to a range of problems at Kivalina (figure 2). Among these problems were inadequate sewage, substandard seasonal water supply, overcrowded residences, risk of storm surge flooding, and coastal erosion.

The study compared alternative solutions to these problems, including moving the existing airstrip to allow village expansion, filling in land on the Kivalina Lagoon to allow village expansion, constructing a bridge across Singauk Entrance for access to more land for village expansion, and relocating the village to one of eight alternative sites. Relocation sites, suggested by Kivalina residents, included these:

- Imnaaquuq, on the lower Kivalina River;
- Sivutchiaq, on the lower Kivalina River 1 mile upstream of Imnaaquuq;
- Ikpikruaq, on the east shore of Kivalina Lagoon, north-northwest of Kivalina;
- Sivu, 14 miles upstream on the Wulik River;
- Kirjiktuuraq, at the mouth of the Wulik River on the Chukchi Sea coast;
- Ushaq, south of Kivalina on the Chukchi Sea coast;
- Igrugaivik, on the lower Wulik River; and
- Kuugruaq, on the lower Wulik River immediately upstream of Igrugaivik.

Options were compared according to criteria including lack of storm surge, water supply, sewage disposal, construction material source, soil conditions, barge access, distance from current site, access to ocean, access to Wulik River, access to Kivalina River, least cost, use of the existing airport, lack of permit requirements, lack of community disruption, availability of funding sources, and potential for a crosswind runway. A weighted rating value scheme for the above criteria was applied with substantial community input. The report recommended relocation to Kuugruaq on the Wulik River, based on the high score this option received, but stated some reservations with regard to potential flooding and prospective land ownership conflicts. Igrugaivik was recommended as second choice. Relocation costs were estimated to be on the order of $50 million.

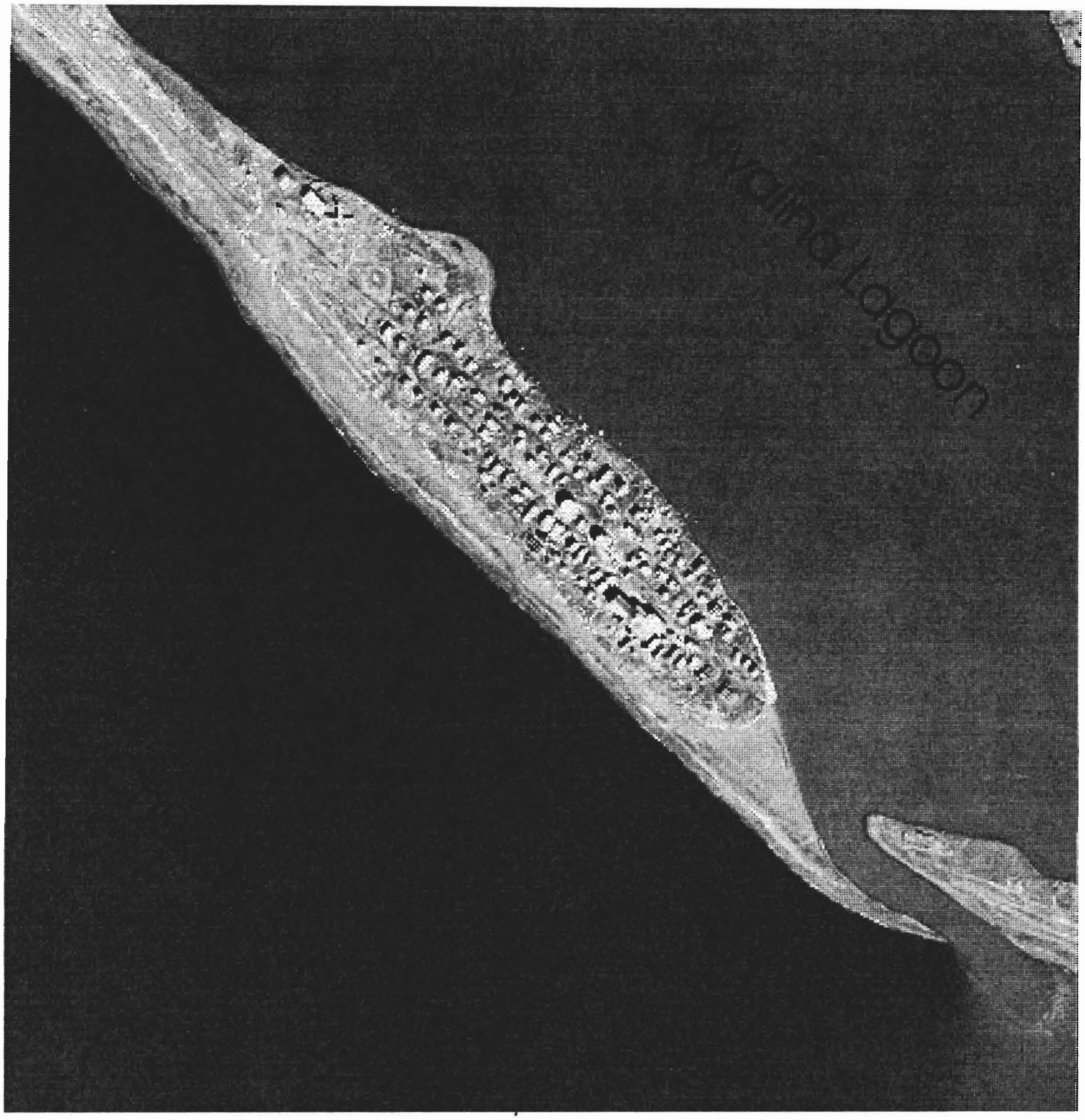

FIGURE 2.--Kivalina, Alaska, September 5, 1997.

3.2 Housing Shortage

Housing data provided by the city of Kivalina and Maniilaq in August 1997 (not counting housing provided for teachers by the school district) indicates 354 people occupy 68 separate residences at an average occupancy of 5 persons per residence. The average number of bedrooms in the residences is two. The maximum occupancy recorded was 17 persons living in one 3-bedroom residence, but other high occupancies of 15, 14, 12, and 10 persons living in 2- and 3- bedroom residences were also recorded.

The DOWL report (1994) presented measurements of 95 structures at Kivalina. Fifty-eight of these were occupied residences at the time of the investigation, most with 750 to 1,000 square feet in floor space. Figure 2 shows the present density of buildings at Kivalina, all located within the 27 acres area now available to the city. Few options exist for constructing additional housing. Clearly, Kivalina residents are pressed into crowded housing conditions far below any acceptable standard. Arctic winters cause these living conditions to be extraordinarily unhealthy from trapped air and heating and cooking fumes and unsafe with regard to fire hazards.

3.3 Water Supply

Two storage tanks (692,000 gallons and 508,000 gallons), filled during the short summer season, currently provide the community water supply. Water is pumped 2-1/2 miles from the surface of Wulik River through a surface transmission line to the tanks. Pumping is done at low tide to avoid brackish water, which can reach this intake point at high tide. The worst problem with the present water supply system is that the storage tanks can't be replenished when the Wulik River is frozen, which is all but 3 months of the year. The water supply is not adequate for fire fighting in any month. Hauling water for home use is an extreme hardship in winter for most residents. Water hauling involves significant personal hazards during frequent winter high winds and cold temperatures. Without running water, most homes cannot maintain healthy standards of cleanliness, a situation exacerbated by extremely crowded housing. No liquid waste disposal system is now in place except in the school buildings and at the community washateria. The water supply could not support flush toilets anyway. Improvements to the water supply system at Kivalina must have a high priority among goals for health and safety.

3.4 Waste Disposal

3.4.1 Human Waste.

Honeybuckets are at best an expedient solution to sanitation, but they have been a way of life for generations of rural Alaskans. The problem of providing flush toilets that function in Alaskan winters is expensive, but this not an insurmountable challenge. One by one, villages across the State have been equipped with modern plumbing, designed for the arctic environment. Financial constraints and the press of other worthy priorities continue to hamper progress. Kivalina, in this regard, is like many other Bush communities.

The recently completed honeybucket dump, located beyond the airstrip approximately a mile and a half from the village, has made it possible to abandon old honeybucket bunkers on the village perimeter. The down side of this new facility is that brim-full honeybuckets must be towed on 4-wheeler trailers or snowmachine sleds for the long haul along the island, frequently in miserable conditions of wind, rain, snow, or cold temperatures. The temptation to wait until the last minute in these conditions is strong, and spills inside and outside Kivalina residences are common. This threat to human health cannot be exaggerated.

A more reliable delivery system would help avoid spills until honeybuckets can be displaced with holding tanks or a continuous system. The waste disposal system in operation among Kivalina school buildings requires careful maintenance but serves its purpose year-round. This small-scale subterranean disposal system works in the well-drained, sandy soil of the island, giving hope that a larger system could be installed and successfully maintained.

3.4.2 Garbage.

A landfill-type garbage disposal facility is in operation by the new honeybucket dump. An older dumpsite has been abandoned and covered just northeast of the airstrip. This landfill serves well, but the long haul across the wind results in a lot of spilled garbage spread across the island shores and into the Chukchi Sea and Kivalina Lagoon. Again, a more efficient delivery system would prevent many accidental spills.

3.5 Flood Risk

Repeated interviews with longtime Kivalina residents reveal no accounts of inundation of the village. Elders tell of instances when shoreline buildings were awash and land was lost to the sea, but do not recall a storm that flooded the town in more than 60 years of living memory. This is remarkable, given the 1997 topographic survey data showing the center of the village at an elevation of only 3.5 m (11.5 ft) above Mean Lower Low Water (MLLW). Wise *et al.* (1981) estimated storm surge heights along this reach of the Chukchi Sea coast could be about 3.6 m with a return period of 100 years and as high as 3.4 m with a 50-year return period. Their computations of storm surge did not account for the added water level increase due to waves breaking on the shore (*i.e.,* wave "setup"), nor the upward swash or "runup" of waves after breaking.

An assessment of storm surge flooding risk, undertaken as a part of this project, is documented in appendix D. A numerical model of circulation of the entire Chukchi Sea and part of the adjacent Bering Sea was developed, which applied historical wind records to estimate wind-induced water level extremes at various points along the Alaska coast, with highest resolution at Kivalina. The analysis estimates the 100-year return period water level to be 3.2 m (10.6 ft), including wave setup. Wave runup on a natural beach could be as much as 2 m higher.

This more accurate estimate seems to match local experience and point out that many of Kivalina's coastal buildings, including the school, are at risk from the sea. Protection from this level of flooding and wave action is a typical requirement for building permits and insurance along the United States coast. Though the mean water level of such a storm surge might not reach the center of town, the effects of waves on seaward buildings, including the school, would be disastrous. A protective barrier against high water and breaking waves could be built to reduce risk to life and property. This protection would be expensive both to construct and to maintain. Such works would not necessarily preclude long-term shoreline retreat that appears to be occurring in the vicinity of Kivalina.

3.6 Erosion

The narrow barrier island on which the village is located appears to follow trends of sandy barrier islands elsewhere in the world. The very straight seaward shore alignment and steep beach profile at the waterline (about 1 vertical to 12 horizontal) are indications of active transport of beach material in the ice-free season. The lagoon side of the island is marked by intermittent spits, which are signs of deposition. The island geomorphology may seem complex in detail, but has the overall appearance of a barrier island migrating shoreward.

Elders tell of a broader expanse of land seaward of the school in decades past. An oblique aerial photograph of Kivalina taken in 1976 shows the basic alignment of buildings and streets that exists today. Comparison to later photographs does not indicate that a dramatic land loss has occurred. DOWL Engineers (1994) reviewed photographs dating back to 1952 without finding dramatic land loss along the Chukchi Sea shore of the village. There may, nevertheless, be a significant risk of dramatic changes in the event of extreme high water when waves could wash completely across the island. An event such as this could cause dramatic erosion, disastrous high water, and direct wave exposure to the village.

Neither ice ramparts nor severe ice scouring of the shoreline at Kivalina appear to be common. The sea ice at this location apparently tends to form as a shorefast barrier to pressure-induced ridges and ride-up of the ice, which can have detrimental effects. The Arctic monsoon causes winter wind to prevail in the offshore direction, which reduces ice pressure that can cause shoreline build up of sea ice. Shore protection works should be designed with a view toward the possibility of ice buildup, however.

Erosion of the shore near the inlet (Singauk Entrance) appears to be a more immediate concern. Tidal inlets generally are not geologically stable features and have a tendency to shift along barrier island coasts, and in severe storms (like East Coast hurricanes), may even close completely as a new inlet opens elsewhere. Ebb flows from both the Kivalina and Wulik Rivers and most of Kivalina Lagoon appear to empty through Singauk Entrance. The other entrance to the lagoon, Kivalik Inlet, appears to carry much less flow than Singauk Entrance. This situation makes the present location of the village advantageous for fishing, with regard to migrations to both the Wulik and Kivalina Rivers.

The point of convergence of Wulik and Kivalina River flows is evident from sediment plumes in aerial photos and generally coincides with a point of chronic erosion at the village waterfront, just inside the inlet on the lagoon shore. Sandbags have been placed here to resist further erosion during periods of high water. The situation is probably worst following the peak of a Chukchi Sea storm, when the lagoon is emptying and winds veer to create waves in the lagoon propagating toward this point on the island. Erosion control in the form of a revetment or bulkhead would be necessary to reliably reduce the difficulties at this point and others that may develop along the lagoon shore.

4. SOLUTION ALTERNATIVES

4.1 Improvements at Existing Site

4.1.1 Site Plan.

Figure 3 illustrates the major civil engineering features proposed for flood and erosion control, as well as landfill for village expansion. Figures I-2 and I-3 in appendix I illustrate a conceptual layout of streets and building lots for new housing. Landfill north of the housing would be used for airport operations and would contain a proposed buried waste disposal system. A 600-ft shift of the runway and corresponding acquisition of State property is deemed necessary to accomplish these works. This shift accommodates minimum safety clearances associated with airstrip operations, according to officials of the Alaska Department of Transportation and Public Facilities.

4.1.2 Coastal Flooding and Erosion Control.

A single coastal works design can accomplish the objectives of preventing high water and wave runup from threatening village structures and preventing loss of valuable property to erosion. A barrier must be constructed that is higher than the water level during a severe storm and has enough freeboard to prevent damaging overtopping from wave runup on the seaward face of the structure. Erosion is controlled by either making this barrier impervious to the effects of high water and waves or by providing material that is sacrificed during a storm.

A beach fill prevents erosion by causing waves to break farther offshore, away from valuable beach-front property, and by providing a broader, shallower surface for wave runup. Though a beach fill of material similar to the natural beach material will tend to erode at the same rate as the natural beach, plans can be made for periodic replenishment.

An offshore bar typically exists at the seaward limit of the surf zone, and this has been found to be the case at Kivalina. Figure 4 is a representative offshore profile at Kivalina, which shows the prominent bar about 300 m offshore that was a continuous feature along the coast by the village in August 1997. Sand deposits, remnants of ancient offshore bars from times of lower water levels, are likely to be found beyond 400 meters offshore, where their excavation will have no significant adverse impacts.

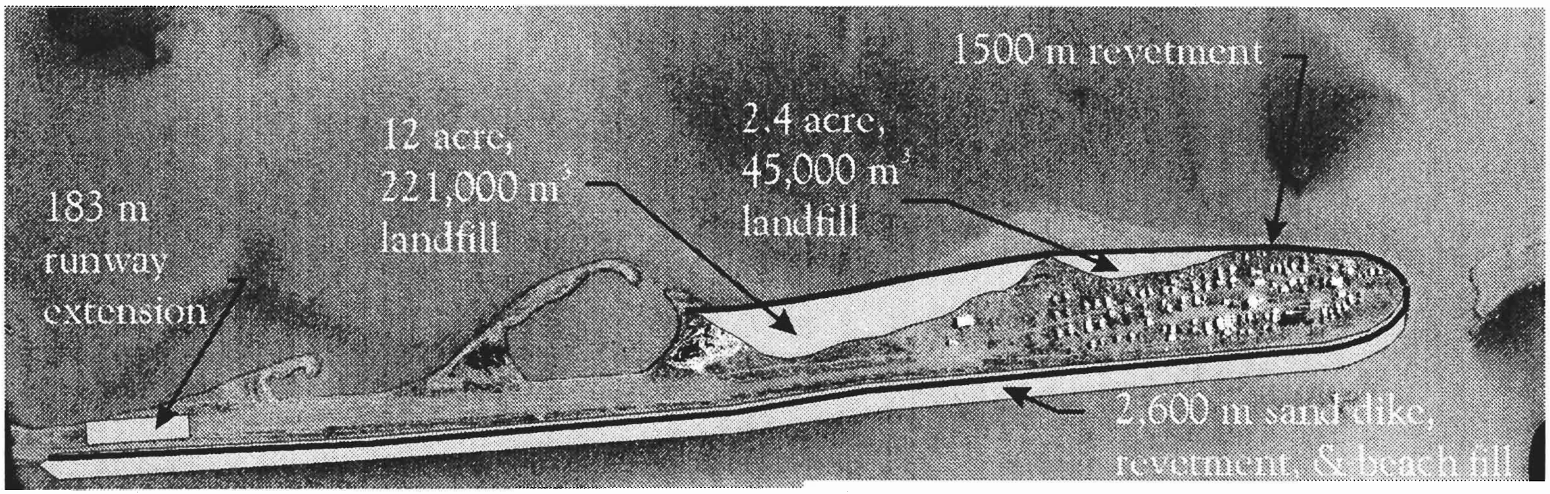

FIGURE 3.--Potential improvements at the present Kivalina site.

Dredging of offshore sand deposits beyond the active littoral zone may provide fill material nearly identical to the existing beach material without disruption of the natural beach profile. A program of geophysical exploration would be necessary to locate such deposits.

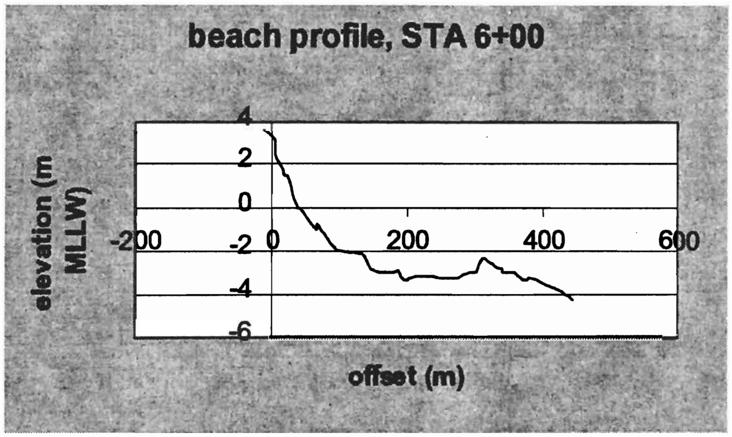

FIGURE 4.--A representative offshore profile measured at Kivalina in August 1997.

A composite shore protection system would be recommended at Kivalina, consisting of a beach fill topped by a sand dike, constructed from the same offshore sand. The dike must be protected from erosion by wave runup to maintain its effectiveness as a flood barrier. A revetment of prefabricated permeable concrete blocks placed on geotechnical filter fabric has proven effective in other arctic coastal areas and on artificial oil-exploration islands. This concept is illustrated in figure 5.

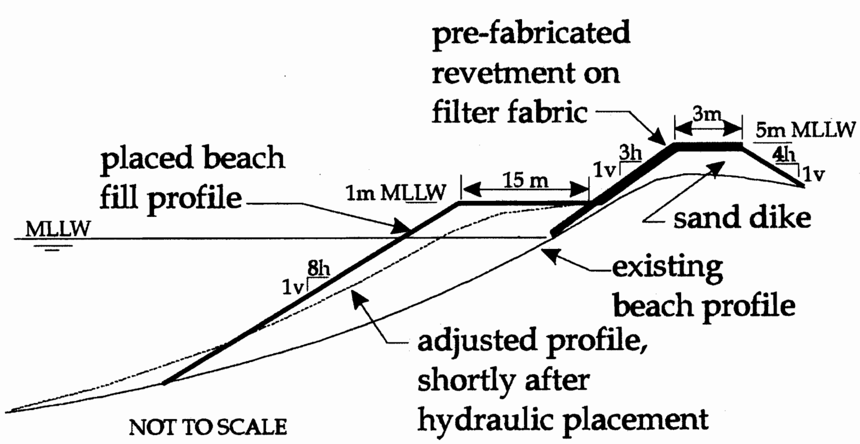

FIGURE 5.--Preliminary design of coastal shore protection at Kivalina.

This shore protection must extend 2,600 m from Singauk Entrance to the end of the extended runway. A beach fill of approximately 72,000 m^3 would require replacement as often as every 5 years. This is equivalent to tripling the first cost of that increment, assuming an interest rate of 7-3/8 percent applied over 25 to 30 years. The revetment may require replacement as often as every 10 years, which is equivalent to doubling its first cost. Construction material quantities associated with initial construction of this design include:

- Sand fill, hydraulically placed: 170,000 m^3
- Prefabricated revetment: 44,000 m^2
- Geotechnical filter fabric: 48,000 m2

4.1.3 Landfill and Kivalina Lagoon Erosion Control.

Figure 3 shows the location of the 14.4 acres of landfill proposed on the Kivalina Lagoon side of the village. Hydraulic placement of offshore sand appears to be the most efficient means of accomplishing this. Both increments of the landfill must be protected from erosion by currents and waves in the lagoon. A 1,100-m revetment is proposed along the lagoon boundary of this landfill with the general design cross section illustrated by figure 6.

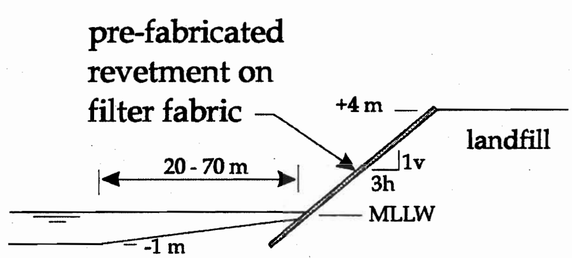

FIGURE 6.--Preliminary design for landfill erosion control on Kivalina Lagoon.

The revetment protecting the new landfill must be extended about 400 m along the lagoon side of the existing village to verge with the proposed Chukchi Sea flood and erosion protection. This extension would provide continuous protection of the expanded village along all of its shores. Some sand fill is necessary to provide a uniform slope for the revetment extension, as illustrated in figure 7.

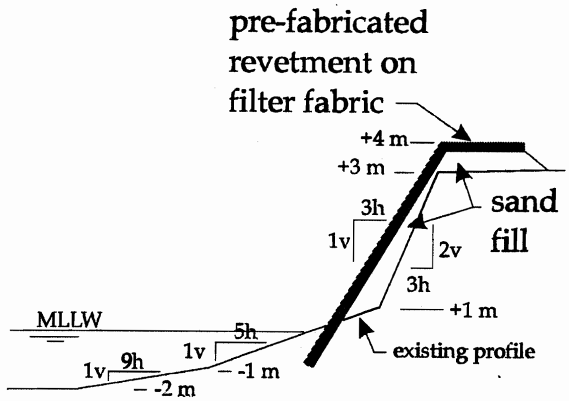

FIGURE 7.--Preliminary design of erosion control on lagoon side of village near Singauk Entrance.

Construction material quantities associated with this design include:

Sand fill:	3,000 m^3
Prefabricated revetment:	17,000 m^2
Geotechnical filter fabric:	19,000 m^2

4.1.4 Water Supply Improvements.

Currently, two storage tanks, one with a capacity of 692,000 gallons and the other 508,000 gallons, are filled during the short summer season to provide the community water supply. Wulik River water is pumped through a hose to fill the tanks. Pumping is done at low tide, since the intake point is close enough to the coast for brackish water to reach the intake at high tide. A primary objective in upgrading the current water supply system is to make it operational for a longer seasonal duration, ideally year-round. Service lines to each residence are also desired.

Increasing the Duration of Fresh Water Supply. Cold weather in September usually brings an end to the present system of filling the storage tanks, though water may still flow in the river. Means of protecting the transmission line from freezing would extend its use, such as providing an insulated transmission pipe with the heat trace contained inside the pipe. This configuration protects against heat damage or even melting of a non-metal line, as long as the line holds water.

An alternative approach to prevent the transmission line from freezing is to submerge the pipe in the river. A high-density polyethylene (HDPE) line could be placed from the intake point to the community site, submerged in the Wulik River by concrete-encased sections, concrete anchor blocks, rock- or sandbag-filled gabions, or other anchoring systems. HDPE pipe sections are joined by heat fusion, which makes the joints stronger than the pipe itself. The material is flexible and can be routed along a curving alignment without special fittings. The pipe's flexibility also allows it to be frozen full of water without damage. Drawbacks to a submerged line would be the difficulty of access if maintenance is required, and possible damage from boats.

Another benefit of an HDPE line is its ability to withstand high pressures. By placing pumps in series, maybe one near the intake point and one near the water storage tank, more water could be stored during each operation. This, combined with an extended operating season, could achieve the increase in total storage required for piped water distribution and piped wastewater collection.

Improved Water Source. A much more significant improvement to water supply at the present community site would be to use ground water (*i.e.,* a well) rather than surface water. The findings of Golder Associates (appendix B) indicate that the thaw bulb of the Wulik River is likely to exist below ground at the present water intake site. A well at this location, with a heated pump house and an insulated aboveground transmission line to the present storage tanks, could provide the community a year-round supply of fresh water. A duplex pump system could be used to maintain constant or near-constant flows through the pipe, which would help keep the line thawed.

Water Distribution. Housing layout to achieve thermal efficiencies must occur at the master planning stage. For the existing buildings, this is not an option, but new buildings could be organized accordingly. Rather than the typical approach of providing a main line with branching service lines, the main itself could be routed house to house, with a service tap within the footprint of the building. This configuration would, in effect, provide a discontinuous utilidor, with each house imparting heat to the water main. Portions of the main line between houses would require insulation. Flows in the main line would help keep it thawed between buildings, and this series configuration would allow quick location of a blockage if freezing were to occur.

4.1.5 Wastewater Disposal.

The volume of wastewater that would eventually be produced at Kivalina is estimated to be 24,000 gallons per day, based on a target population of 600 people and a usage rate of 40 gallons per person per day. The strongly stated preference of community residents is to have piped water and sewerage. They consider the present system of hand-hauled water and honeybuckets to be inadequate and inconsistent with the rest of the world.

The soils at the present site consist of beach sand typical of barrier islands in the region. According to the findings of Golder Associates (appendix B), the top of the permafrost is approximately 12 feet below the surface. A well drilling log taken in 1976 indicates a layer of frozen beach sand at 6 to 10 feet, followed by a layer of unfrozen beach sand at 10 to 18 feet. Permafrost was noted in the drilling log between 18 and 58 feet.

A subsurface disposal system should be possible, given the high permeability of the sandy soil and the depth to permafrost. This type of system would be relatively simple to operate and maintain. The existing washateria at Kivalina already has a subsurface disposal system that has operated satisfactorily for several years.

The treatment process would include a bar screen, either an Imhoff tank or large septic tank, and a subsurface disposal field, as illustrated in figure 8. The purpose of the bar screen is to remove large objects such as bones, rocks, or rags. An Imhoff tank is a container fitted with cross-walls, weirs, and baffles to allow sedimentation of sewage in upper compartments and sludge digestion in lower compartments. An Imhoff tank may need to be buried up to 32 feet deep because of the volume required to store and digest the sludge. Permafrost may be present at this depth, which could preclude the use of an Imhoff tank. If this were the case, a large septic tank could be used. Septic tanks also allow both sedimentation and digestion of sludge, but do not provide separate compartments for these processes. Sludge would have to be pumped out of either type of tank two or three times a year. Sludge could be discharged to the present honeybucket disposal site with approval of the Alaska Department of Environmental Conservation.

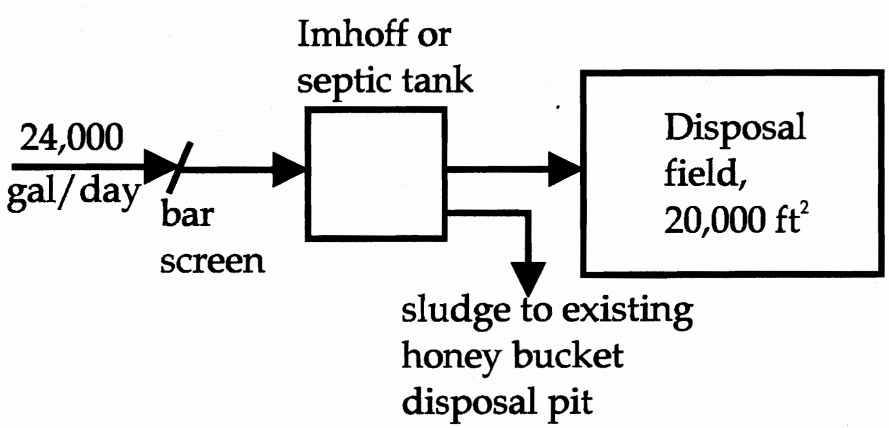

FIGURE 8.--Schematic flow diagram of proposed wastewater system at the existing site.

The size of the disposal field would depend on the infiltration capacity of the soil. Assuming that the soil has a percolation rate similar to a coarse to medium sand, the

Environmental Protection Agency-recommended application rate is 1.2 gal/ft^2 of bottom area/day. For a flow of 24,000 gal/day, the disposal field would be 20,000 ft^2, or approximately one-half acre. The disposal field could be located in the northern half of the proposed new landfill. This part of the landfill would be dedicated to airport operations and would not be available for residential development. This location would be far enough cross-wind from proposed residence sites to avoid an odor problem.

4.1.6 Housing and Public Buildings.

Figures I-2 and I-3 in appendix I illustrate a concept for expanding the village at its existing site. Some reconstruction of village infrastructure would take place, including improved water collection, treatment, and distribution, and wastewater disposal. Approximately 50 new building lots would be provided, allowing an overall housing expansion of 60 percent or more, with respect to the present number of dwellings. This would reduce overcrowding and allow for anticipated population growth to a target population of 600 residents.

4.1.7 Other Considerations.

Garbage disposal would continue at the present landfill site beyond the end of the runway. The proposed 185-m runway extension would not affect the utility of this landfill. The runway extension requires the extensive services and cooperation of the Alaska Department of Transportation and Public Facilities and the Federal Aviation Administration. The runway would remain in its crosswind orientation along the natural alignment of the island. Real estate north of the existing edge of town (*i.e.,* just beyond the last buildings) is now owned by the State and must be conveyed to the city for this expansion to be possible. Transportation would remain essentially as it is now, with small-plane service to Kotzebue, barge service by sea, and local transportation by four-wheeler, motorcycle, and snowmachine. The sand dike would induce snowdrifts to form seaward of waterfront buildings, rather than on the buildings themselves. Installing a seasonal snow fence along the crest of the dike could enhance this effect.

4.1.8 Cost.

An order-of-magnitude estimate for the overall development cost for improving Kivalina at the existing site is presented in table 4-1. This cost is presented as if all these increments were completed at once, while in reality, the costs would be spread over 5 to 10 years or more among the budgets of numerous State and Federal agencies and non-government interests.

TABLE 4-1.--*Initial estimate for proposed improvements at the existing Kivalina site*

Item	**Estimated cost ($)**
Landfill and erosion control	13,600,000
New housing	9,600,000
Improvements to existing facilities	900,000
Relocated buildings	0
Site work	9,100,000
Airstrip expansion	900,000
Project total	**$34,100,000**

4.2 Relocation to the Kivalina River (Imnakuk Site)

4.2.1 Site Plan.

This site is located 12.9 km (8 miles) north of the existing village on the north bank of the Kivalina River. (See figure 1.) The site selected for development is in the northwestern portion of Section 21, Township 28 North, Range 26 West, Kateel River Meridian. The ground at Section 21 along the north bank of the Kivalina River is well above danger of flooding and does not appear prone to erosion. The site is gently sloping upward to the north with bedrock beneath a shallow veneer of clay-rich permafrost and tundra, according to the recent topographic maps (Terra Surveys 1997), geophysical surveys (Golder 1997), and test pit observations of this project. Based on visual observations in August, permafrost lies within 3 feet of the ground surface.

Section 21 is owned exclusively by NANA and can be easily conveyed to the city. Challenges for relocating to the Imnakuk site include construction of a new infrastructure of public buildings, residences, businesses, other structures, power distribution, telephone lines, water supply, and wastewater disposal. Neither land nor water access to the Imnakuk site from the present village is now available; therefore, a new runway at Imnakuk would have to be built. On the positive side, the new runway could be built in line with prevailing winds, beyond risk of coastal erosion and flooding. A new road to the coast would be necessary for delivery of heavy and bulky cargoes by barge. Figure 9 illustrates the proposed alignment of a 13.4-km road from the Imnakuk site to the beach just north of Kivalina Lagoon.

4.2.2 Water Supply.

The proposed water supply system at the Imnakuk site, described in appendix G of this report, consists of a well, pump house, water treatment building, relocation of an existing water storage tank, and a circulation distribution system. Golder Associates (1997) found indications that a well near the bank of the Kivalina Rive r would provide a year-round source of treatable water.

4.2.3 Wastewater Disposal.

A gravity collection system seems to be the best approach to wastewater disposal, because of the steady, gentle slope of the land. The permafrost at the site would make

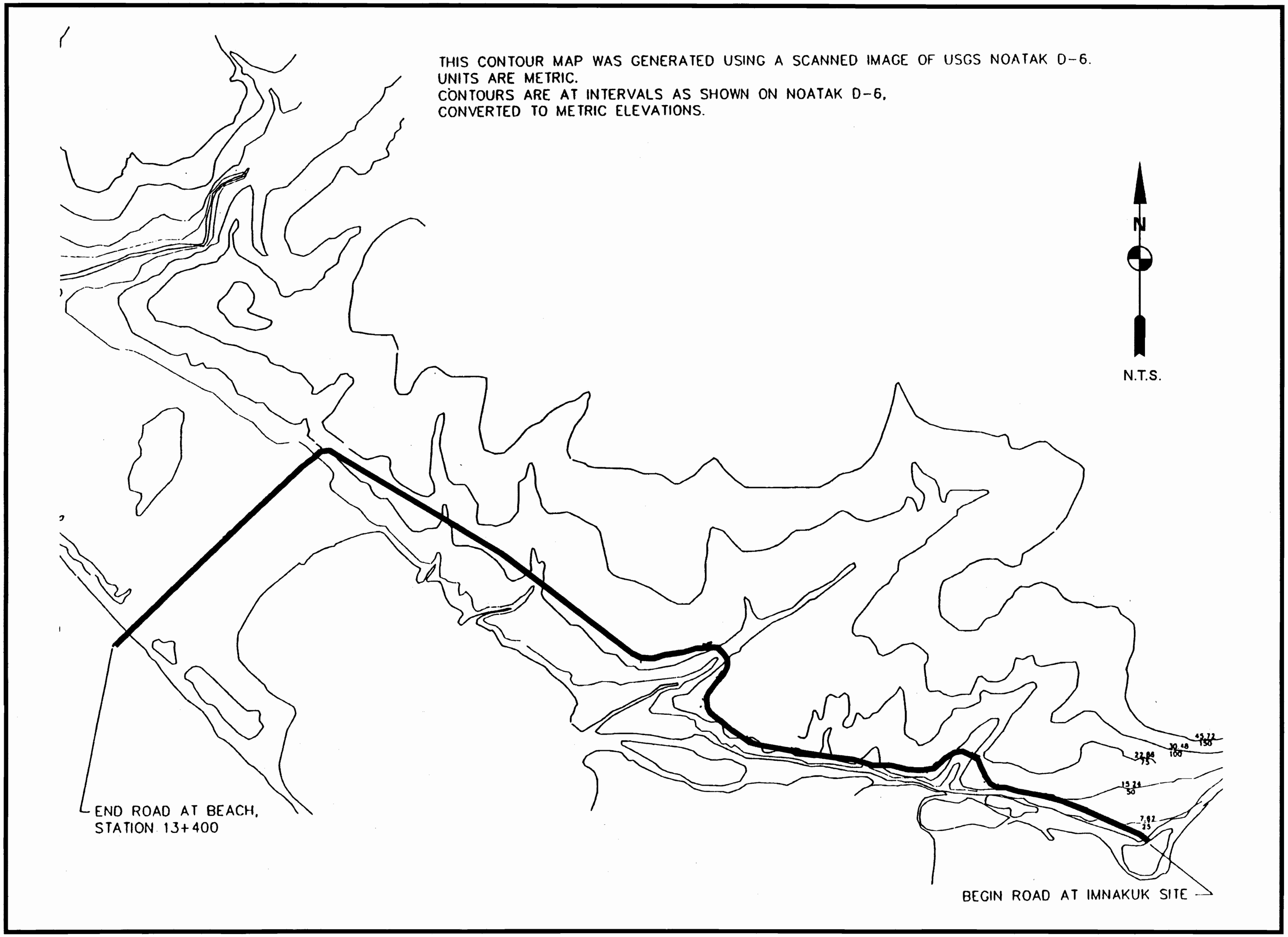

FIGURE 9.-- Alignment of the road to Imnakuk site.

burial expensive. Construction of an aboveground utilidor appears to be a more cost-effective design. A single pump station located at the base of the slope would probably be sufficient to collect all the wastewater.

A series of two stabilization ponds is recommended for wastewater treatment. This is one of the simplest and least expensive wastewater treatment systems to operate and maintain, with successful experience at Alaskan and Canadian Arctic sites. Pretreatment would consist of a simple bar rack and flow measurement structure. The screening from the stabilization ponds would be hauled by truck to the landfill.

The best place to locate the ponds appears to be on the northwest corner of Section 21, near a small creek that empties into the lower Kivalina River. The area required for a series of stabilization ponds to serve 600 people at 40 gallons per person per day for 10 months of storage is approximately 4.5 acres. A two-cell system would be best to conserve heat and maintain a thawed flow path, as illustrated in figure 10. Controlled discharge would be directed into the creek during July and August. The Alaska Department of Environmental Conservation may not require disinfection of the effluent, since the creek is not near the village or a potential drinking water supply. Appendix H of this report provides additional information.

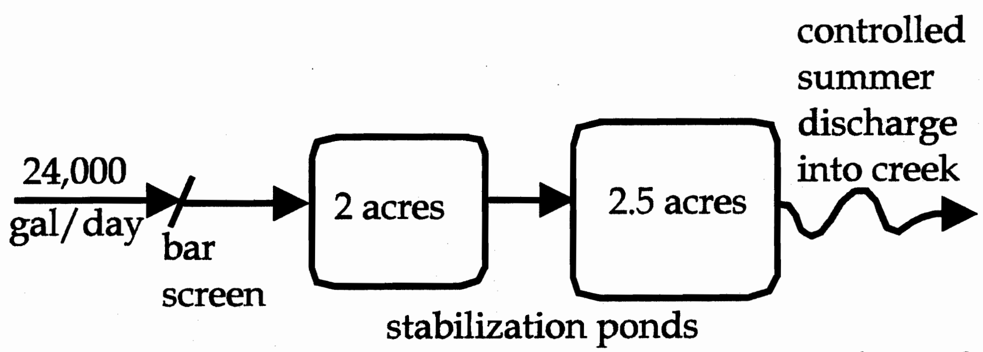

FIGURE 10.--Schematic flow diagram for sewage treatment at the Imnakuk site.

4.2.4 Road to Coast.

Since the Kivalina River is not navigable by most boats during times of low flow, access to the beach for barge deliveries must be provided in the form of a new 13.4-km (8.3-mile) road. Figure 9 shows the proposed alignment of the road. Its typical cross-section is shown in figure 11.

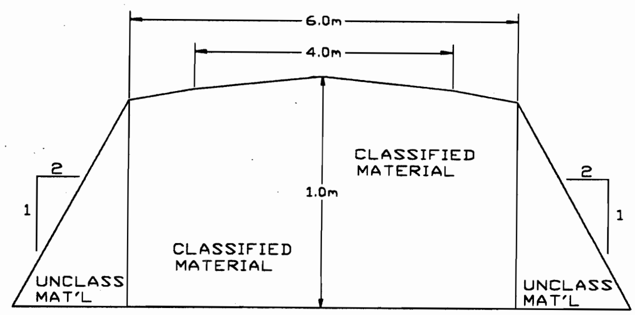

FIGURE 11.--Typical cross-section of a 13.4-km road from Imnakuk to the coast.

Design considerations for the road to this site are similar to those for the Wulik River site, as described in appendix F of this report. The road could probably be built without insulation over the prevailing foundation conditions, though the road alignment has yet to be surveyed or explored for geotechnical conditions. The following material quantities would be required:

Classified fill:	84,900 m^3
Unclassified fill:	60,645 m^3
Total fill:	145,545 m^3
Geotechnical filter fabric:	80,400 m^2
Total cut (excavation):	5,650 m^3

4.2.5 Community Layout.

Figures I-6 and I-7 in appendix I of this report illustrate a system of streets and building lots intended to accommodate the target Kivalina population of 600 residents and the existing economic, subsistence, government, and cultural activities of the community. Elevations in the area range from 24 to 31 meters above sea level. The plan includes 98 residential building lots, with room for expansion to the northeast and northwest. The area available in Section 21 is much larger than required. The community should remain as compact as possible, since large building lots and a widely spread housing plan make water supply and wastewater disposal more difficult and expensive. The area in the northwest corner of Section 21 is chosen to minimize the length of the beach access road and to be closer to the recommended location of the wastewater disposal system.

A new airstrip fits easily into the remaining NANA-owned land adjacent to this relocation site. A new 1,200-meter gravel runway could be constructed approximately

1.5 kilometers (0.9 miles) to the west of the community and connected to the village by a gravel access road. The Alaska Department of Transportation and Public Facilities (ADOT&PF) would locate and orient the airstrip, after completing additional surveys and a study of wind patterns.

Because this proposed village site is separated from the river, a 1.1-km (0.7-mile) river access road is planned to extend from the village to the north bank of the Kivalina River. At the terminus of this road is a river access area where skiffs and marine vehicles could be stored or launched for use on the Kivalina River. The river is generally navigable by small boats upstream of the braided delta, which begins just below the village site. A new landfill would be constructed off the river access road about 0.7 km (0.4 miles) from the community. Appendix I provides additional information on the proposed layout at this site.

The final community plan, if this alternative is selected, should be the product of a thorough program of public involvement in every detail. Local knowledge should be applied to the maximum extent, and the cultural and subsistence-related preferences of residents should be applied as design criteria for buildings, streets, and other features of the village. Appendix J of this report describes the Cree Native Village of Oujé-Bougoumou in northern Quebec, Canada, and the planning process that resulted in its award-winning design and construction. This process could serve as a worthy model for the planning and design of a relocated village of Kivalina.

4.2.6 Other Considerations.

Section 21 was chosen for mapping and geophysical exploration in part because it is not complicated by Native allotments and is owned entirely by NANA. Conveyance of lands for development of the new village at this site would be relatively simple. The road to the coast crosses Native allotments (see appendix C of this report), and these owners would have to agree to the road crossing their property.

Longtime local residents report winter winds from the north as a severe constraint on comfort at this location. Winds otherwise prevail onshore in summer and offshore in winter, so alignment of the new runway would require careful study and a program of wind measurements. Snow fences and some added considerations for alignment of buildings and streets may be warranted with strong north winds in mind.

The uniformity of the land allows almost any layout to be equally practical. The foundation conditions allow building piles to be a practical construction method.

Though a road to the coast and a road to the Kivalina River above the delta are planned, access to Kivalina Lagoon is not explicit in this plan. A landing could be built at the shallow north end of the lagoon, but no means of more convenient access to readily navigable parts of the lagoon appears possible from the Imnakuk site.

4.2.7 Cost.

An order-of-magnitude estimate for the overall development cost for relocation of Kivalina to the Imnakuk site is presented in table 4-2. This cost is presented as if all these increments were completed at once, while in reality, the costs would be spread over 5 to 10 years or more among the budgets of numerous State and Federal agencies and non-government interests.

TABLE 4-2.—*Estimated cost of proposed improvements at Imnakuk (Kivalina River) site*

Item	**Estimated cost ($)**
Relocate houses	1,200,000
New housing (to replace unrelocatable homes)	8,700,000
New (added) housing	10,300,000
Relocated city buildings	600,000
New buildings (to replace unrelocatable structures)	10,000,000
Access Road to coast	5,000,000
Site work	18,000,000
Airstrip	5,800,000
Project total	**$59,600,000**

4.3 Relocation to the Wulik River (Igrugaivik Site)

4.3.1 Site Plan.

Two sites were investigated on the south bank of the Wulik River, at Kuugruaq and downstream at Igrugaivik. These two sites were recommended in that order by DOWL (1994), but risk of flooding was identified as a critical concern at both sites.

The earlier study (DOWL 1994) did not have the benefit of the topographic maps, which were created from surveys and aerial photographs as a part of this project. These maps reveal the highest ground along the lower banks of the Wulik River to lie in the northern half of the Igrugaivik area. The site is located approximately 5 kilometers east of the existing town site on the east bank of the Wulik River (Section 24, Township 27 North, Range 26 West, Kateel River Meridian). At least 50 acres in the area mapped is well above the 100-year flood plain, according to results of a flood risk analysis documented in appendix E of this report.

Foundation conditions are not ideal, but are typical of many Arctic river communities across Alaska. Silty ice-rich permafrost lies beneath a shallow active layer of peat and tundra plants. The permafrost must not be thawed by heat from buildings, or settlement can occur. Arctic engineering has advanced in past decades to develop a number of options for safe, practical construction in this common Alaskan situation.

The Wulik River is readily navigable by ordinary small boats all the way from Igrugaivik to Kivalina Lagoon and on through Singauk Entrance to the Chukchi Sea. The river is not navigable by barge under normal circumstances, so a road must be built for access to the coast where barges can offload heavy cargoes. A 5.3-km (3.3-mile) road alignment is proposed, as shown in figure 12, which leads to the coast and along the spit to Singauk Entrance. The road goes past a 6-acre tundra pond that could be developed as a sewage treatment lagoon. Barges could either land on the open coast or enter the lagoon at Singauk Entrance. The road also provides an alternative for villagers to beach boats on the lagoon shore by Singauk Entrance for ready access to the lagoon and the ocean.

4.3.2 Flood and Erosion Risk.

An analysis of Wulik River flows, measured by a gauge upstream near the Red Dog Mine, and simulations of flows in the river downstream to the mouth near Igrugaivik, indicate the 100-year flood elevation is probably no higher than 4 meters above

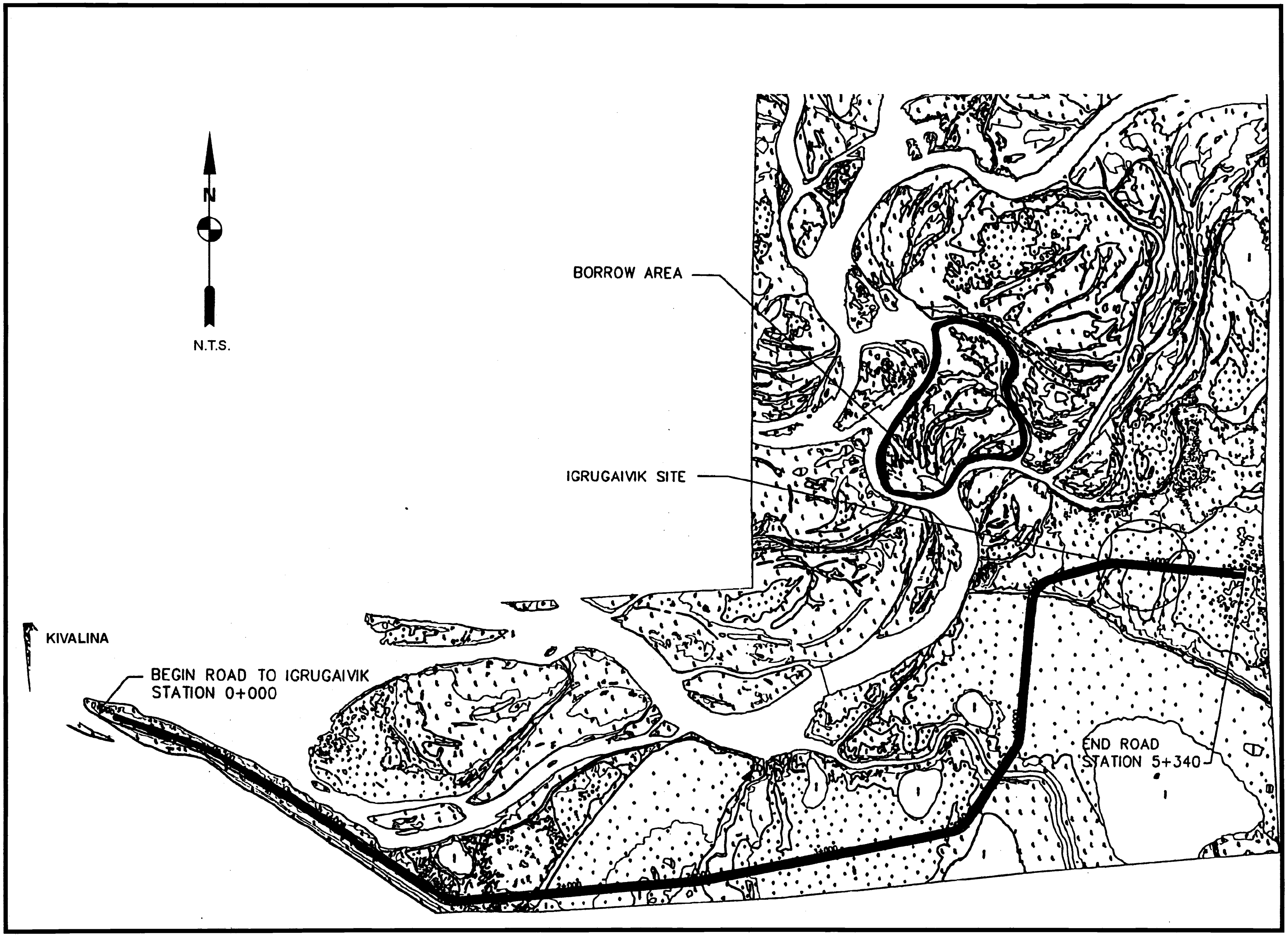

FIGURE 12.-- Alignment of the road from Kivalina to Igrugaivik.

MLLW. This analysis is documented in appendix E of this report. A substantial amount of land along the east bank of the Wulik River is above this elevation, according to topographic maps prepared from survey data and controlled aerial photography accomplished during this project.

Buildings and other expensive community developments should be sited well away from the riverbank to avoid risk of erosion problems. The banks appear to be relatively stable, but permafrost banks of this type have experienced rapid erosion in other areas of Alaska. A setback line for building development of at least 100 feet from the present riverbank should be established at Igrugaivik. Should erosion occur in the future that advances into this setback area, appropriate erosion control measures can be taken before valuable structures are damaged or lost. No revetments or other engineering works for erosion control are warranted at this time, if the setback option is exercised.

4.3.3 Water Supply.

The proposed water supply system at the Igrugaivik site is described in appendix G of this report, consisting of a well, pump house, water treatment building, relocation of an existing water storage tank, and a circulation distribution system. Golder Associates (1997, appendix B) found indications that a well near the bank of the Wulik River would provide an adequate year-round source of readily treatable water. A test well is recommended as a beginning step towards a year-round system at Igrugaivik. The well would be monitored for its flow capacity throughout a 12-month period. The effect of this withdrawal on flows in the river would also be monitored to assess the effect on fish.

After treatment, clean water would be stored in a large tank, ready for distribution to homes, businesses, and community structures. The tank would be large enough to hold a reserve for periods when the well or treatment machinery is being repaired and for fire-fighting. An aboveground distribution system with forced circulation of drinking water is proposed. Circulation in series among homes and buildings should be considered as a means of applying building heat to keep the system thawed in winter.

4.3.4 Waste Disposal.

Because of the flat terrain and permafrost at Igrugaivik, a vacuum collection system appears to be a good means of transporting liquid waste (sewage) to a treatment facility. The village of Noorvik in the Northwest Arctic Borough has successfully operated a vacuum collection system for several years. Wastewater treatment could be accomplished by development of a settlement lagoon at the 6-acre tundra pond near the proposed beach access road. State regulations allow the development of tundra ponds as settlement lagoons, if there are no other viable means of treatment and the village has a population less than 1,000. Kivalina meets these criteria. Discharge of effluent after settlement of sludge could be directed to a minor channel of the Wulik River by the pond. This pond is far enough downstream from the proposed well and village site for this arrangement to be safe and not to cause an odor problem.

A separate solid waste disposal (garbage dump) facility must be developed for a new village at Igrugaivik. this disposal site could be excavated by the road near the sewage treatment lagoon. Sludge from the sewage treatment lagoon would have to be regularly removed and transported to the solid waste disposal area. Earth dikes could be placed around the facility during construction as a stockpile of material to periodically cover the waste deposited there. Borrow material to cover solid waste is often lacking in other Arctic villages, resulting in odor problems and spreading of garbage by storm winds. Figure 13 is a diagram of a possible sewage treatment system for the Igrugaivik site.

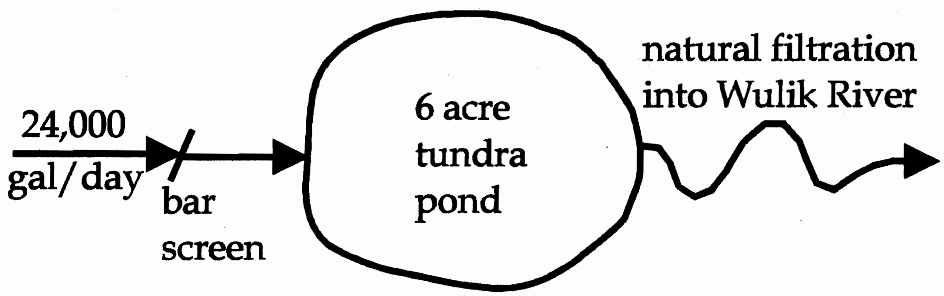

FIGURE 13.--Schematic flow diagram for sewage treatment at the Igrugaivik site.

4.3.5 Road to Coast.

Design of a road from Igrugaivik to the coast is described in appendix F of this report. The proposed route is relatively flat, so earth fill up to the bottom of the road sub-base design elevation results in a fairly uniform design cross section (figure 14) that requires little excavation. Unclassified fill would be used to build the subgrade up to the required elevation and for constructing the side slopes. Classified fill is required for the rest of the road section. A 1-meter layer of this material appears adequate in these conditions to provide an appropriate depth of roadbed. The subgrade materials beneath the road would thaw during the summer, but the active (seasonally thawing) layer would not exceed its pre-road depth. Some heaving and cracking would occur, but this could be readily repaired with conventional road maintenance equipment (*e.g.,* a bulldozer or grader).

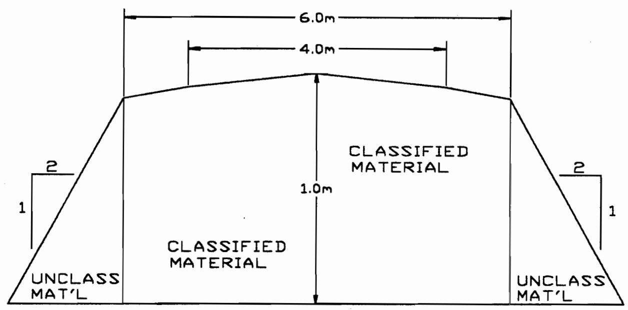

FIGURE 14.--Proposed cross section for the Wulik River road.

4.3.6 Community Layout.

Figures I-4 and I-5 (appendix I) show a conceptual site plan for the Igrugaivik site, including the proposed 5-km (3.1-mile) road to the coast and the sewage treatment lagoon and solid waste disposal sites along that road. Elevations in the proposed town site area range from about 5.5 to 7.5 meters above sea level and generally slope from east to west. The plan shows 117 residential building lots, with room for expansion to the east. A new 1,200-meter gravel runway would be constructed to the northeast of the community, connected to the village by an access road of a design similar to that proposed to connect Igrugaivik to the coast. Features of this plan, such as the location of community buildings and a church, anticipate the desires of local residents, who will ultimately develop the actual layout to meet their preferences. This preliminary plan should be considered a starting point for an extensive program of local involvement to develop the master plan for future construction at Igrugaivik.

4.3.7 Cost.

The terms of reference for this project call for preparation of order-of-magnitude cost estimates for implementation of each alternative community improvement at

Kivalina. Estimates were prepared with a view toward comparison of alternatives. Much more detailed work will be required to develop cost estimates with accuracy and reliability sufficient for actual programming or appropriation of funds to implement any one of the proposed alternatives. Table 4-3 presents the estimate for development of the improvements proposed at Igrugaivik.

TABLE 4-3.—*Estimated cost of proposed improvements at Igrugaivik (Wulik River) site*

Item	**Estimated cost ($)**
Relocate houses	723,460
New housing (to replace unrelocatable homes)	4,220,366
New (added) housing	4,977,959
Relocated city buildings	367,462
New buildings (to replace unrelocatable structures)	4,808,962
Access road	820,496
Site work	5,748,861
Airstrip	2,299,566
Subtotal	$24,967,132
General conditions and profit	10,769,598
Contingencies	8,237,317
Total construction cost	$43,794,047
Engineering and design costs	4,397,405
Administrative, legal, and related costs	2,938,572
Moving families, businesses, and institutions	420,000
Subtotal	$51,730,024
Project contingency, 5%	2,586,501
PROJECT TOTAL	**$54,316,525**

5. COMPARISON OF ALTERNATIVES

Table 5-1 displays a comparison of the three alternatives for Kivalina that were considered in detail: remaining at the present Kivalina site, moving to the Igrugaivik site on the Wulik River, and moving to the Imnakuk site on the Kivalina River.

TABLE 5-1.—*Comparison of three alternative sites*

Comparison criteria	Sites		
	Kivalina Town	**Wulik River**	**Kivalina River**
Above 100-year flood plain	No	Yes	Yes
Accessibility to rivers	Good	Fair	Fair
Accessibility to ocean	Good	Fair	Poor
Expansion capability	Poor	Good	Good
Development as part of a phased approach	Good	Good	Poor
Efficiency of layout (utilities, circulation, etc.)	Poor	Good	Good
Environmental impact/permitting ability	Moderate	Moderate	Good
Initial construction cost	$34 million	$54 million	$60 million

6. PUBLIC INVOLVEMENT

6.1 Opinions of Community Residents

6.1.1 Opinions of Individuals.

Agencies representing Kivalina residents have sent letters commenting on the draft version of this report. These are reprinted in appendix M. Some of these report comments by individuals. Letters from individuals were not received, but many spoke out at public meetings. The nature of various individual verbal expressions of feelings and concerns are interpreted by the writers of this report to fall in the following general areas:

a. Kivalina residents must come together to decide the future of the village and work together to see it happen.

b. Kivalina residents must pray together and seek Divine guidance as their future unfolds.

c. Dealing with honeybuckets is unacceptable in any plan for the future.

d. The present site has known problems, and other sites will have unforeseen problems.

e. Moving off the coast and off the island was already decided by previous studies and many previous meetings.

f. The economic future of Kivalina, with regard to jobs and business opportunities, is not addressed by any of the relocation options.

g. The Kivalina river has bad winds in winter, but has good high ground.

h. The present site is at risk of flooding and erosion from the sea.

i. Some claimed the Wulik River site may be at risk of flooding. Others said it has never flooded in their memory.

6.1.2 Special Election.

The community met with Northwest Arctic Borough officials in a series of meetings in January and February 1998 to arrange a special election for Kivalina residents to decide among three options for relocation:

a. Stay at existing site.

b. Relocate to the Kivalina River (Imnakuk) site.

c. Relocate to the Wulik River (Igrugaivik) site.

The rules of the State of Alaska for public elections were generally followed, though this was not a legal necessity, since no public official was to be elected, bonding issue to be decided, or other binding political issue resolved. The ballot was instead more in the form of a referendum to measure the feelings of residents regarding the relocation options. Voting was open to permanent residents of Kivalina 18 years or more in age. Voting took place on February 26, 1998. Results were certified by a joint resolution of the City Council and the IRA Council on March 6, 1998. Copies of the ballot announcement, a sample ballot, and the certification of the results are printed in appendix M. The ballot results are:

Option	Votes in favor	Percent of vote
Stay at existing site	19	15
Relocate to the Kivalina River (Imnakuk) site	25	19
Relocate to the Wulik River (Igrugaivik) site	85	66
Total number of votes counted	129	100

Relocation to the Wulik River site is preferred by a majority of adult Kivalina residents.

6.2 Views of Other Public Agencies

Comments of other agencies on the draft version of this report were solicited in December 1997. Verbal comments in telephone conversations were generally supportive of the planning process to date and pledged support for the decisions of the community. Written comments received are printed in appendix M.

7. CONCLUSION

The problems of the Kivalina community have been identified, including flood risk, erosion risk, inadequate water supply, substandard sanitary systems, and crowded housing. The most promising options for comprehensive solutions were formulated and compared on an equal basis. The work of previous studies and preliminary investigations at Kivalina were applied to define three basic options: (1) stay at the present site, (2) relocate to the lower Kivalina River at Imnakuk, and (3) relocate to the lower Wulik River at Igrugaivik.

Local knowledge and the opinions of Kivalina residents were incorporated throughout the study process. Previously undetermined flood risks at the present site and on the lower Wulik River were resolved. Rational plans for substantially improved water supply and wastewater disposal (*i.e.,* running water and flush toilets in residences) were formulated for each option. Other community improvements regarding flood control, erosion control, solid waste disposal, and transportation by air and by sea were addressed. Implementation costs were estimated for each of the three options.

All of this information was presented in a draft report, which was distributed in December 1997 to Kivalina residents, Northwest Arctic Borough officials, and agencies across Alaska with an interest in the future of the community. A special election was conducted in February 1998 among Kivalina residents to determine their preference. Relocation to the Wulik River site was preferred by a majority of adult Kivalina residents. An implementation plan to accomplish the relocation is presented in appendix L.

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APPENDIX A

KIVALINA COMMUNITY PROFILE

APPENDIX A
KIVALINA COMMUNITY PROFILE[1]

1. GENERAL DESCRIPTION

1.1 Basic Facts

Current Population:	349
Incorporation Type:	Second-Class City
Borough:	Northwest Arctic Borough
School District:	Northwest Arctic Schools
Regional Native Corporation:	NANA Regional Corporation
Located at:	Longitude 164° 32' W., latitude 67° 43' N.
Land Area:	1.8 mi^2
Water Area:	3.2 mi^2

1.2 Location Description

Kivalina is at the tip of an 8-mile barrier island located between the Chukchi Sea and Kivalina Lagoon. It lies 80 miles by air northwest of Kotzebue.

1.3 History and Culture

Kivalina has long been a stopping-off place for seasonal travelers between arctic coastal areas and Kotzebue Sound communities. It is the only village in the region where people hunt the bowhead whale. Kivalina is a traditional Eskimo village. Subsistence activities provide most food sources. The sale or importation of alcohol is banned in the village. Due to concerns for erosion and other difficulties at the present site, the city intends to relocate to a new site 3 to 8 miles away. Funds have been provided since the early 1990's to assess relocation alternatives.

1.4 Economy

Kivalina's economy depends on traditional subsistence patterns. The Native craft industry has recently expanded; carvings and jewelry are produced from ivory and caribou hooves. The community is interested in developing an Arts and Crafts Center that could be readily moved to the new city site. The major employers are the school, city, Maniilaq Association, village council, airlines, and local stores. The Red Dog Mine also offers employment. Six residents hold commercial fishing permits.

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[1] Much of the information in this appendix comes from the Alaska Department of Community and Regional Affairs (ADCRA) Community Database, maintained on the Internet at http://www.comregaf.state.ak.us/CF_ComDB.htm.

1.5 Facilities

The Wulik River provides water through a surface transmission line. The water is treated and stored in a 600,000-gallon tank. Water is hauled from this point. One-third of homes have running water for the kitchen. Four honeybucket disposal bunkers are located in the city. Funds have been requested to develop a master plan for development of a piped water and sewer system at the relocation site. New landfill and honeybucket dumpsites were recently completed.

1.6 Transportation

The major means of transportation are plane, barge, small boat, and snowmachine. There are no roads outside of the village. The community needs a road to the proposed new city site. A State-owned 3,000-foot gravel airstrip, 60 feet wide, is maintained by the Alaska Department of Transportation and Public Facilities, Northern Region (Fairbanks). The airstrip serves daily small aircraft commercial flights from Kotzebue. Crowley Maritime hauls heavy cargo and fuel from Kotzebue each summer, landing on the open coast or occasionally in Kivalina Lagoon to offload. Small boats, all-terrain vehicles, and snowmachines are used for local travel.

1.7 Climate

Kivalina's climate is characterized by long, cold winters and cool summers. Temperatures range from –54 °F. to 85 °F. Snowfall averages 50 inches, with 10 inches of precipitation per year.

1.8 Population and Housing

The following population and housing data is from the 1990 U.S. Census. This is the only source of detailed community-level information available statewide. Kivalina is located in the Northwest Arctic Census Area. The figures are estimates, subject to sample variability. In Kivalina, 45.1 percent of all households were sampled. Current socio-economic measures could differ significantly. Table A-1 presents the 1990 Kivalina population by gender and ethnic group. Historical population statistics for the community are listed in table A-2.

TABLE A-1.--*Population and ethnicity*

Category	**1990 population**
Total population	317*
Male	170
Female	147
Eskimo	309
Aleut	0
Caucasian	8
African-American	0
Asian/Pacific Islands	0
Other ethnic	0

* **Note:** Current population, certified December 1996 by the Alaska Department of Community and Regional Affairs, is 349.

TABLE A-2.--*Population history*

Year	**Population**
1880	0
1890	0
1900	0
1910	0
1920	87
1930	99
1940	98
1950	117
1960	142
1970	188
1980	241
1990	317
1996	349

The following tables, A-3, A-4, A-5, and A-6, contain statistics about the houses and households in Kivalina.

TABLE A-3.--*Housing characteristics*

Item	Amount
Total housing units	71
Occupied housing	67
Vacant housing	4
Owner-occupied	48
Renter-occupied	19
Persons in owned units	252
Persons in rented units	65
Median value of owned homes	$45,000
Median monthly rent	$625

TABLE A-4.--*Structure types*

Description	Number
Single-family	66
Single-family attached	2
Trailers/mobile homes	3
Other types	0

TABLE A-5.--*Household types*

Description	Number
Occupied households	67
Average persons per house	4.7
Family households	57
Non-related households	10

TABLE A-6.--*Plumbing, water, sewer, heating, and telephones*

Description	Percent
Plumbing, households that do not have	
complete plumbing (lack sink, bath/shower, or flush toilet)	90.9
complete kitchen (lack stove, refrigerator, or running water)	71.2
Water, households using	
Public water system	95.5
Individual well	4.5
Sewer, households using	
Public sewer system	1.5
Septic tank/cesspool	7.6
Other disposal	90.9
Heating methods, households using	
Fuel oil, kerosene	100.0

2. INCOME AND EMPLOYMENT DATA

The following income and employment data is from the 1990 U.S. Census. (See information about the census in subsection 1.8.) Current socioeconomic measures could differ significantly.

Table A-7 lists income information for Kivalina. Table A-8 presents employment by broad category, while table A-9 lists employment by occupation and industry.

TABLE A-7.--*Household income and community poverty levels*

Item	**Number**
Families with income --	
Less than $10,000	12
$10,000 - $19,999	11
$20,000 - $29,999	11
$30,000 - $39,999	11
$40,000 - $49,999	9
Over $50,000	0
Median household income	$28,036
Percent below poverty	32.2%
Median family income	$27,500
Persons in poverty	98

TABLE A-8.—*Employment by category*

Description	**Number**
Total potential workers (16+):	168
Private sector	22
Total employment	48
Self-employed	0
Armed Forces employment	0
Local government	15
State government	9
Federal Government	2
Unemployed (and seeking work)	60
Adults not in labor force	60
Adults not in labor force	71.4%
Percent unemployed	55.6%

TABLE A-9.--*Employment by occupation and industry*

Occupation	Residents employed	Industry	Residents employed
Executive/administrator	4	Forestry/fishing/farming	0
Professional specialty	9	Mining	3
Technician	3	Construction	3
Sales	4	Non-dur. manufacturing	0
Administrative support	8	Durable manufacturing	0
Private household	0	Transportation	7
Protective service	0	Communications/utilities	2
Other professional service	8	Wholesale trade	0
Forestry/fishing/farming	0	Retail trade	6
Precision craft or repair	5	Finance/insurance/real estate	0
Machine operators	3	Business & repair service	0
Transportation or materials	0	Personal services	2
Handler/equipment/labor	4	Entertainment/recreation	0
		Health services	3
		Education services	16
		Public administration	5
		Other prof. services	1

3. FACILITIES, UTILITIES AND SERVICES

3.1 General Description of Local Facilities

The Wulik River provides water through a surface transmission line, which is treated and stored in a 600,000-gallon tank. Water is hauled from this point. One-third of homes have running water for the kitchen. Four honeybucket disposal bunkers are located in the city. Funds have been requested to draw up a master plan for development of a piped water and sewer system at the relocation site. A new landfill and honeybucket dump site were recently completed.

3.2 Water System

Water System Operator:	City	Community Well Source:	No
Piped Water System:	No	Surface Water Source:	Yes
Central Watering Point (Haul):	Yes	Water Is Filtered:	Yes
Multiple Watering Points:	No	Water Is Chlorinated:	Yes
Water Truck (Delivery):	No	DEC Water Permit:	Yes
Individual Wells:	No		

3.3 Sewer System

Sewer System Operator:	City	Community Septic Tank:	No
Piped Sewer System:	No	Sewage Pumper:	No
Honey-bucket Haul:	No	Sewage Lagoon:	Yes
Honey-bucket Pits:	Yes	Sewage Lift Station:	No
Individual Septic Tanks:	No	Outhouses:	Yes

3.4 Refuse/Landfill System

Refuse Collector:	Not available
Landfill Operator:	Unknown
DEC Landfill Permit:	No

3.5 Electric Utility

Electric Utility Name:	AVEC
Utility Operator:	REA Co-op; City
Power Source:	Diesel
Kilowatt Capacity:	986
Rate/Kilowatt Hour:	21.4 cents/kWh
Power Cost Equalization Subsidy:	Yes

3.6 Bulk Fuel

Tank owner	No. of tanks	Total capacity (gal)
Alaska Village Electric Co-Op	12	94,743
Northwest Arctic Borough Schools	8	48,668
Native store	13	88,826
Red Dog Port/AIDEA		10,000
Other	7	38,668

3.7 Health Care

Clinic/Hospital:	Kivalina Health Clinic (907-645-2141)
Operator:	City; Maniilaq
Clinic Owner:	City
Year Clinic Built:	1981
Public Health Service Lease:	Yes
Clinic Has Piped Water:	Yes
Clinic Has Flush Toilet:	No

Clinic/Hospital Status: Flush toilets are installed in the clinic but are not operative. The clinic needs major renovations.

3.8 Communications

In-State Phone:	OTZ Telephone Co.
Long-Distance Phone:	AT&T Alascom
TV Stations:	ARCS Programming
Radio Stations:	KOTZ-AM
Cable Provider:	City
Teleconferencing:	Alaska Teleconferencing Network

3.9 Other Local Services

Airline Service:	Cape Smythe Air Service
Police:	VPSO (Village Public Safety Officer)
Fire/Rescue:	City/Volunteer
Bingo:	City
Library:	School Library

3.10 School Districts and Schools

School District

District Name:	Northwest Arctic Schools
Operated By:	Borough
Total Schools:	15
Total Teachers:	152
Total Students:	2,000
Student/Teacher Ratio:	13.2
Dropout Rate (9-12 Grade):	5.2%
Percent Native Students:	94.4%
Geographic Cost Differential:	1.45
Expenditures Per Student:	$12,449

Local School

School Name:	McQueen School
Grades Taught:	Preschool through 12
Number of Students:	114
Certified Staff:	8

3.11 Municipal Officials and Employees

General Municipal Information

Year of Incorporation:	1969
Manager or "Strong Mayor":	Mayor
Regular Election:	1st Tuesday in October
Assembly/Council Meets:	First Tuesday
Sales Tax:	2%
Property Tax:	None
Special Taxes:	None

City Office Contact Information

Address:	P.O. Box 50079, Kivalina, AK 99750-0079
Phone:	907-645-2137
Fax:	907-645-2175

Mayor (year term as mayor ends)

Oscar Sage, Sr.	(1998)

City Council (year term ends)

Oscar Sage, Sr., Mayor	(1998)
Tillman Adams	(1998)
Ray Abner Hawley	(1998)
Becky Norton	(1998)
Oran Knox, Sr.	(1998)
___ Swan	(1999)
___ Adams	(1999)

Advisory School Board (year term ends)

Lucy Adams, Chair	(2000)
Betty Swan, Secretary	(1997)
Theodore Booth, Jr.	(1998)
Lucille Wesley, Vice Chair	(1997)
Bertha Adams	(1999)

Planning Commission (year term ends)

Under Northwest Arctic Borough
Enoch Adams, Commissioner (1998)

Municipal Employees

Administrator:	Betty Swan
Airport Manager:	Caleb Wesley
City Clerk:	Marilyn Booth
Custodian:	Conrad Koenig
Fire Chief (Volunteer):	Oral Hawley
Police Officer (VPSO):	Dennis Swan
Public Utility Manager:	Bob Hawley, Jr.
Public Works Director:	Victor Adams, Jr.

4. LOCAL CONTACTS

4.1 City of Kivalina

Primary Contact/Title:	Oscar Sage, Sr., Mayor
Address:	P.O. Box 50079, Kivalina, AK 99750-0079
Phone:	907-645-2137
Fax:	907-645-2175

4.2 Native Village of Kivalina

Primary Contact/Title:	Jerry Norton, President
Address:	P.O. Box 50051, Kivalina, AK 99750-0051
Phone:	907-645-2153
Legal status:	IRA Council (recognized by Bureau of Indian Affairs)

5. ALASKA NATIVE CLAIMS SETTLEMENT ACT (ANCSA) LAND STATUS

5.1 ANCSA Land Entitlement

Village Corporation: NANA Regional Corporation

12(a) Land Entitlement*: 92,160 acres

12(b) Land Entitlement**: 0

* ANCSA 12(a) land entitlement to village corporation from Federal Government
** ANCSA 12(b) land reallocated to village corporation from regional Native corporation

5.2 14(c)(3) Land Status

14(c)(3) Status ***:	In Process
14(c)(3) Agreement Signed:	No
14(c)(3) Acres:	0.0
Municipal Land Trust:	No

*** Under ANCSA 14(c)(3), villages must reconvey surface estates to the local city government to provide for community use and expansion.

APPENDIX B

GEOPHYSICAL GROUNDWATER SOURCE INVESTIGATION

Golder Associates Inc.

1750 Abbott Road, Suite 200
Anchorage, AK USA 99507-3443
Telephone (907) 344-6001
Fax (907) 344-6011

APPENDIX B

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Report to

City of Kivalina

For

PHASE 1

GEOPHYSICAL GROUNDWATER SOURCE INVESTIGATION KIVALINA, ALASKA

October 1997

Distribution: City of Kivalina - 2 copies
Mark Anderson, Indian Health Service - 2 copies
Orson Smith - CRREL

D/F: RGD-97/53321006RPT/DOC

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1. INTRODUCTION

The City of Kivalina (City) and the Indian Health Service (IHS), Office of Environmental Health and Engineering (OEH&E) are involved in a cooperative effort to evaluate possible relocation sites that would provide adequate fresh groundwater supplies to the relocated village. Golder Associates Inc. (GAI) was contracted to provide geophysical consulting services to target potential sites for exploratory water wells at two of the candidate relocation sites. This report presents the results of geophysical investigations conducted in the vicinity of prospective new relocation sites. In addition, the report presents a cost estimate for drilling exploratory wells at the recommended well sites.

The work described in this report was carried out in accordance with the letter of agreement dated July 31, 1997. Field work was conducted from August 6 to August 12, 1997 while the U.S. Army Corps of Engineers (Corps) was carrying out other investigations and surveys related to the village relocation.

1.1 Scope of Work

The scope of work for the project consisted of a review of existing data and aerial photographs, a geologic and hydrologic reconnaissance of two candidate relocation sites to determine locations for geophysical surveys, geophysical surveying using a variety of methods, and preparation of summary report. The report was to include recommendations of locations to drill for water and a cost estimate for investigative drilling.

On arriving at Kivalina we learned in a meeting with representatives of the Corps and the City that the Sivutchiaq site, which was originally identified as a candidate relocation site in the request for proposal (RFP), was no longer being considered due to complications with land ownership, and that the new site would occupy Section 21, located between the Imnaaqquq and Sivutchiaq sites identified by DOWL (1994). We have designated this site as "Imnakuk" after the bluff at the north end of it, as shown in Figure 1. We also learned that the Igrugaivik site, which was not a candidate site for our investigation, was being reconsidered since there was an ownership problem with the Kuugruaq site. We therefore investigated both the Kuugruaq and Igrugaivik sites.

2. SITE SETTING AND BACKGROUND

The City of Kivalina is situated on the coast of the Chukchi Sea about 80 miles northwest of Kotzebue. The location is approximately 67°43′ N latitude and 164°32′ W longitude. Precipitation averages about 10 in. per year. The average annual temperature is about 20°F.

Kivalina has a population of about 350. The village is situated at the tip of a barrier island near the mouth of the Wulik River and is separated from the mainland by Kivalina Lagoon, as shown in Figure 1. There is no road access to Kivalina. Access is typically by boat, barge, or air by way of Kotzebue. Winter travel is by air or snow machine. The village is served by a 2,400 ft airstrip.

Currently, the water supply system for the village consists of heated water storage tanks. These are replenished in the summer via a 3 mile fire hose to an intake in the Wulik River opposite the Kuugruaq site. The intake is located within tidally affected water and therefore water is only pumped at low tide. Although many of the village buildings are plumbed, the water supply is inadequate for general distribution. The water storage tanks have run dry on occasion forcing the residents to haul ice.

Water wells drilled near the school by the Bureau of Indian Affairs produced only salt water and were abandoned. One well was drilled to a depth of 215 ft and encountered unconsolidated sediments ranging in size from clay to gravel. Frozen ground was reported from 6 ft to 137 ft with some unfrozen layers (possibly due to high salt content). At present, there are no water wells in the vicinity of Kivalina.

3. METHODS OF INVESTIGATION

3.1 Data Review and Interpretation of Aerial Photographs

Prior to mobilization to the field, reports and maps pertinent to the geology, permafrost regime, and hydrology of the area were reviewed. These included publications by the U.S. Geological Survey and a consultant report by DOWL engineers. Later we obtained a well log from an attempted water well at Kivalina. Aerial photographs of the project area were obtained and interpreted in stereo to map surficial geologic features that could be related to aquifers. These photographs included false color infra-red at a scale of 1 in. = 1 mile which covered all prospective sites. Color photography taken in 1978 at a scale of 1 inch = 2,000 ft. was only available for sites along the Kivalina River. Subsequent to the field investigation, 1997 color photographs were obtained at a scale of 1 in. = 1000 ft covering all sites.

3.2 Site Reconnaissance

We conducted a general reconnaissance of the area encompassing the candidate relocation sites. The reconnaissance included helicopter overflights with spot landings and ground traverses to observe and photograph surface features. The reconnaissance was used to identify sites for geophysical surveying. In general, we targeted recently abandoned channels adjacent to elevated terrain as offering the best location to encounter relic thaw bulbs which were accessible, and which could be protected from potential flooding by minor additions of fill. Along the Kivalina River, we also searched for springs and evidence of faulting in the bedrock, as possible conduits for groundwater. A drained-lake feature was also targeted to investigate the possible presence of a relic thaw bulb.

3.2.1 Geophysical Surveys

Several geophysical survey methods were employed to investigate the electrical properties of the subsurface. The electrical conductivity of the subsurface is related to its water bearing potential. Locations of geophysical survey lines were staked in the field and the position obtained with a hand-held global positioning system (GPS). Later the Corps survey crews used differential GPS to pinpoint the position of these stakes. We were assisted by Ted Booth and Caleb Wesley of Kivalina in the deployment of the geophysical equipment.

The following provides a brief description of each of the geophysical techniques used:

3.2.1.1 VLF

The VLF method is an electromagnetic (EM) method that can effectively locate steeply dipping structures (> 30 degrees) that have different geoelectric properties from their surroundings. This method is thus well suited for water prospecting in fracture zones or other dipping aquifers.

An ABEM Wadi VLF instrument was used for the survey. This is a portable unit with two 15 cm long antennas that measure the vertical and horizontal components of VLF radio signals. The signals originate from military transmitters and have a frequency between 15 and 30 kHz. In this study, signals from the VLF station in Annapolis, Maryland (21.4 kHz) were used. The measurements were stored digitally in the memory of the Wadi and later downloaded to a computer for further processing.

The VLF transmitter is a vertical cable emitting a powerful signal that creates a horizontal magnetic field. The lines of this field comprise concentric rings that ripple out from the transmitter and eventually pass through the study area. When the field strikes a body with a high electrical conductivity, secondary currents are created in the body. These secondary currents, in turn, create a secondary magnetic field that is opposed to the original field emitted from the transmitter.

The receiver is tuned to the VLF transmitter and detects the magnetic field caused by this signal. In order for a conductive body to produce a secondary magnetic field that is detectable with the Wadi, the body should be of sufficient size (greater than 150 ft long and

30 ft deep) and its strike must be roughly in line with the transmitter. The survey lines are oriented roughly perpendicular to a line connecting the observer with the transmitter. At the Imnakuk Site the survey lines ran approximately west to east and measurements were taken every 25 to 50 ft.

The two components of the magnetic field measured by the Wadi instrument are called the real and imaginary. For all practical purposes, only the real component is of interest for water prospecting. An anomaly caused by a conductive body would be indicated by the real component values changing from positive to negative. The center of the conductive body corresponds to the point where the real component value is zero, i.e. the cross-over point (Wright, 1988). The raw data was processed on a computer with the Sector software package (ABEM AB, Sweden) and a Fraser filter was applied to the data. The filter was designed to emphasize anomalies from deeper sources (approximately 20 m) and represents the center of the anomalies with a peak in the data plot instead of a cross-over. This filter presents the data in a form that is easier to interpret. All filtered VLF data is presented in Appendix A.

3.2.1.2 FDEM (Frequency Domain Electromagnetics—Geonics EM34)

A Geonics EM34 instrument was used for the FDEM geophysical survey in order to map horizontal variations in subsurface electrical conductivity. The EM34 is a portable instrument consisting of a separate transmitter coil and a receiver coil. This instrument requires two operators, one for each of the coils. The receiver coil is attached to a conductivity meter that displays the apparent conductivity of the sample area.

The EM34 instrument introduces an electromagnetic field into the ground via the transmitter coil. This field generates secondary eddy currents, which produce a secondary magnetic field that is measured at the receiver coil along with the primary field. The quadrature-phase component of the magnetic field is measured by the EM34 and is linearly related to the ground electrical conductivity. The conductivity value is displayed by the conductivity meter and is measured in millisiemens per meter (mS/m).

Coil separations of 10, 20 and 40 m are possible with the EM34. Also, two coil orientations, vertical dipole and horizontal dipole, are possible. The term, vertical dipole, indicates that the principal direction of the electromagnetic field is vertical, or perpendicular to the ground surface, and a horizontal dipole means the principal direction is parallel to the ground surface. For any one coil spacing, the electromagnetic field with a vertical dipole samples the conductivity of deeper material than the horizontal dipole. The depth of penetration of the EM34 can be as great as 160 ft using vertical dipoles at 40 m spacings.

3.2.1.3 TDEM (Time-Domain Electromagnetic)

As with conventional frequency-domain electromagnetic (EM) systems, time-domain EM (TDEM) systems consist of a transmitter and receiver coil. The TDEM system consists of a square transmitter loop (typically insulated copper wire 20 to 500 m on a side) laid on the ground surface and connected to a regulated current source. The receiver is a smaller multiple-turn coil in the center of the transmitter loop or a loop coincident with the transmitter loop. A variety of field arrays are used to collect TDEM data in either vertical sounding or profiling mode. A current is run through the transmitter loop and cycled on and off as a square waveform of alternating polarity. The cycling of the transmitter current creates a time-varying primary field that induces eddy currents into the subsurface. These eddy currents create a secondary magnetic field that is measured by the receiver at the ground surface. As the eddy currents decay into the subsurface, they are increasingly influenced by the electrical properties of deeper layers. A series of voltage measurements recorded during the transmitter off cycle creates a decay curve of normalized voltage versus time. This decay curve is analyzed using modeling techniques to develop a layered model of subsurface geoelectric properties. TDEM methods are useful in mapping changes in geoelectric properties related to the bedrock surface, hydrostratigraphic units, groundwater contamination plumes, saltwater intrusions, and permafrost.

The maximum depth of exploration depends on the conductivity of the subsurface, the transmitter loop size, available power from the transmitter, and ambient noise levels. As a general rule, the maximum effective depth of exploration is between one and three times the transmitter loop diameter. The minimum resolution depth is a function of ramp time (the time required to bring the current in the transmitter loop to zero) and the resistivity of the near surface material. The ability to resolve a given layer is dependent on it having sufficient thickness and electrical contrast with the surrounding materials to create an inflection in the decay curve. As the electrical contrast between layers increases, thinner layers can be detected. As a general rule, the vertical resolution is about one-fourth the transmitter loop size and is best at shallow depth and decreases with increasing depth.

3.2.1.4 RI (Electrical Resistivity Imaging)

Electrical resistivity imaging (RI) is a survey technique for developing continuous resistivity profiles of the subsurface. It is useful for mapping the depth to bedrock and any lateral variations in the electrical resistivity of the bedrock or overburden deposits related to fractures zones, thawed and frozen conditions, or changes in grainsize.

The electrical resistivity is measured by transmitting a current into the ground with two electrodes and measuring the voltage drop with two other electrodes. Cables fitted with takeouts and electrodes at predetermined positions and control software within the resistivity meter are used to collect high-density data both laterally and with depth. This technique involves multiple traverses along a survey line at progressively larger electrode separations with the depth of investigation increasing with larger electrode separation. The result is a psuedosection of apparent resistivity versus apparent depth beneath the survey line. This contoured psuedosection provides a qualitative view of the spatial distribution of resistivity with depth and may be modelled to convert the apparent resistivity and depth to true resistivity and depth. Thaw bulbs within permafrost regions and variations in grainsize within alluvial deposits are common examples of geologic features that will cause variations in the resistivity and can be detected with this method.

The RI data were collected using a Sting™ R1 Earth Resistivity Meter (Advanced Geosciences, Inc., Austin, Texas) combined with an automatic multi-electrode data acquisition system. The system has 28 electrodes that are evenly spaced along the geophysical survey transect. The survey lines were surveyed with a 12 m electrode spacing in order to cover as much area as possible and have the greatest depth penetration.

Various electrode arrays are possible with this method and the Wenner and dipole-dipole arrays were both used. The Wenner array is less susceptible to electrical noise and generally provided the best results for each resistivity array. The results of the Wenner array are provided in this report. Further discussions of these arrays and the electrical resistivity method are provided in Ward (1993).

The contoured psuedosections of the apparent resistivity were inverted into electrical resistivity depth models using RES2DINV Version 2.0 (Loke, 1996) computer program. The depth models are presented as colored contoured cross-sections in this report.

3.2.1.5 GPR (Ground Penetrating Radar)

A GSSI SIR 2 Ground Penetrating Radar (GPR) system with a 100 MHz antenna was used for this survey. The GPR method is a high frequency (20 MHz to 1 GHz) reflection technique that transmits radar pulses into the subsurface and records the subsequent reflections. A radar antenna is pulled along the ground surface, and radar pulses are transmitted into the ground for every few inches of forward motion when moved at a slow walking pace. The transmitted pulses are reflected from subsurface discontinuities that have contrasting electrical properties such as the soil-bedrock interface, water table, stratification within the soil layers, boulders, buried utility lines and other discontinuities in the subsurface. A graphic record is produced in the field that depicts a cross-sectional view of the subsurface along the survey transect.

Identification and classification of a target or subsurface reflector is based on the interpretation of the reflection patterns displayed on the GPR record. The characteristic reflection pattern, or "signature", of subsurface targets and soils depends on the depth, size, orientation, and electrical properties of the feature. Discrete targets, such as boulders or utility lines, appear as a hyperbolic or inverted crescent shaped reflection patterns on the

GPR record. Large concentrations of cobbles and boulders appear as an anomalous zone of high amplitude signal on the GPR record. The top of the permafrost would appear as a continuous horizontal reflector.

The GPR survey consisted of a single test line near the high school building within the Village of Kivalina. The purpose of the survey was to determine if the GPR would be useful for future investigations to map the top of shallow permafrost and variations in alluvial deposits for geotechnical purposes.

4. RESULTS

4.1 Regional Geology

The Kivalina area is located in a coastal area of low topographic relief that largely consists of gently sloping, rubble-covered hills separated by broad expanses of tundra on unconsolidated surficial deposits. Elevations range from sea level to a few hundred feet. Devonian bedrock of limestone and dolomite outcrops along river-cut bluffs and at the top of the hills at the northern edge of the study area (Mayfield et. al., 1987).

Marine deposits resulting from a seawater transgression about 2 million years ago overlie the bedrock near the mouth of the Kivalina River. Early to middle Pleistocene glaciers originating in the mountains of the Western Brooks Range covered the upper reaches of the Wulik and Kivalina Rivers but did not advance into the study area (USGS, 1962). Low-lying areas are covered with unconsolidated Quaternary deposits of unknown thickness, ranging in size from clay to gravel. The floodplains of the Wulik and Kivalina Rivers are broad and braided.

The region is characterized by continuous permafrost which may be encountered within a few feet of the ground surface. Polygonal ground indicative of shallow permafrost and numerous pingos, or ice-cored mounds, occur in the low-lying tundra-covered terrain in the lower reaches of Wulik River. Boreholes drilled at Chariot, about 40 miles north of Kivalina, reported permafrost thicknesses of about 1000 ft. The reported thickness of the permafrost at Kotzebue was about 240 ft (Pewe, 1975). The thickness of the permafrost inland of Kivalina is unknown but, based on the above, is inferred to be about 600 ft.

Although permafrost generally exists within a few feet of the ground surface, thaw bulbs develop under the larger lakes and rivers. The lateral and vertical extent of thaw bulbs associated with rivers depends primarily on the size of the river and history of the river's migration across the floodplain (Williams and Waller, 1963).

4.2 Terrain Units

Several types of terrain units were identified in the vicinity of the candidate relocation sites. The following is a description of each unit:

Active Floodplain (Map Symbol - Fp)

Floodplain deposits are located within the active zone of the floodplain and are laid down by the Kivalina or Wulik Rivers during periods of high water. They are generally composed of granular materials that are free of vegetative cover. These deposits are free of near-surface permafrost.

Abandoned Floodplain (Map Symbol - Fpa)

Abandoned floodplain deposits are an older portion of the floodplain in the process of being refrozen. The surface layers may contain ice-rich silty material and fine-grained alluvium up to several feet thick overlying granular alluvium (Fp). These deposits are vegetated with sedges, willow, and relatively thin tundra. They may be flooded in extremely high water events of limited duration. Taliks (thawed zones) may exist under the surficial permafrost.

Old Terrace Deposits (Map Symbol - Fpt)

Old terrace deposits are alluvial deposits that are no longer flooded. They have well developed tundra vegetation and may have polygons. They are typically organic-rich and ice-rich near the surface. Permafrost occurs near the surface and likely extends to great depth.

Drained-Lake (Map Symbol - L)

Drained-lake deposits are characterized by saturated fine-grained materials and organics resulting from the draining of a thaw lake. Depth to permafrost is variable depending on the size and depth of the lake that occupied it and the length of time that the deposits have been drained.

Frozen Upland Silt (Map Symbol - Elx)

Frozen upland silt (Elx) consists of ice-rich silty deposits. The surface is characterized by well-developed tundra vegetation including lichens, blueberries, and tussocks. Permafrost occurs near the surface and likely extends to great depth.

Marine Deposits (Map Symbol - M)

Marine deposits consist of wet, blue-gray, silty clay. These deposits are covered with tundra. On upland areas where the deposits are close to the surface, they overlie bedrock.

Bedrock (Map Symbol - Bx)

Bedrock consists of light gray to tan limestone and dolomite. The limestone is slightly weathered, hard, blocky, and effervesces in hydrochloric acid.

The distribution of these terrain units at the candidate sites is shown in Figures 2, 6, 8 and 9.

4.3 Site Geology and Geophysics Results

4.3.1 Imnakuk Site

The Imnakuk site is located 6 miles north of Kivalina at the base of Imnakuk Bluff as shown in Figure 1. The site is characterized by a south-facing, tundra-covered hillside which slopes gently to the floodplain of the Kivalina River, as shown in Figure 2. The Kivalina River drainage area above this site is about 740 mi^2. Limestone bedrock outcrops intermittently in cutbanks of the river and on top of the hill. Clayey marine deposits mantle the bedrock on the slope between the river and the top of the hill. These deposits appeared to be several feet deep and became frozen within about 3 ft of the ground surface, based our visual observations on test pits excavated in early August by the Corps of Engineers. A zone of subtle lineations oriented parallel to the slope were observed on the slope. At the base of the slope and coincidental with the lineations is a small drainage which discharged about 2 gallons per minute (gpm) during our August reconnaissance.

Recently abandoned floodplain deposits (Fpa) at the base of the slope extend for approximately 0.5 miles. These deposits are covered with dense alder up to 10 ft tall and are incised by sedge-covered sloughs which were mostly dry at the time of our field work.

Geophysical surveying at the site consisted of VLF and RI methods.

VLF Survey

VLF survey lines were oriented perpendicular to the slope to determine if bedrock fractures could be associated with the subtle drainage lines identified on the aerial photographs. These features and the location of Line VLF-2 are shown in Figure 2. Line VLF-1 was oriented parallel and approximately 2000 ft to the north of Line VLF-2. Profiles of the filtered VLF data are presented in Appendix A.

The two VLF survey lines, VLF-1 and VLF-2, were 3,800 ft and 2,100 ft long, respectively. The data collected along Line VLF-1 showed an anomaly located at approximately station 2000 that is characteristic of a deep conductive body. This anomaly corresponded with the location of the west edge of the north-south trending linear drainage feature. There was no obvious corresponding anomaly on the parallel line, VLF-2. The lack of a corresponding anomaly could indicate that the conductive body is not completely continuous between the two lines.

RI Survey

Line KR-1 was conducted near the contact between the abandoned floodplain deposits and the marine silty clay over bedrock unit (Figure 2). The purpose of Line KR-1 was to determine if the north-south drainage feature is associated with a hydraulically conductive zone that may be connected to a relic thaw bulb associated with the Kivalina River. A second line, KR-2, was conducted in active floodplain deposits to determine the depth of thaw in the active floodplain, and to compare the resistivity signature of active floodplain deposits with that of inactive floodplain deposits, or bedrock, at the floodplain margin. A third and fourth RI lines (KR-3 and KR-4) were conducted on the slopes above the floodplain and oriented parallel and perpendicular to the linear drainage feature. The purpose of these two lines were to map the boundary of the thaw bulb between the floodplain and higher slopes, as well as detect any geoelectric anomalies associated with the linear drainage feature.

The geoelectric cross-section for KR-1 is shown in Figure 3a. The cross-section has a shallow zone of higher resistivity values (1000 to 3000 ohm-m) between electrode 7 and 14. The eastern boundary of this high resistivity zone is at the point of intersection of the linear drainage feature and the floodplain. Lower resistivity values (100 to 1000 ohm-m) are along the remainder of KR-1 between electrodes 15 and 28 and at depths greater than 55 to 70 ft below the high resistivity zone. The resistivity values in KR-1 are lower than the typical permafrost resistivity (greater than 4000 ohm-m) detected along Lines KR-3 and KR-4 at this site and at other sites (WR-1 through WR-6). A likely interpretation of KR-1 is that this line is within the thaw bulb of the Kivalina River and the higher resistivity zone between electrodes 7 and 14 represents a possible channel of coarse-grained alluvium cut into the finer-grained sediments represented by the lower resistivity values.

The geoelectric cross-section for KR-2 is shown in Figure 3b. The cross-section has a range of resistivity values from approximately 2000 ohm-m near the upper east edge to less than 100 ohm-m at depth greater than 120 ft. Since KR-2 is within the active floodplain of the Kivalina River and thus within the thaw bulb, it is not surprising that the resistivity values are much lower than the values for permafrost measured along other RI lines. The higher resistivity values (1000 to 2000 ohm-m) at the west end of the cross-section likely correspond with an increase in grain-size of the fluvial deposits. At the maximum depth of the resistivity data at approximately 160 ft, the resistivity values remain below 100 ohm-m, thus the bottom of the thaw bulb was not detected along line KR-2.

The geoelectric cross-sections for KR-3 and KR-4 are shown in Figure 4. The resistivity values range from approximately 1000 ohm-m at the south end of KR-3 to more than 30,000 ohm-m in the remainder of the KR-3 and throughout KR-4. The zone of lower resistivity values on line KR-3 corresponds with the location of the abandoned floodplain. The edge of the thaw bulb is interpreted to be at approximately electrode 4, which was the location of the northern edge of the floodplain and corresponded with the change in resistivity values from less than 2000 ohm-m to greater than 2000 ohm-m. The high resistivity zones in the remainder of KR-3 and throughout KR-4 are characteristic of permafrost areas. Although there was some variation in the resistivity values along Line KR-4, there was no significant anomaly that corresponded with the linear drainage feature between electrodes 11 and 18 or was characteristic of a bedrock fracture zone. Also, since there was no corresponding VLF anomaly on Line VLF-2, it is unlikely that there is a significant bedrock fracture zone associated with the linear drainage feature.

4.3.2 Imnakuk Summary

The best location for a test well appears to be at the northern edge of the abandoned floodplain deposits at the point where the small drainage discharges, as shown in Figure 2. State plane coordinates for this location are: N 1539128.255 and E 561039.839. This location combines a potentially coarse-grained deposit (based on the relatively higher resistivity values) with a potential relic thaw bulb. The conceptual geologic cross-section of the Imnakuk Site (Figure 5) shows that the proposed well location is at the edge of the thaw bulb associated with the Kivalina River. The geophysical results did not indicate a bedrock fracture zone associated with the linear drainage feature, thus it is unlikely that any significant recharge would occur from the bedrock units upslope of the well site. The most likely source of groundwater recharge for the well location would be from the Kivalina River.

An alternate drilling site would be at a location closer to the Kivalina River, since the opportunity to encounter a better water supply increases toward the center of the thaw bulb. Although this location would be more prone to flood damage, a small embankment could be established around the well to protect it from potential flooding.

4.3.3 Kuugruaq Site

The Kuugruaq site is located about 3 miles northeast of Kivalina on the south side of the Wulik River. A USGS gage has been installed 23 miles upriver. The Wulik River drainage basin to this gage is 822 mi^2 with an average annual runoff of 772,200 acre-feet (USGS, 1979). The Kuugruaq site has little relief. It is bounded on the north and west by the main channel of the Wulik River and to the south and east by sloughs, which are mostly drained at low tide. The western portion of the site is covered with recently abandoned floodplain deposits (Fpa) which support willows and thin tundra vegetation, as shown in Figure 6. Most of the rest of the site consists of old terrace deposits (Fpt) capped by thick tundra with poorly developed polygons.

Geophysical surveying at the Kuugruaq Site consisted of RI, EM34 and TDEM surveying.

RI Survey

Two intersecting electrical imaging lines, WR-1 and WR-2, were run at this site to determine the configuration of a possible thaw bulb associated with the abandoned floodplain (Figure 6). The eastern half of Line WR-1 was located near the contact between abandoned floodplain and old terrace deposits and the western half extended onto the active floodplain deposits of the Wulik River. The southern half of line WR-2 was on old terrace deposits and extended north to the Wulik River across the abandoned and active floodplain.

The geoelectric cross-sections for WR-1 and WR-2 are shown in Figure 7. The electrical resistivity values ranged from less than 100 ohm-m to 2000 ohm-m in the floodplain area to greater than 10,000 ohm-m in the old terrace deposit area. Resistivity values below approximately 2000 ohm-m are interpreted to represent thawed zones. The results from these surveys suggested that a deep thaw bulb exists at the intersection of the WR-1 and WR-2, and extends towards the Wulik River to the north and west. The elevated terrace deposits along the south half of WR-2 and the abandoned floodplain deposits at the eastern end of WR-1 are interpreted to be permafrost zones. The bottom of the permafrost zones were not detected with the RI survey but the results show that the permafrost may extend to a depth of at least 120 ft.

EM34

An EM34 survey line was conducted along WR-2 to confirm the results of the RI survey. The EM measurements were made at 10-meter intervals along a single transact at the Kuugruaq site. Measurements were taken at the 20-meter coil separations with both the vertical and horizontal dipole. The EM34 data are presented in Appendix B.

The conductivity values from the EM34 survey are 2 to 5 times higher over the abandoned and active floodplain compared to the old terrace deposits. These results support the RI data that indicates that the boundary of the thaw bulb exists at the contact between the old terrace and floodplain deposits.

TDEM

TDEM soundings were made on the elevated terrace deposits to determine the depth to the base of permafrost. The depth models from the TDEM soundings were interpreted to be a two layer case with a high resistivity layer (60 ohm-m) underlain by a low resistivity layer (4 to 17 ohm-m). The TDEM method does not accurately measure the resistivity of shallow materials (less than 140 ft) thus it was difficult to use this method to confirm the results of the RI survey. Although the measured resistivity of the upper layer (60 ohm-m) is suspect, it is at least five times greater than the resistivity of the lower layer. Thus, the upper layer is interpreted to be frozen ground. The low resistivity values of the bottom layer are typical of silty and/or clayey material or possible saline groundwater, neither of which would be suitable targets for a water supply well. The transition between the two layers is at approximately 160 ft below ground surface and may be the lower limit of the bottom of the permafrost. Despite the low resistivity values of the bottom layer, there may be thin frozen zones within this layer (less than 60 ft thick) that are too thin to be detected by the TDEM method. The TDEM data and depth models are included in Appendix C.

4.3.4 Kuugruaq Summary

The best site for a test well appears to be on RI line WR-1 at the southern edge of the abandoned floodplain deposits near the contact with the old terrace deposits (Figure 6). State plane coordinates for this site are: N1531324.093 and E 565396.436. This location is within a potential relic thaw bulb and is relatively protected from possible flooding. The conceptual geologic cross-section of the Imnakuk Site (Figure 13) shows that the proposed well location is at the edge of the thaw bulb associated with the Wulik River, although there may be thin, shallow permafrost zones at the limits of the thaw bulb. The recharge for the well at this location would most likely be from the Wulik River.

An alternate drilling site would be at a location closer to the Wulik River, since the opportunity to encounter a better water supply increases toward the center of the thaw bulb. As with the Imnakuk Site, this location would be more prone to flood damage, however, a small embankment could be established around the well to help protect it.

4.3.5 Igrugaivik Site

The Igrugaivik site is located about 2.5 miles east of Kivalina, directly south of the Kuugruaq site. The site is bound by a main channel of the Wulik River to the west and sloughs to the north and south. The south half of the site is characterized by drained-lake deposits (L). The northern half of the site is occupied by abandoned floodplain (Fpa), old terrace (Fpt), and frozen upland silt (Elx) as shown in Figures 8 and 9. The remainder of a small pingo, which has been truncated by the Wulik River, occupies a topographic high point on the northwest edge of the site.

Geophysical surveying at the Igrugaivik Site consisted of RI and TDEM surveying.

RI Survey

Four RI lines, WR-3 through WR-6, were collected at this site to determine the configuration of a possible thaw bulb associated with the drained lake area and abandoned floodplain (Figure 9). Line WR-3 was located over the drained lake deposits and upland frozen silts. Lines WR-4, and WR-6 were centered at the contact between the abandoned floodplain and old terrace deposits, and line WR-5 was centered at the contact between the abandoned floodplain and upland frozen silt.

The WR-3 geoelectric cross-section is shown in Figure 10. The resistivity values between the depths of 0 and 130 ft range from 4000 to greater than 10000 ohm-m and are characteristic of frozen ground. Thus, there is no indication of a shallow thaw bulb beneath WR-3. However, resistivity values below 130 ft decrease and are between 2000 and 4000 ohm-m. These low resistivity values indicate that unfrozen material may be at or close to 130 to 160 ft below line WR-3. Based on the interpretation of the RI data, it is unclear whether this possible thawed layer is the bottom of permafrost or a thin layer of thawed material within the permafrost zone.

The geoelectric cross-sections for lines WR-4, WR-5, and WR-6 are shown in Figures 11 and 12. Resistivity values for all of these section are much lower on the abandoned floodplain side of the survey line and support the conclusion that the boundary of the thaw bulb corresponds approximately with the contact between the abandoned floodplain and the old terrace and upland frozen silts. The bottom of the thawed zone below lines WR-4 and WR-6 was not detected. The thaw bulb beneath the northern end of WR-5 appears to be approximately 140 ft thick. It is important to remember that the vertical resolution of the RI method decreases with depth, thus there may be thin frozen zones within the interpreted thaw bulbs that cannot be detected with this method.

The bottom of permafrost zones along the southern halves of WR-4 and WR-5 (Figure 11) appear to be deeper than 160 ft, thus beyond the maximum depth of penetration for the RI survey. However, the permafrost below southern half of WR-6 (Figure 12) is interpreted to be thinner (approximately 60 ft thick).

TDEM

One TDEM sounding was made on the drained lake deposits to determine the depth to the base of permafrost. The results of the sounding and the depth model are similar to the TDEM soundings at the Kuugruaq Site, with a high resistivity layer (90 ohm-m) underlain by a low resistivity layer (4 to 17 ohm-m). The TDEM method does not accurately measure the resistivity of shallow materials (less than 140 ft) thus it was difficult to use this method to confirm the results of the RI survey. Although the measured resistivity of the upper layer (90 ohm-m) is suspect, it is at least five times greater than the resistivity of the lower layer. Thus, the upper layer is interpreted to be frozen ground. The low resistivity values of the bottom layer are typical of silty and/or clayey material or possible saline groundwater, neither of which would be suitable targets for a water supply well. The transition between the two layers is at approximately 160 ft below ground surface and may be the lower limit of the bottom of the permafrost. Despite the low resistivity values of the bottom layer, there may be thin frozen zones within this layer (less than 60 ft thick) that are too thin to be detected by the TDEM method. The TDEM data and depth models are included in Appendix C.

4.3.6 Igrugaivik Summary

The best location for a test well appears to be at the southern edge of the abandoned floodplain deposits on RI line WR-4 near the contact with the old terrace deposits and the alternate location would be closer to the Wulik River (Figure 9). The first location is within a potential relic thaw bulb and is relatively protected from possible flooding. State plane coordinates are: N 1530552.370 and E 565994.733. The conceptual geologic cross-section of the Igrugaivik Site (Figure 13) shows that the proposed well location is at the edge of the thaw bulb associated with the Wulik River, although there may be thin, shallow frozen zones at the limits of the thaw bulb. As with the Kuugruaq Site, the most likely source of recharge would be from the Wulik River.

An alternate drilling site would be at the center of RI line WR-6 which has a similar thaw bulb configuration. State plane coordinates are N 1530378.285 and E 565789.757.

4.4 GPR Survey Test Line

The GPR method was tested along a survey line near the high school building. The GPR survey was successful in detecting the top of shallow permafrost (less than 12 ft). Based on these results, the GPR method would be useful for mapping variations in shallow soils for geotechnical investigations. However, the accessibility to any future study sites should be considered before making a final decision as to whether a GPR survey would be effective.

5. RECOMMENDATIONS FOR TEST WELL DRILLING

Test well drilling will be required to further assess the possibility of obtaining adequate groundwater at the candidate village sites. We propose drilling 6 test wells, two wells at each prospective village site. We assume a maximum depth of 60 ft/well based on the anticipated permafrost conditions. Pump tests of 8 to 24 hours duration should be conducted on each well encountering a significant aquifer. The primary locations for the test wells are at the edge of the abandoned floodplain deposits as discussed in the previous section.

Several factors complicate drill rig access to the prospective well sites. These include but are not limited to:

- No existing roads.
- The 2400 ft runway is too short to mobilize a track-mounted drill by air.
- The rivers are too shallow and local vessels too small to mobilize an adequate drill by water.
- Only one barge delivery per year.
- Track-mounted heavy equipment is not available to move a sled-mounted drill setup.

A cost effective, stand-alone, plan for multiple test well drilling is to mobilize a heli-portable CME-45 drill to Kivalina during the summer and move the drill site-to-site with a helicopter. The wells would be drilled with 4.25 in. inner diameter (ID) hollow stem auger equipped with seals at the joints to keep surface water out of the holes. A 2 in. ID casing and screen with a pre-packed sand pack would be installed in each well prior to pump testing. Pump testing will be limited to about 10 gpm due to the small size of the pump that will fit into the screen. These wells cannot be converted to standard community wells but will be adequate to assess the groundwater resource at multiple locations. The wells can still be used as non-standard wells if they are found to be productive; however, we assume that a larger standard well(s) will be installed when the final village location is determined and an access road constructed to the site.

We have considered winter access with a track-mounted drill by way of the Red Dog airstrip. This would involve moving the drill about 18 miles along the coast from the mine's port facility to the village. This option is more expensive due to the high cost of air freight with a C-130. It is also less desirable because of the potential for breakdown in a remote area, uncertainties associated with water crossings of rivers, lakes and lagoon channels, and inefficiencies and hazards associated with conducting remote site work in winter conditions.

An estimate for drilling the test wells, conducting pump tests, analyzing the aquifers, and preparing a report is provided in Table 1. It may be possible to realize significant savings on the mobilization costs if the project can be combined with other compatible drilling or helicopter operations that may occur at the Red Dog Mine or elsewhere in the Kotzebue region. A helicopter drilling program using similar equipment is currently nearing completion at the Red Dog Mine.

6. REFERENCES

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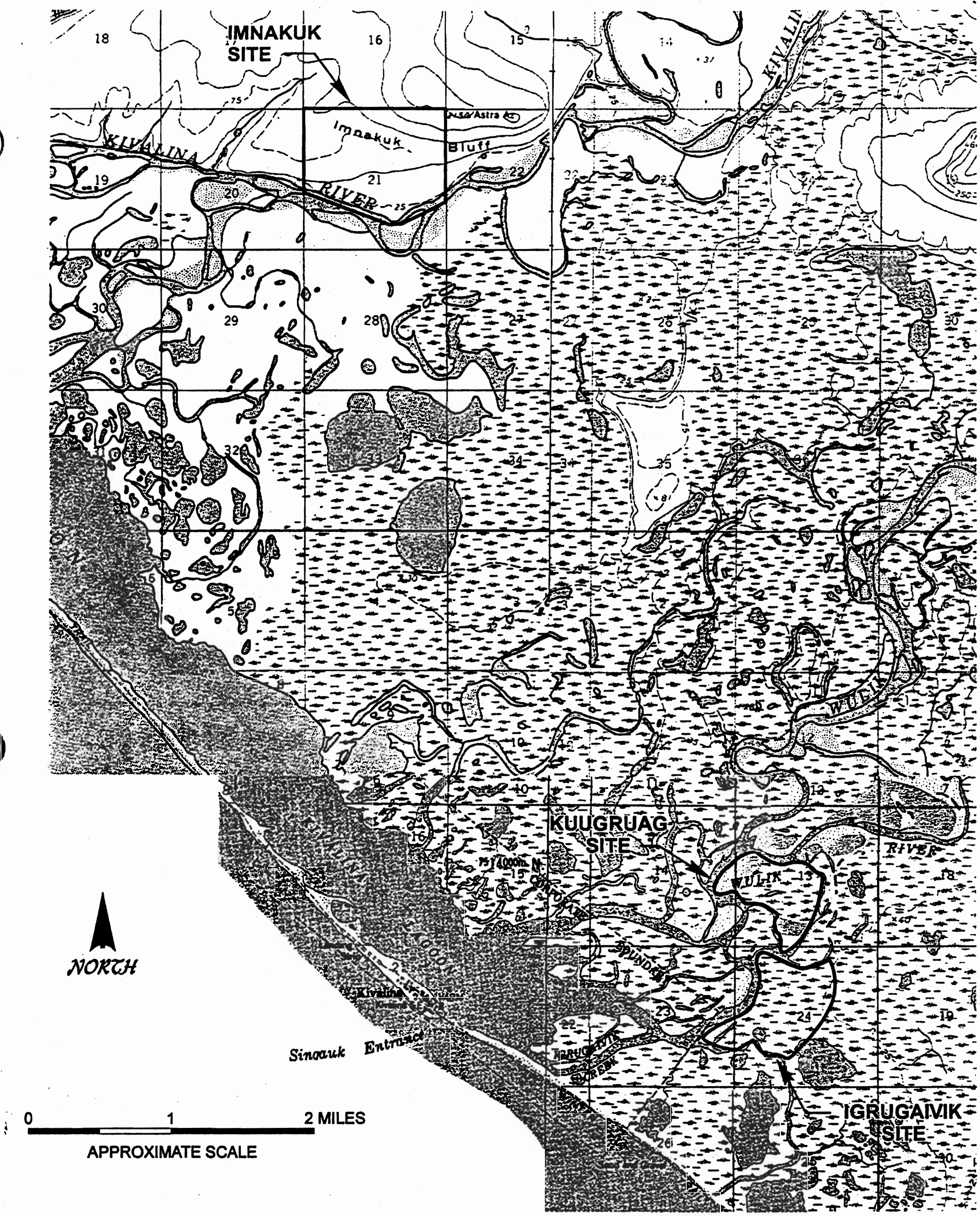
TABLE 1

PRELIMINARY COST ESTIMATE FOR EXPLORATORY DRILLING
KIVALINA, ALASKA

COST CATEGORY	PAY UNIT	NUMBER OF UNITS	RATE/UNIT	ITEM COST	SUBTOTALS
MATERIALS					
Well Materials	well	6	660	3960	
Geo supplies/equipment	day	7	100	700	
Communications	day	1	300	300	
Computer, Reproduction	lump	1	500	500	
Misc. Expendables	well	6	275	1650	
					7110
LABOR					
Drill Crew	day	9	1300	11700	
Local Labor	day	18	250	4500	
Cook	day	9	250	2250	
Project Manager	hr	100	110	11000	
Hydrogeologist	hr	80	110	8800	
Field Engineer/Geologist	hr	150	70	10500	
Drafting	hr	40	50	2000	
Secretary	hr	16	40	640	
					51390
TRANSPORTATION					
Freight Charter to Kiva.	Round trip	2	13000	26000	
Helicopter Mob/demob	Round trip	1	13000	13000	
Helicopter Day Rate	day	7	2800	19600	
Helicopter hours	hours	21	450	9450	
Helicopter fuel	day	7	450	3150	
Travel to/from Kiva.	Round trip	4	800	3200	
Air Freight to/fm Kotz	one way	2	5000	10000	
Support Boat	day	9	200	1800	
Per Diem	man-day	40	110	4400	
					90600
HEAVY EQUIPMENT					
Drill Rig (CME-45)	day	7	1100	7700	
Generator/Pump	day	7	250	1750	
					9450
TOTAL					$158,550
CONTINGENCY- 10% of SUBTOTAL					$15,855
GRAND TOTAL					$174,405

ASSUMPTIONS

Project includes analysis of pump tests and preparation of report
Crew accomodations/kitchen available in Kivalina



REFERENCE: U.S.G.S TOPOGRAPHIC MAPS "NOATAK (C-5, C-6 AND D-5), ALASKA", 1:63,360.

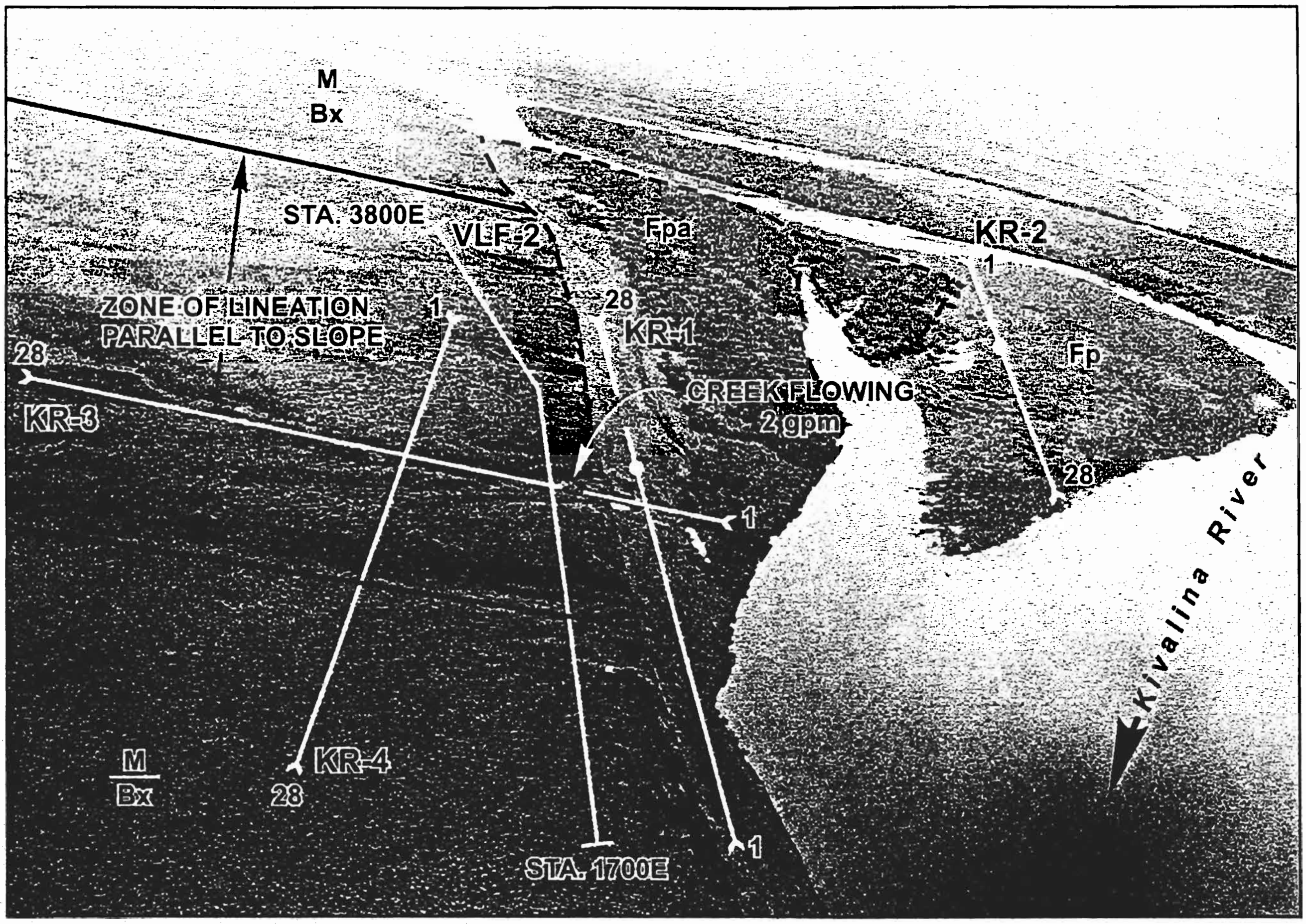
Figure 1

PROJECT LOCATION MAP

CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: LOCATIONMAP.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates



VIEW LOOKING EAST

LEGEND:

Fp	FLOODPLAIN
Fpa	ABANDONED FLOODPLAN
M	MARINE DEPOSITS
Bx	BEDROCK
– – – – – –	APPROXIMATE GEOLOGIC CONTACT
28 ⟩——⟨ 1	ELECTRICAL IMAGING LINE (WITH ELECTRODE NUMBERS)
├——┤	VLF SURVEY LINE
◇	TDEM SOUNDING LOCATION
⊕	PROSPECTIVE DRILL SITE

NOTE: LINE VLF-1 IS PARALLEL AND APPROXIMATELY 2000 FEET TO THE NORTH OF VLF-2.

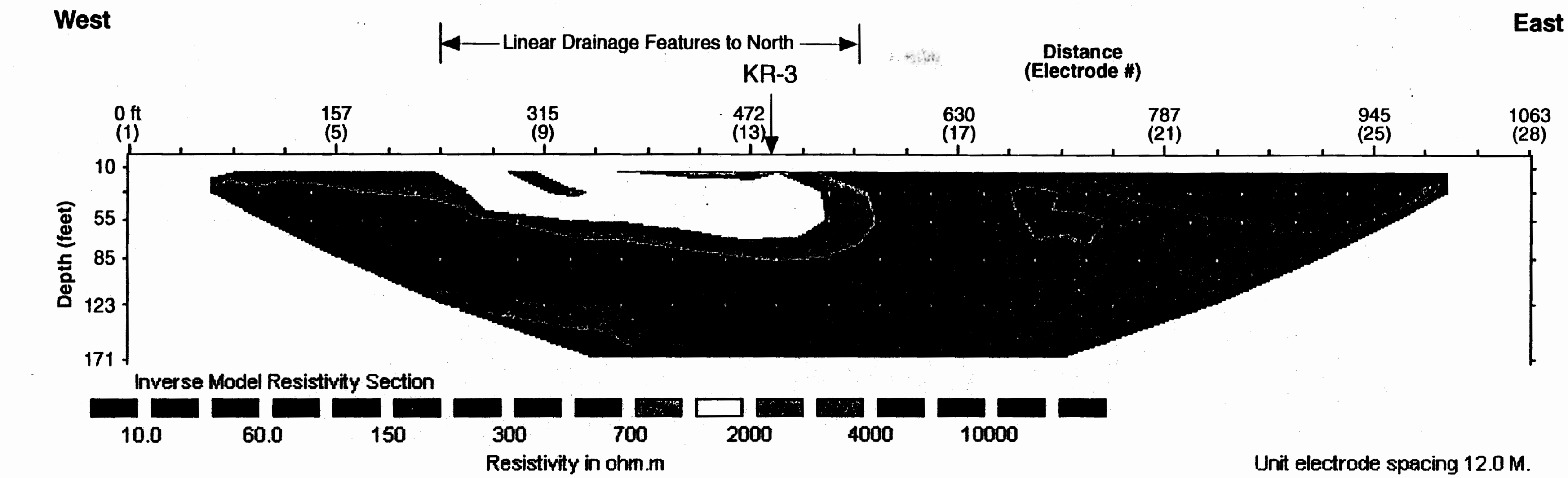
Figure 2

IMNAKUK SITE - GEOPHYSICAL SURVEY LOCATIONS AND TERRAIN UNITS

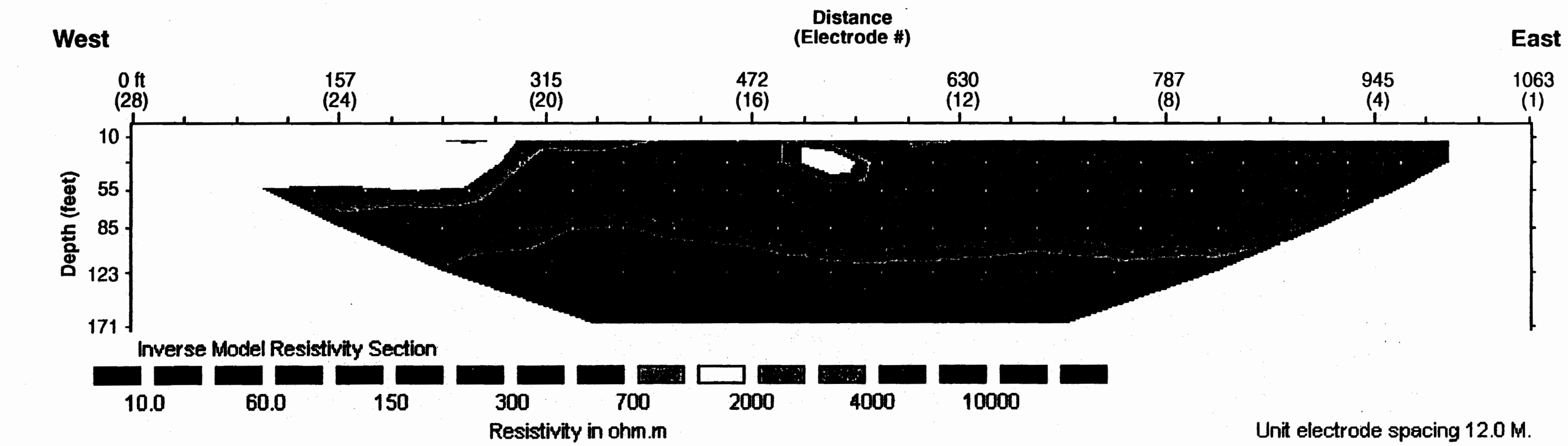
CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: IMNAKUK.CD7 DATE: 8/97 DRAWN: SJM

Golder Associates



a) LINE KR-1



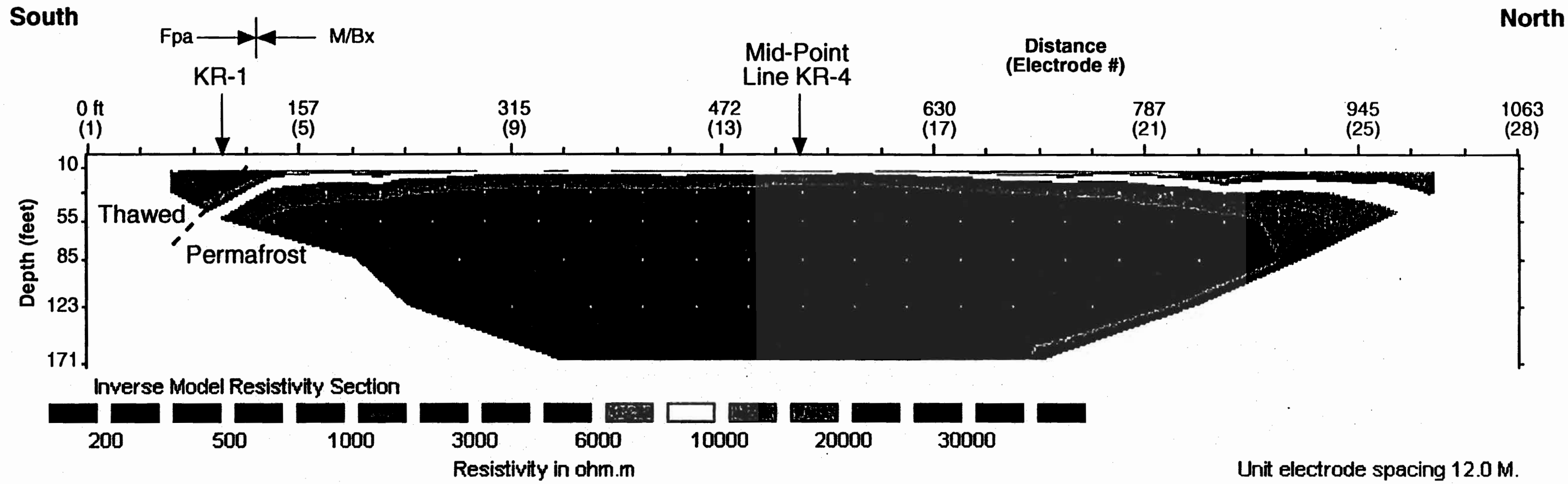
b) LINE KR-2

FIGURE 3

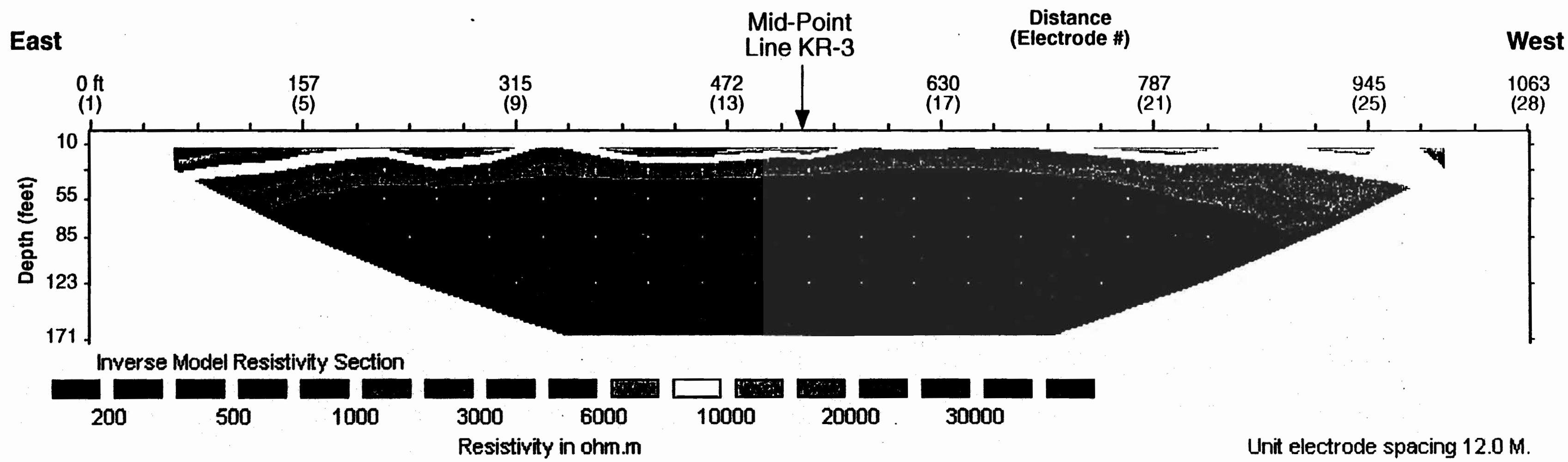
RI CROSS-SECTIONS
WENNER ARRAY DATA
CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73877 DATE 9/29/97 DRAWN BY EA

Golder Associates



a) LINE KR-3



b) LINE KR-4

LEGEND

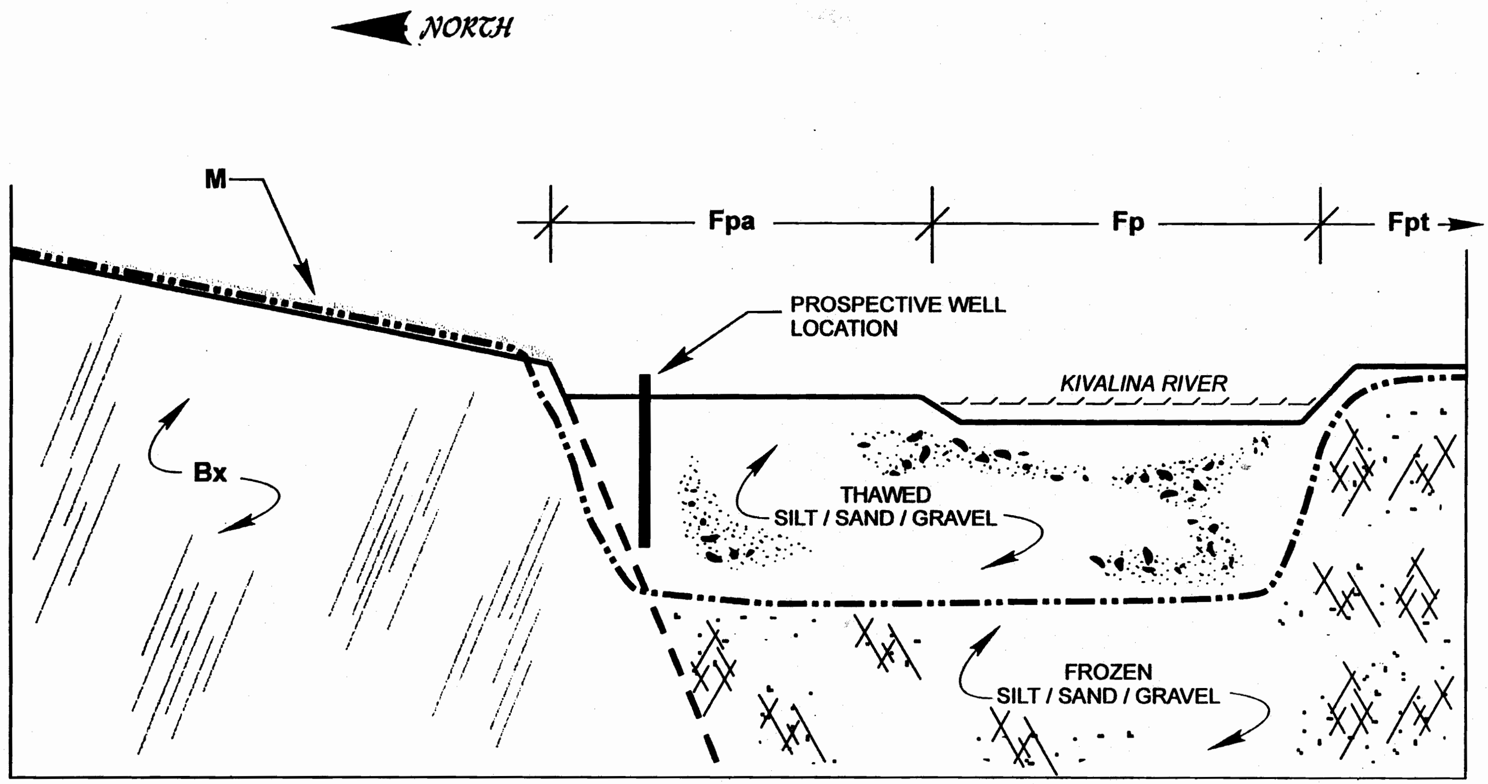
- - - - - Approximate Permafrost Boundary

Fpa, M/Bx See Figure 2

FIGURE 4
RI CROSS-SECTIONS
WENNER ARRAY DATA
CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73878 DATE 9/29/97 DRAWN BY EA

Golder Associates



NOT TO SCALE

LEGEND:

- **Bx** BEDROCK
- **Fp** FLOODPLAIN
- **Fpa** ABANDONED FLOODPLAN
- **Fpt** OLD TERRACE DEPOSITS
- **M** MARINE DEPOSITS
- ‑ ·· ‑ PERMAFROST BOUNDARY
- ‑ ‑ INFERRED GEOLOGIC CONTACT

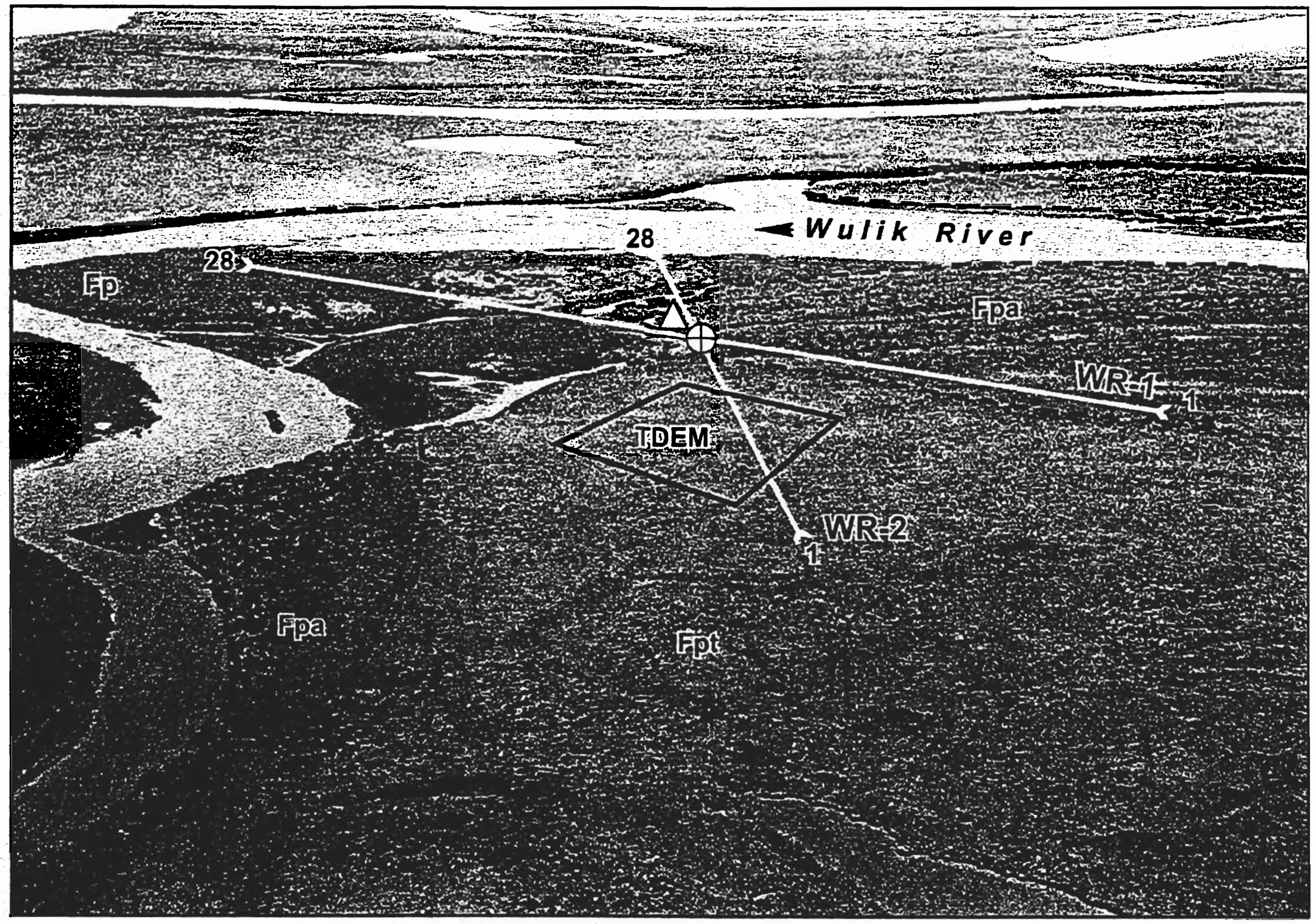
Figure 5

CONCEPTUAL GEOLOGIC CROSS SECTION AT IMNAKUK SITE

CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: ImnakukXsec.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates



VIEW LOOKING WEST

LEGEND:

Fp	FLOODPLAIN
Fpa	ABANDONED FLOODPLAN
Fpt	OLD TERRACE DEPOSITS
– – – – – – –	APPROXIMATE GEOLOGIC CONTACT
28 ›——‹ 1	ELECTRICAL IMAGING LINE (WITH ELECTRODE NUMBERS)
◇	TDEM SOUNDING LOCATION
⊕	PROSPECTIVE DRILL SITE
△	ALTERNATE DRILL SITE

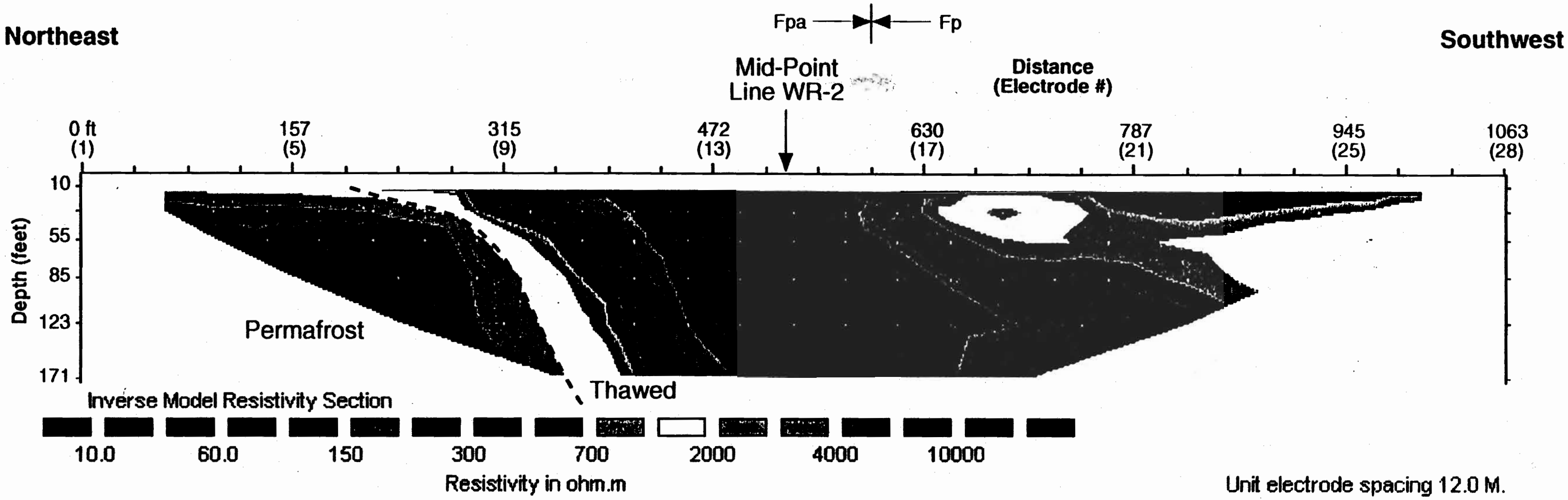
Figure 6

GEOPHYSICAL SURVEY LOCATIONS AT KUUGRUAG SITE

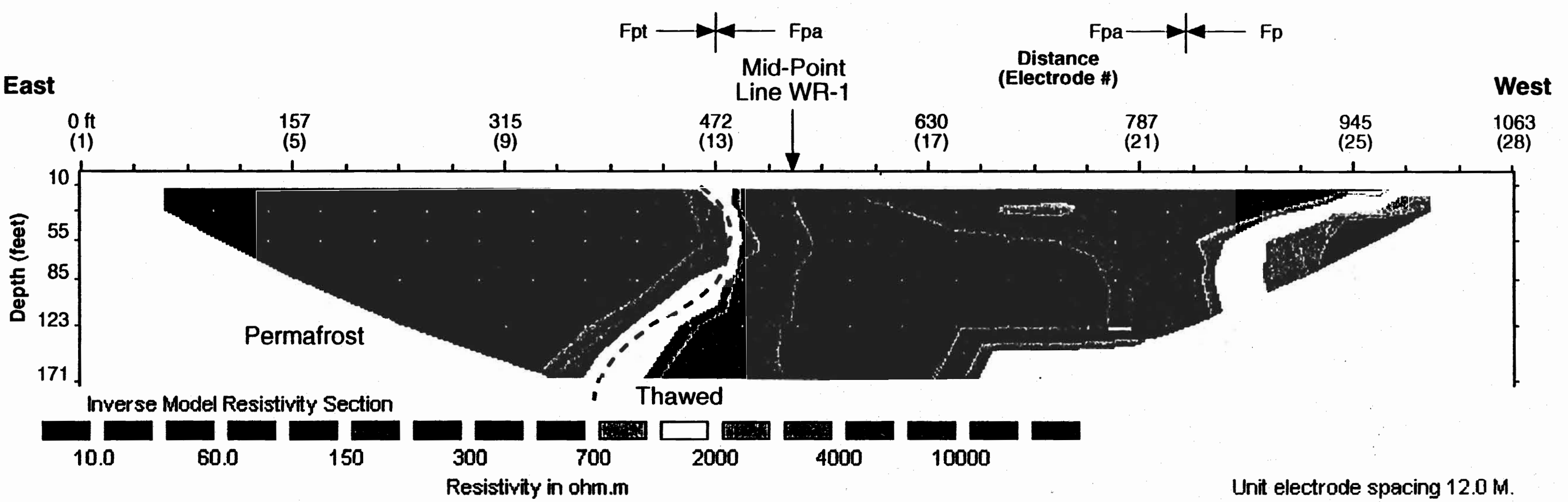
CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: KUUGRUAG.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates



a) LINE WR-1



b) LINE WR-2

LEGEND

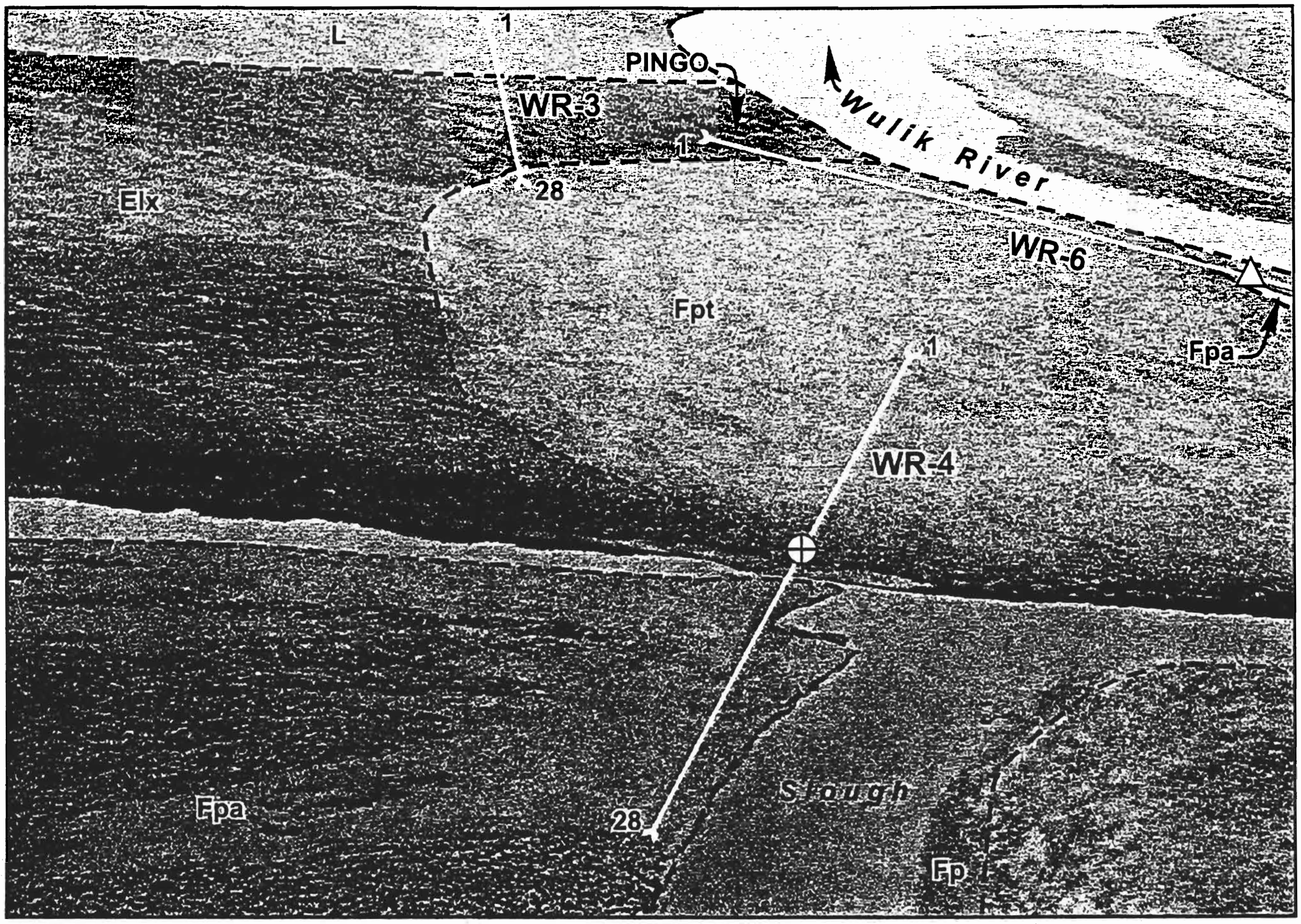
- - - - - Approximate Permafrost Boundary

Fpa, Fp, Fpt — See Figure 6

FIGURE 7
RI CROSS-SECTIONS
WENNER ARRAY DATA
CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73879 DATE 9/29/97 DRAWN BY EA

Golder Associates



NOTE: VIEW LOOKING SOUTHWEST.

LEGEND:

Fp	FLOODPLAIN
Fpa	ABANDONED FLOODPLAN
Fpt	OLD TERRACE DEPOSITS
L	DRAINED LAKE DEPOSITS
Elx	UPLAND FROZEN SILT
- - - - - - -	APPROXIMATE GEOLOGIC CONTACT
28 ⟩———⟨ 1	ELECTRICAL IMAGING LINE (WITH ELECTRODE NUMBERS)
├———┤	VLF SURVEY LINE
◇	TDEM SOUNDING LOCATION
⊕	PROSPECTIVE DRILL SITE
△	ALTERNATE DRILL SITE

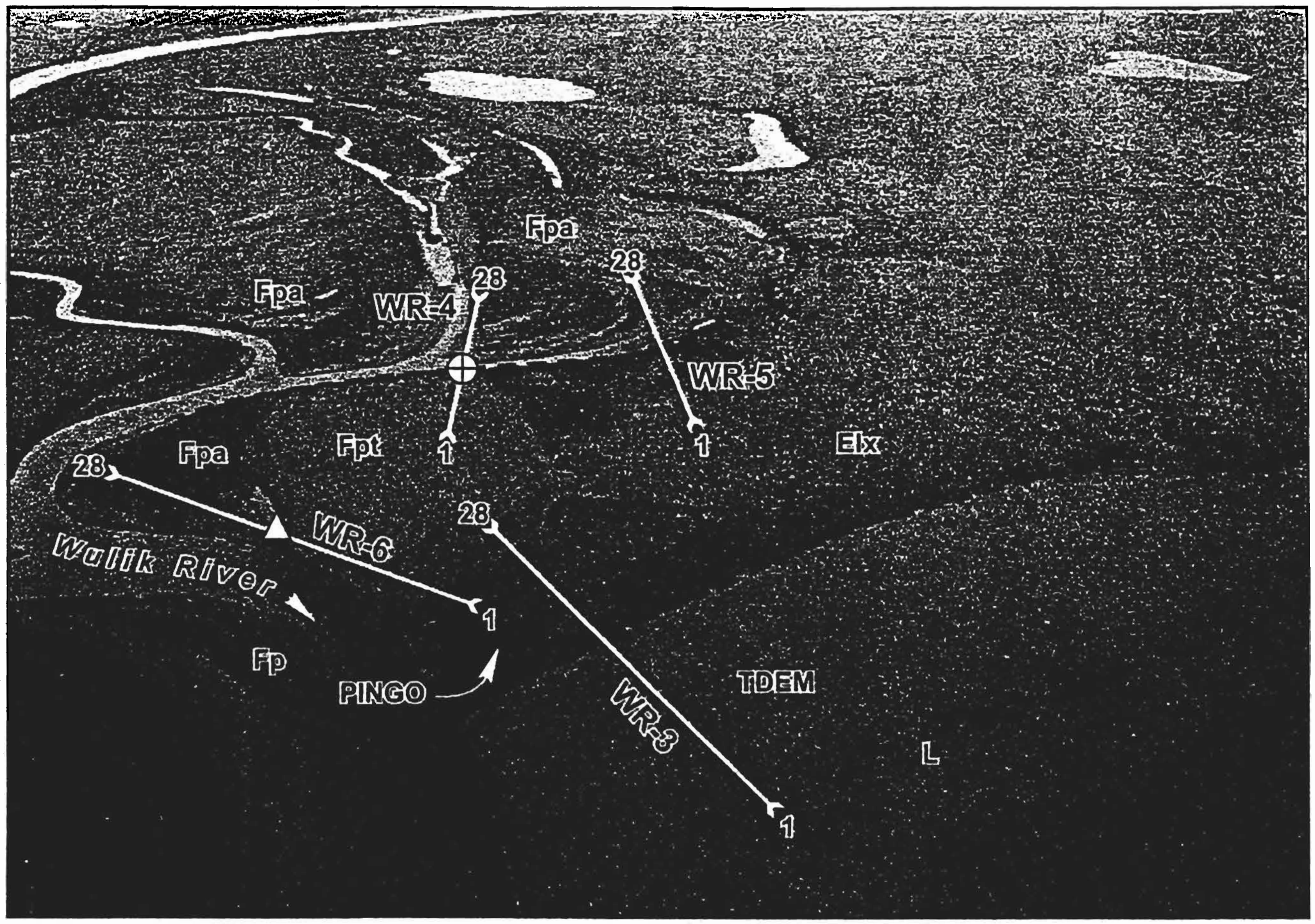
Figure 8

TERRAIN UNITS AT IGRUGAIVIK SITE

CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: IGRUGAIVIK2.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates



VIEW LOOKING NORTHEAST

LEGEND:

Fp	FLOODPLAIN
Fpa	ABANDONED FLOODPLAN
Fpt	OLD TERRACE DEPOSITS
L	DRAINED LAKE DEPOSITS
Elx	UPLAND FROZEN SILT
– – – – – – –	APPROXIMATE GEOLOGIC CONTACT
28 ——— 1	ELECTRICAL IMAGING LINE (WITH ELECTRODE NUMBERS)
◇	TDEM SOUNDING LOCATION
⊕	PROSPECTIVE DRILL SITE
△	ALTERNATE DRILL SITE

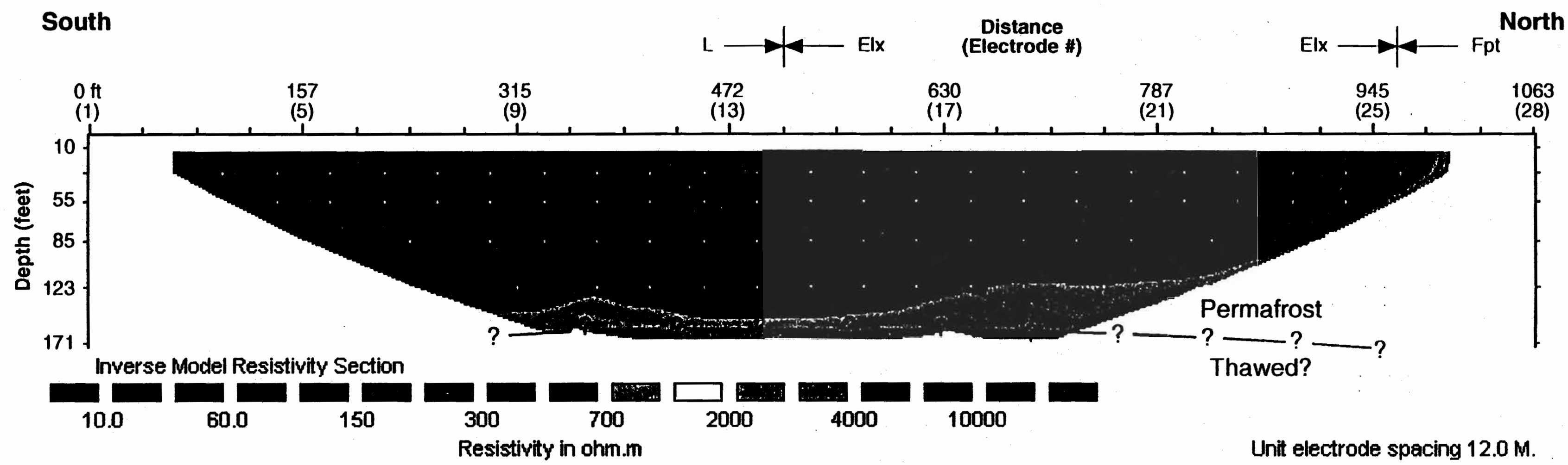
Figure 9

GEOPHYSICAL SURVEY LOCATIONS AT IGRUGAIVIK SITE

CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: IGRUGAIVIK.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates



LINE WR-3

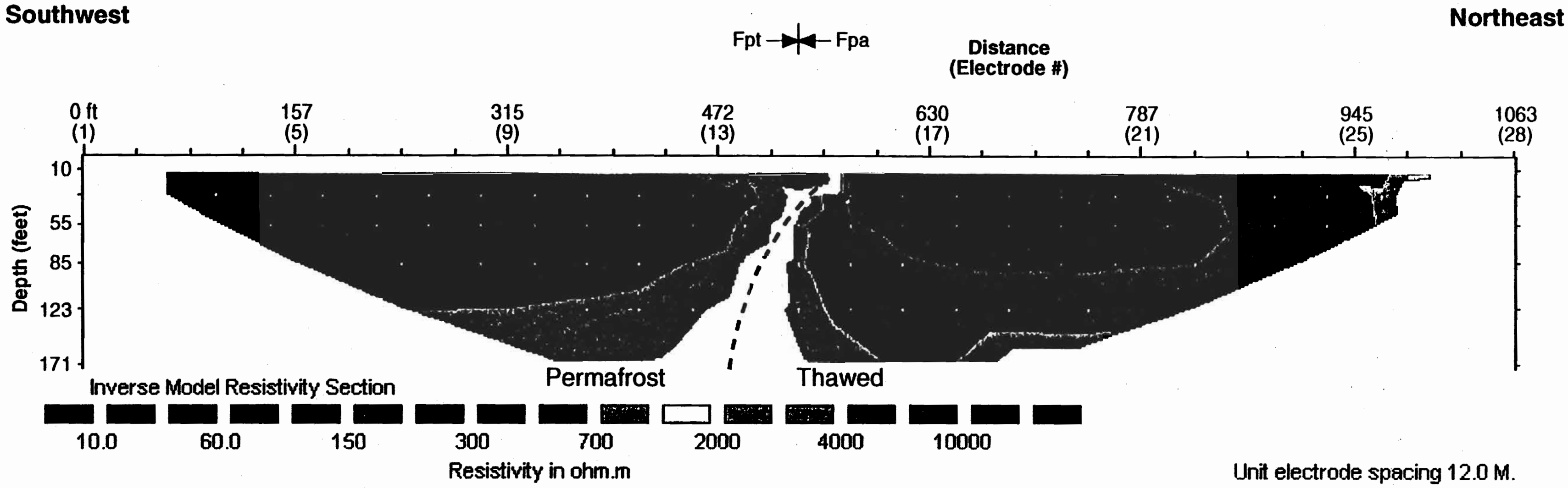
LEGEND

- - - - -	Approximate Permafrost Boundary
L, Elx, Fpt	See Figure 9

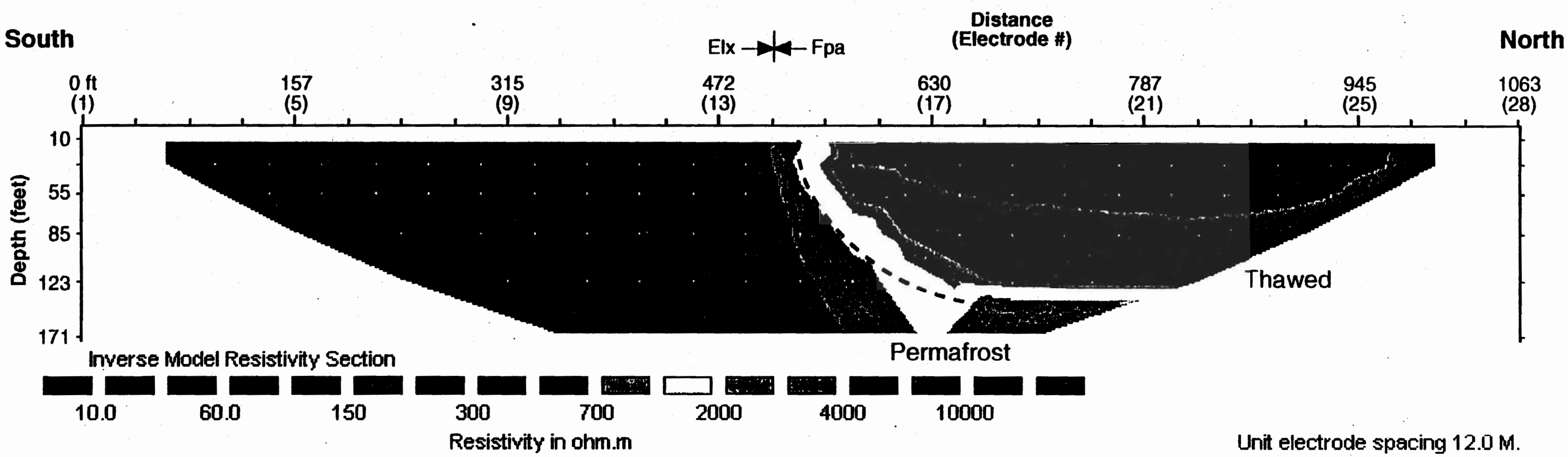
FIGURE 10
RI CROSS-SECTION
WENNER ARRAY DATA
CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73880 DATE 9/29/97 DRAWN BY EA

Golder Associates



a) LINE WR-4



b) LINE WR-5

LEGEND

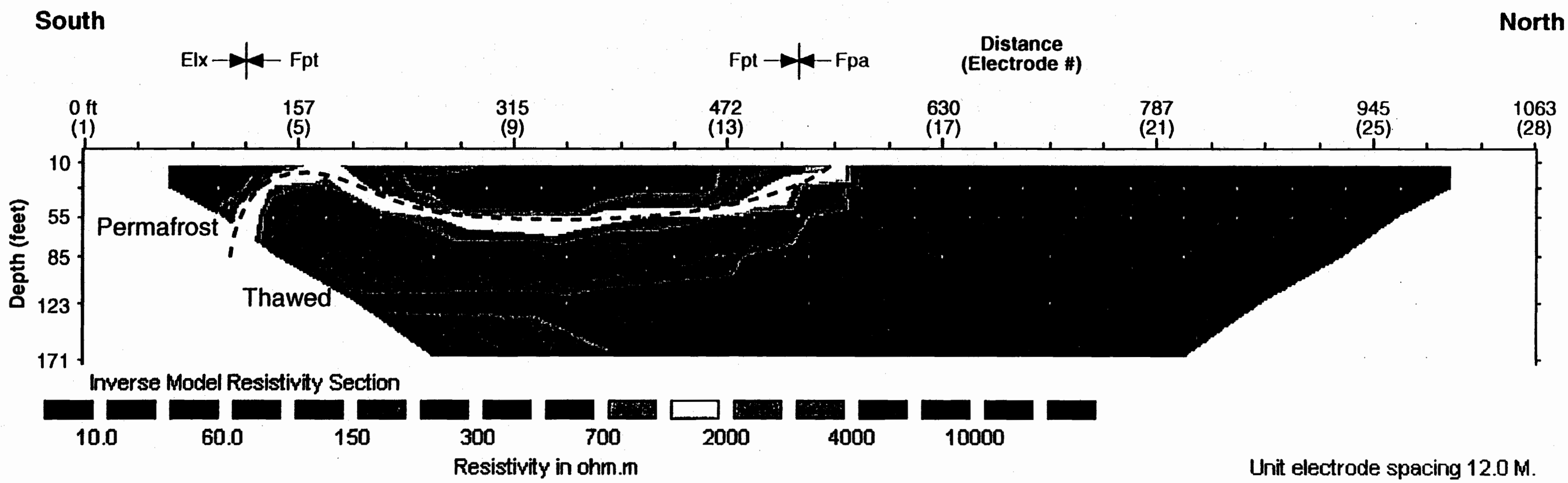
- - - - - Approximate Permafrost Boundary

Fpt, Elx, Fpa See Figure 9

FIGURE 11
RI CROSS-SECTIONS
WENNER ARRAY DATA
CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73881 DATE 9/26/97 DRAWN BY EA

Golder Associates



Line WR-6

LEGEND

- - - - - Approximate Permafrost Boundary

Elx, Fpt, Fpa See Figure 9

FIGURE **12**

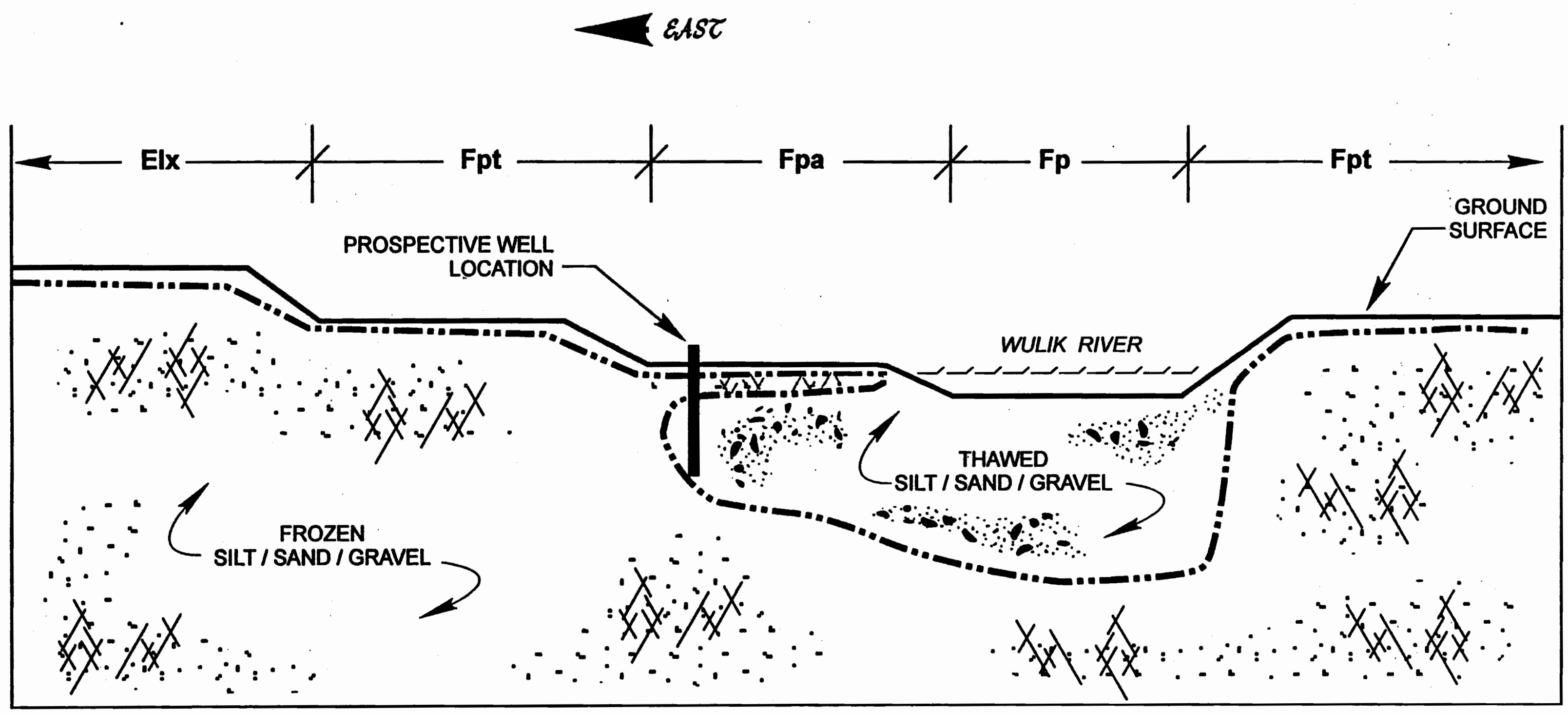
RI CROSS-SECTION

WENNER ARRAY DATA

CITY OF KIVALINA/WATER SUPPLY/AK

PROJECT NO. 973 5332 DRAWING NO. 73882 DATE 9/26/97 DRAWN BY EA

Golder Associates



NOT TO SCALE

LEGEND:

Elx UPLAND FROZEN SILT

Fp FLOODPLAIN

Fpa ABANDONED FLOODPLAN

Fpt OLD TERRACE DEPOSITS

—··— PERMAFROST BOUNDARY

Figure 13

CONCEPTUAL GEOLOGIC CROSS SECTION AT KUUGRUAG AND IGRUGAIVIK SITE

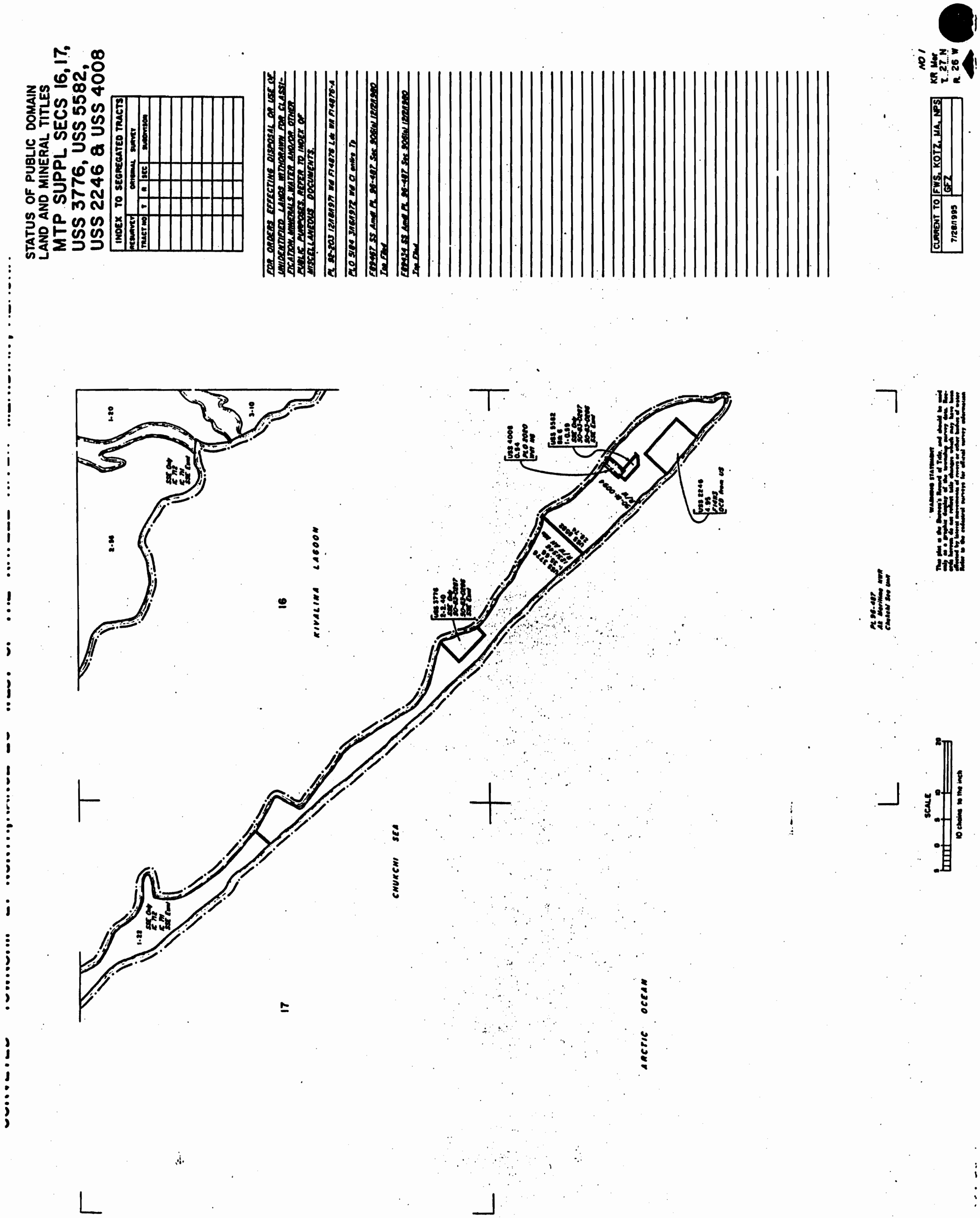
CITY OF KIVALINA / GROUNDWATER SOURCE / AK

JOB NUMBER: 973-5332 FILE NAME: KUUGRUAGXsec.CD7 DATE: 9/97 DRAWN: SJM

Golder Associates

APPENDIX C

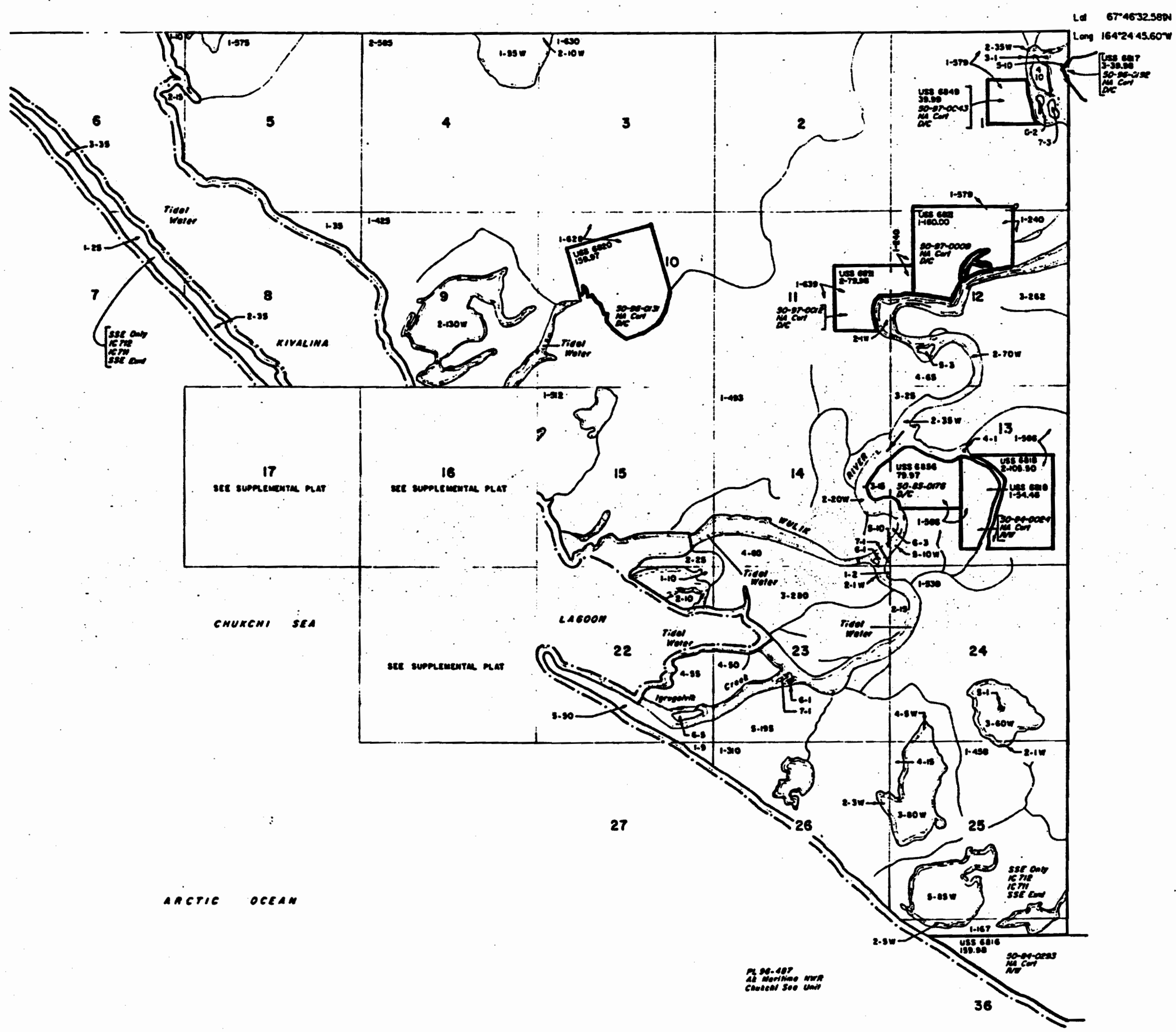
LAND OWNERSHIP MAPS



Maps in this appendix are from the U.S. Department of Interior Bureau of Land Management, Anchorage, Alaska.

SURVEYED TOWNSHIP 27 NORTH, RANGE 26 WEST OF THE KATEEL RIVER MERIDIAN, ALASKA

2-K-1684



SCALE

30 chains to the inch

WARNING STATEMENT

This plat is the Bureau's Record of Title, and should be used only as a graphic display of the township survey data. Records hereon do not reflect title changes which may have been effected by lateral movements of rivers or other bodies of water. Refer to the cadastral surveys for official survey information.

STATUS OF PUBLIC DOMAIN
LAND AND MINERAL TITLES

MTP

INDEX TO SEGREGATED TRACTS				
RESURVEY	ORIGINAL SURVEY			
TRACT NO	T	R	SEC	SUBDIVISION

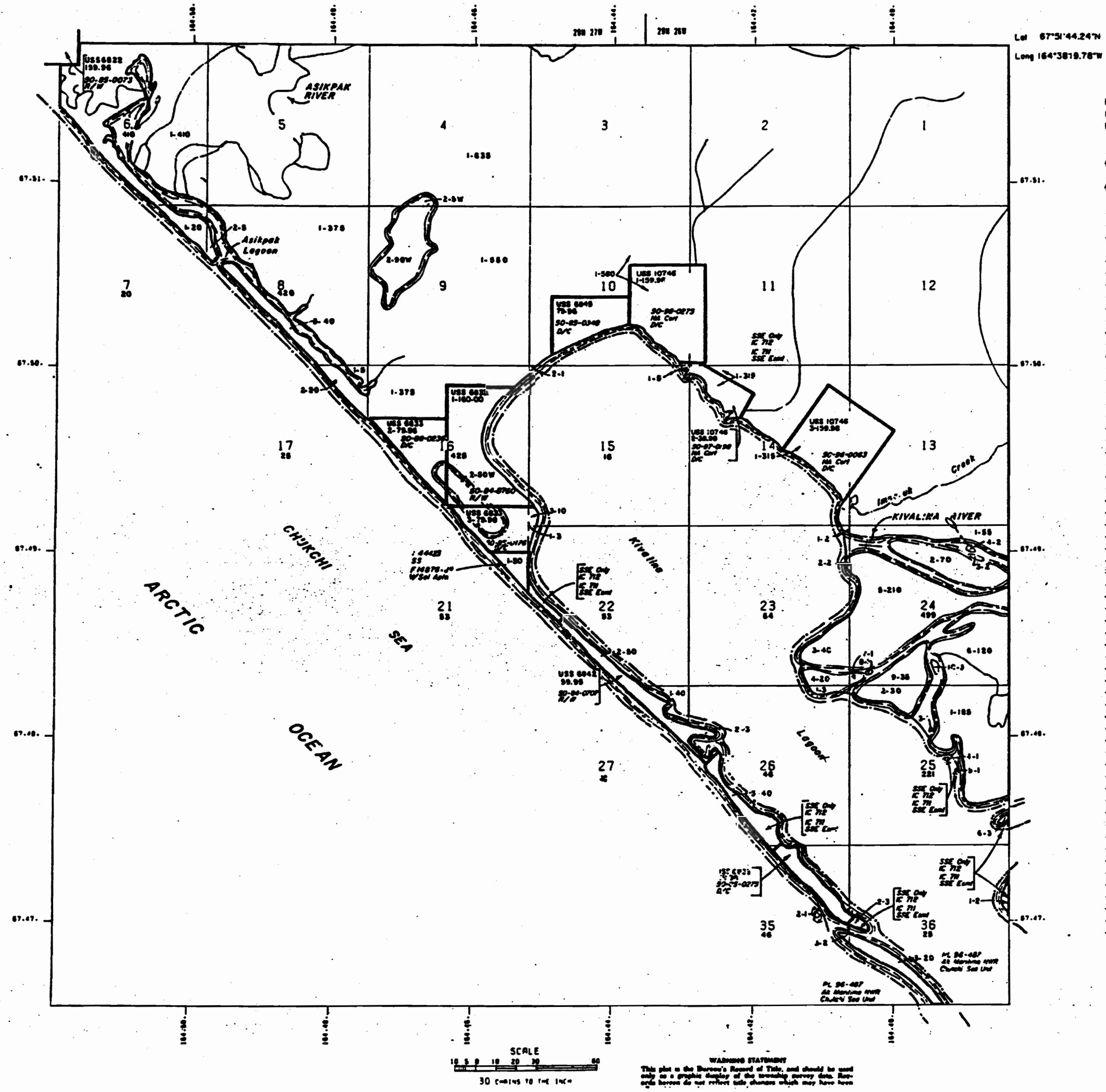
FOR ORDERS EFFECTING DISPOSAL OR USE OF UNIDENTIFIED LANDS WITHDRAWN FOR CLASSIFICATION, MINERALS, WATER AND/OR OTHER PUBLIC PURPOSES, REFER TO INDEX OF MISCELLANEOUS DOCUMENTS.

PL 92-203 12181971 Wd F14876 Lands Wd F14876-A

PLO 5184 3161972 Wd Cl entire Tp

CURRENT TO	MA, KOTZ, FWS, GFZ
12-5-1996	ABC

KR Mer
T 27 N
R 26 W



STATUS OF PUBLIC DOMAIN
LAND AND MINERAL TITLES

MTP

FOR ORDERS EFFECTING DISPOSAL OR USE OF UNIDENTIFIED LANDS. REFER TO INDEX OF MISCELLANEOUS DOCUMENTS.

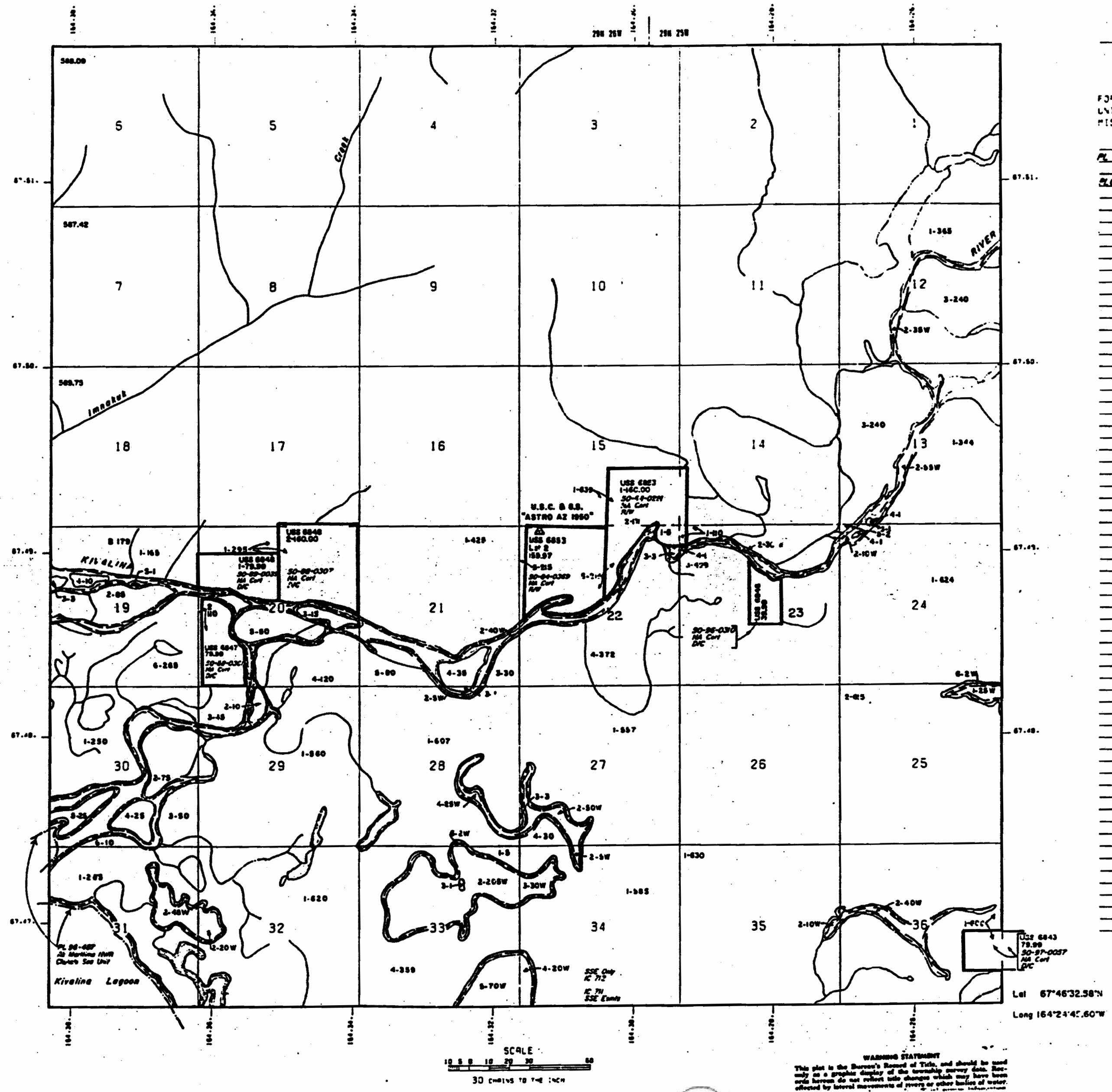
PL 92-203 12/18/1971 WA F14876 Ljs WA F14876-J

F.C 9184 3/16/... WA Cl ... Tp

F44423 SS Amd PL 96-487 12/2/1980 Sec 906(a)
Tep Filed

CURRENT TO	KOTZ, MA, FWS
4-10-1997	GFZ

KR Mer
T 28 N
R 27 W



LAND AND MINERAL TITLES

MTP

FOR ORDERS EFFECTING DISPOSAL OR USE OF UNIDENTIFIED LANDS. REFER TO INDEX OF MISCELLANEOUS DOCUMENTS.

PL 92-203 12/18/1971 WA F14876 Lds WA F14876-A

PLO 5184 3/16/1972 WA

CURRENT TO	KOTZ.MA.GFZ	KR Mer
12-4-1996		T 28 N
		R 26 W

APPENDIX D

STORM SURGE RISK ANALYSIS

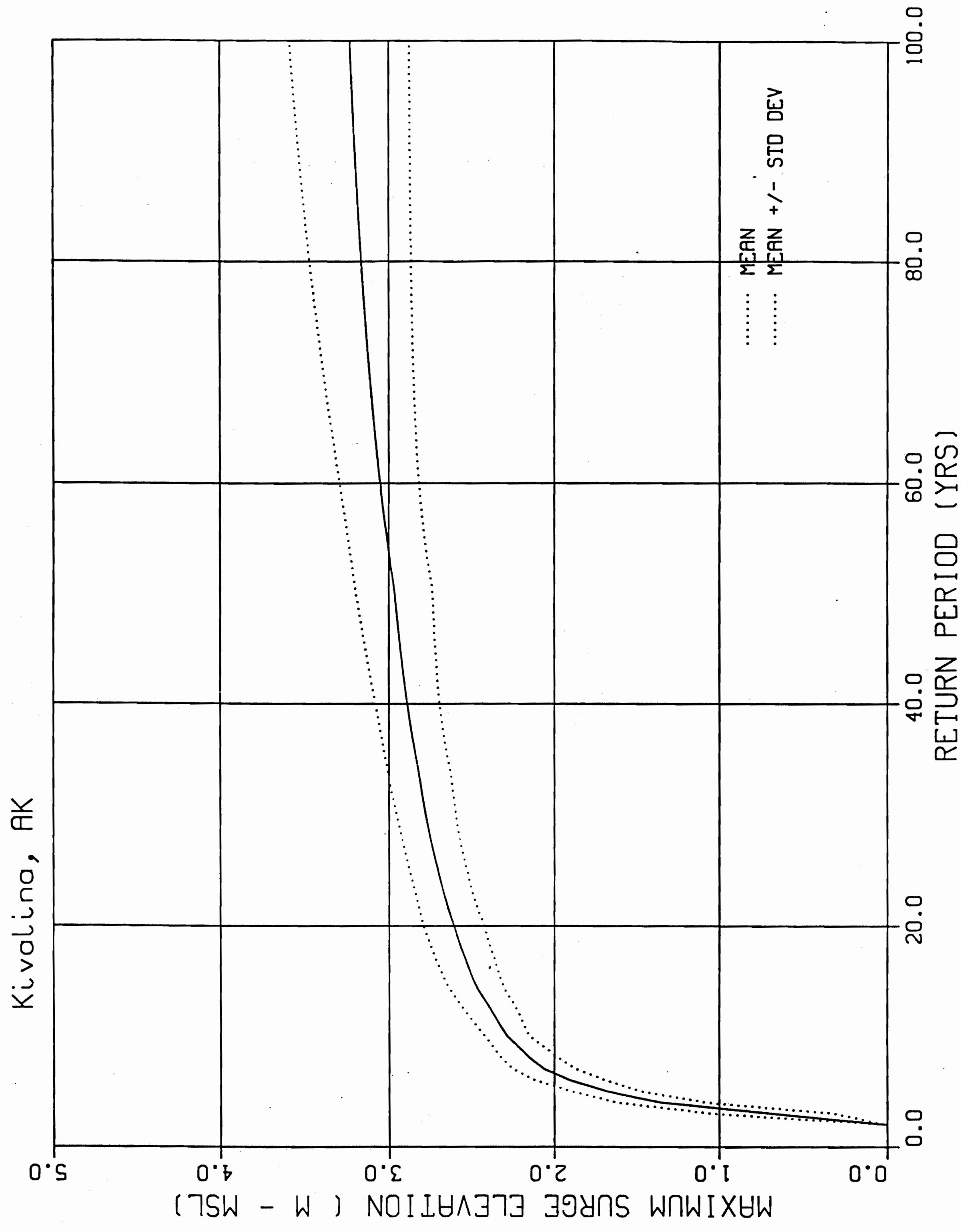


FIGURE D-6.—Mean value/standard deviation relationships for Kivalina.

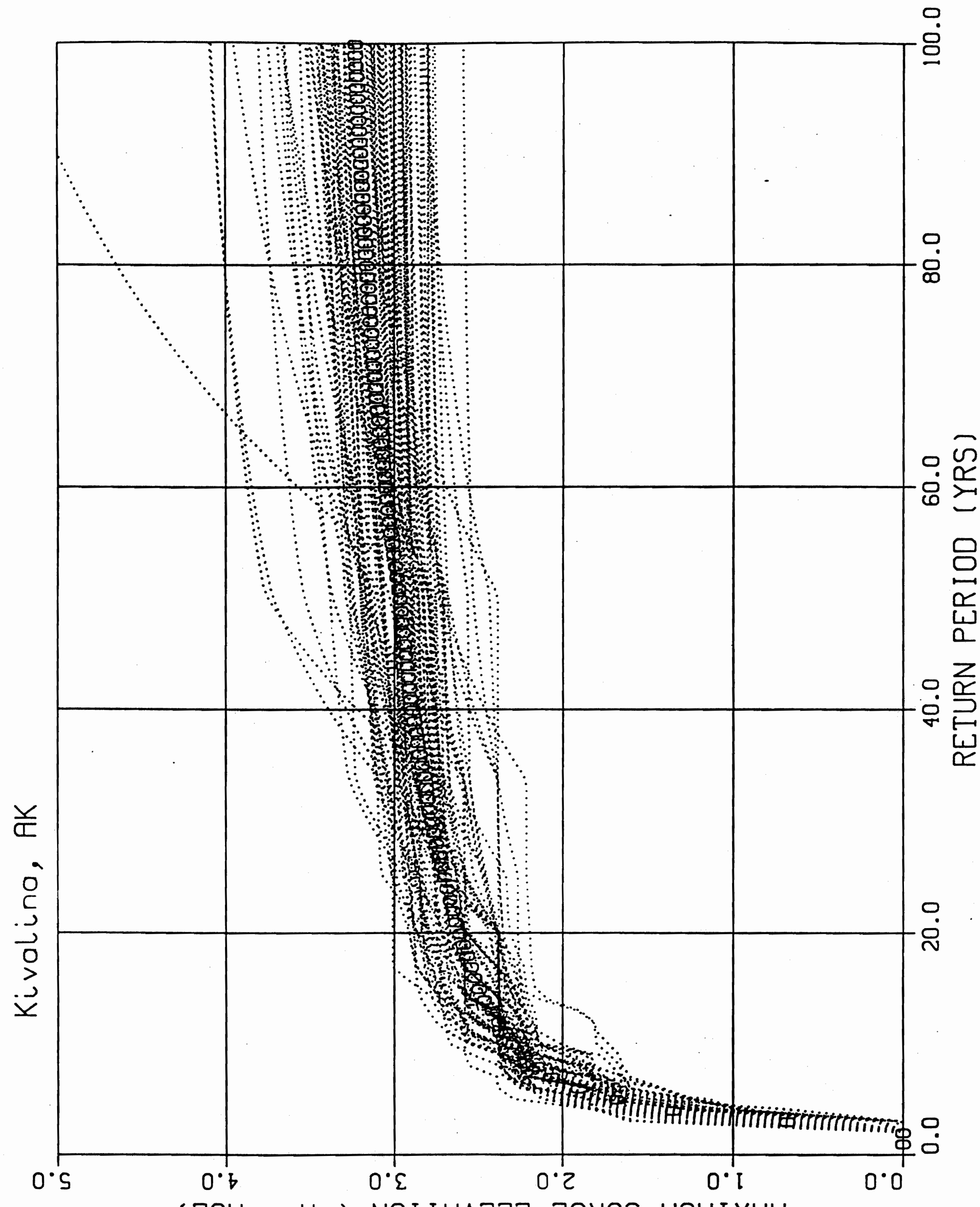


FIGURE D-5.—Frequency relationship for Kivalina.

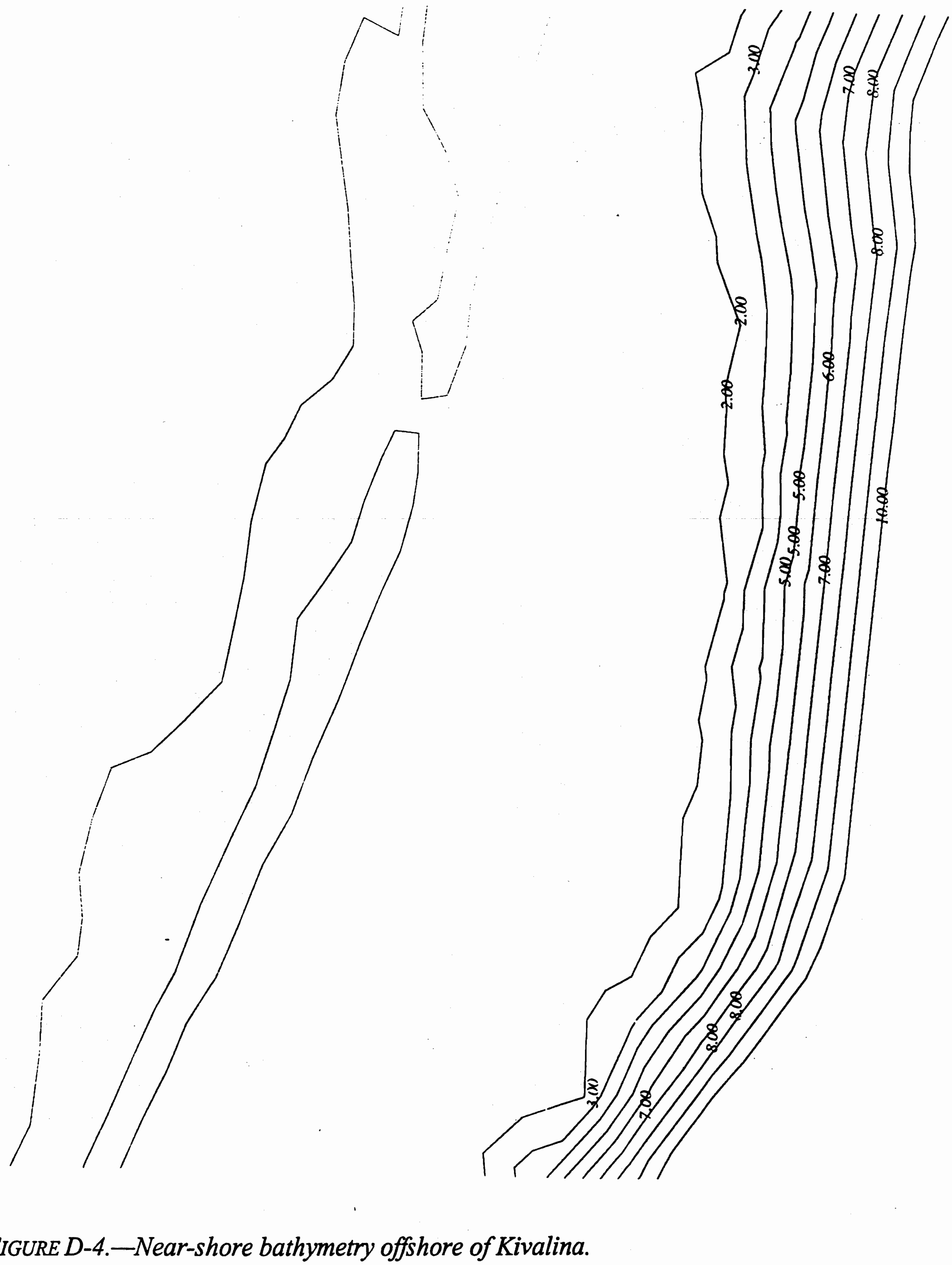


FIGURE D-4.—Near-shore bathymetry offshore of Kivalina.

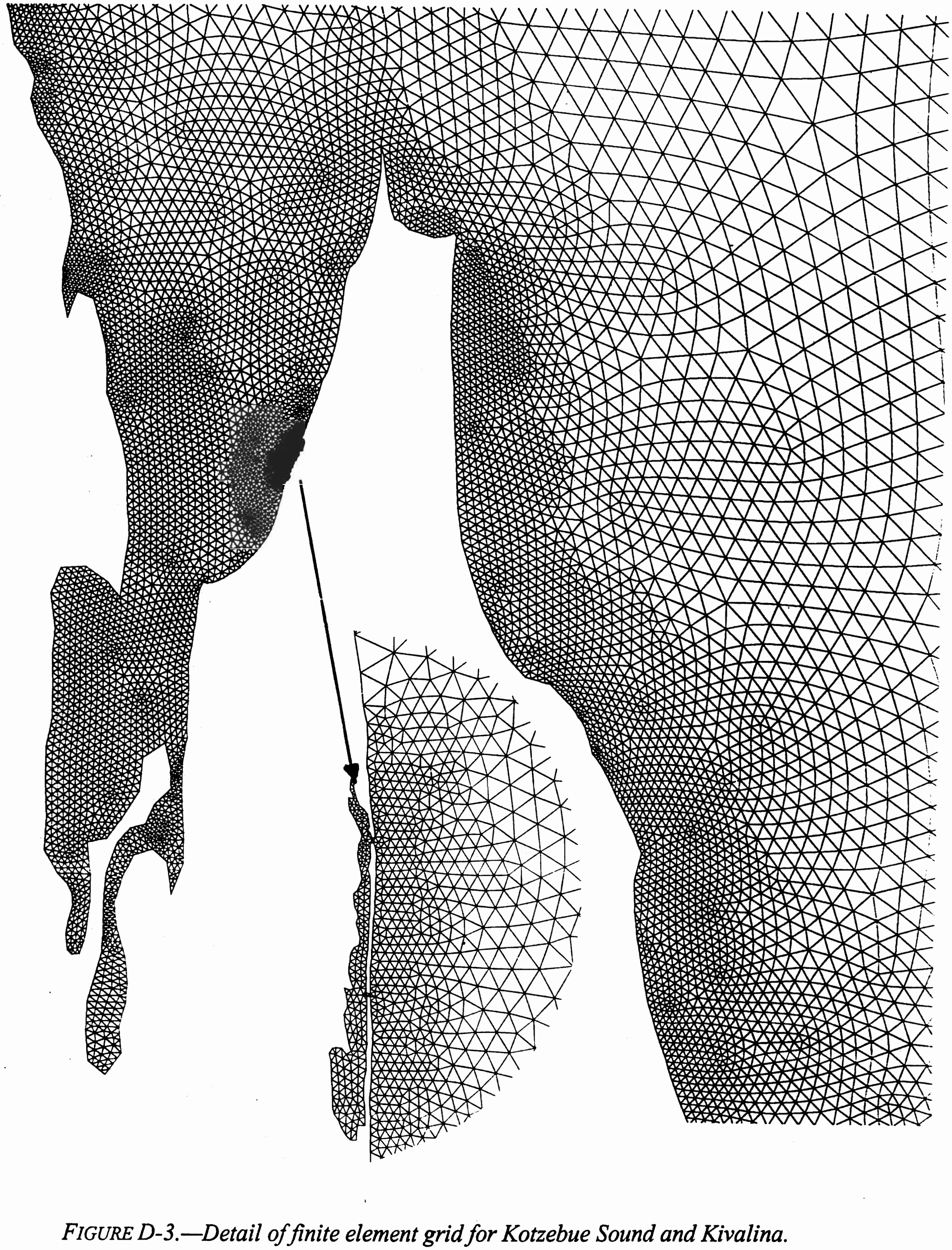


FIGURE D-3.—Detail of finite element grid for Kotzebue Sound and Kivalina.

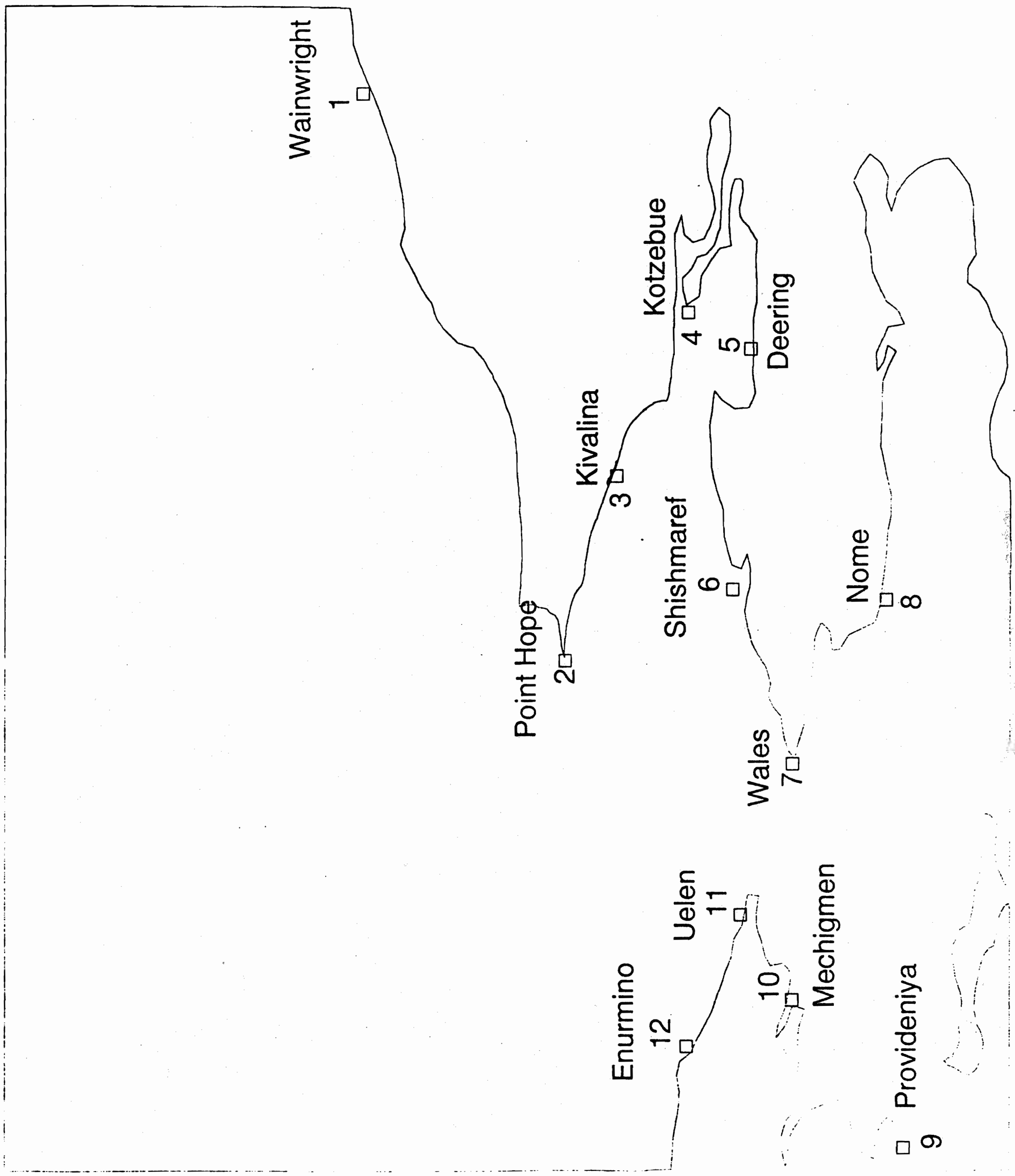


FIGURE D-2.—Key locations within computational grid.

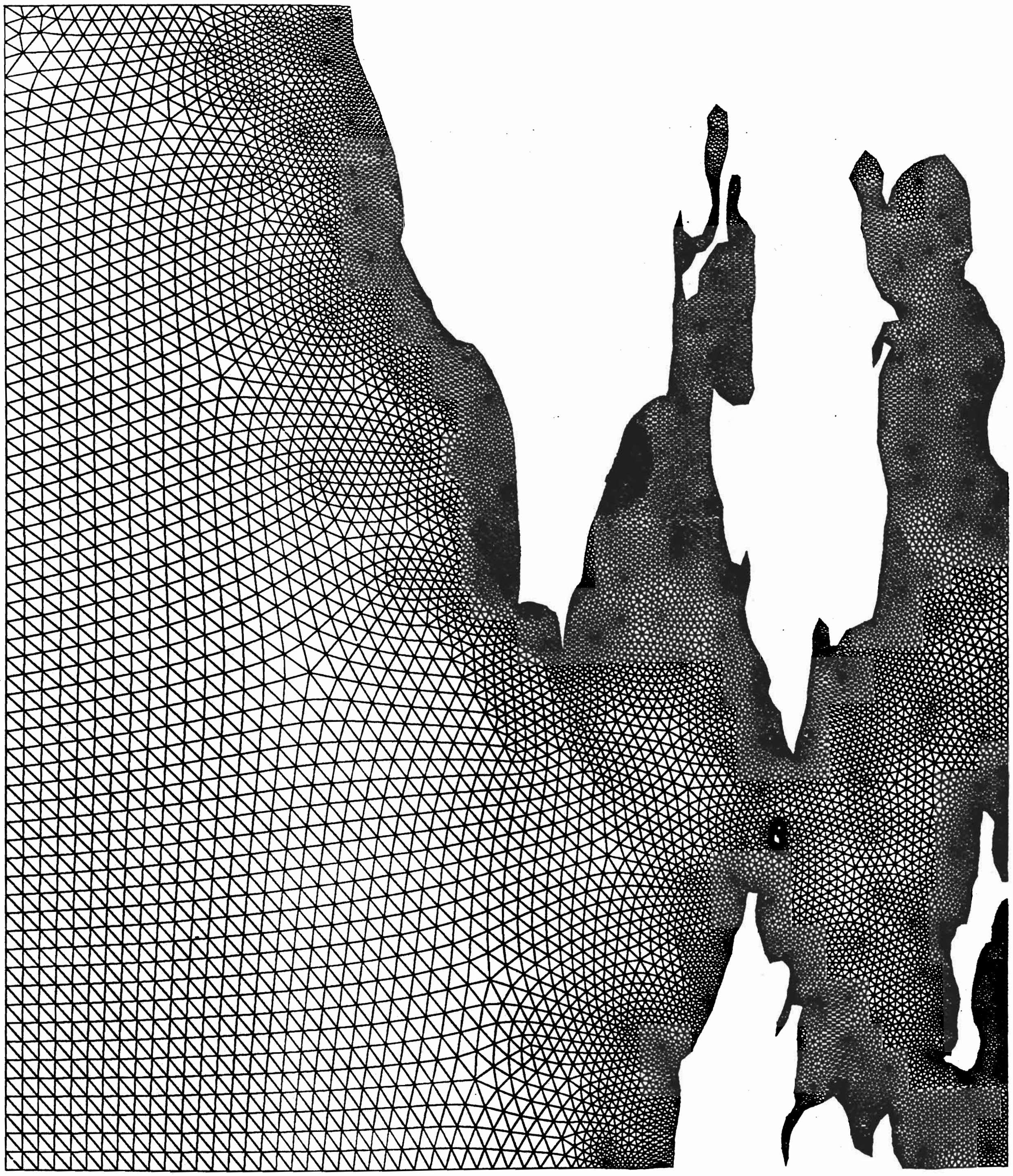


FIGURE D-1.—Finite element grid used in the ADCIRC computation of storm surges.

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surge that has a 0.01 probability of occurring in a single year) is 3.23 m (10.6 ft). This magnitude is consistent with surges that have been observed at the site (DOWL Engineers 1994).

$$S_{xx} = \frac{1}{8} \rho g^2 \left(\frac{3}{2}\right)$$

Substitution gives the following relationship for one-dimensional setup resulting from shore-normal waves:

$$-\frac{3}{8}\kappa^2 \frac{dh}{dx} = \frac{d\eta}{dx}\left(1+\frac{3}{8}\kappa^2\right)$$

where κ is the breaking index of approximately 0.8.

Integration across the surf zone yields the following relationship for setup at the shore (x=0.0):

$$\eta(0) = \eta_b + \left[\frac{\frac{3\kappa^2}{8}}{\left(1+\frac{3\kappa^2}{8}\right)}\right] h_b = 0.19\, h_b$$

where η_b is the setup at the breaker line (small compared to the breaker height) and h_b is the breaking wave height. Bathymetry offshore of Kivalina is on the order of 1.5 m; therefore, waves are depth-limited to approximately 0.8*1.5=1.2 m. Conservative computations yield a setup for Kivalina to be approximately 0.23 m.

6.2 Runup

Wave runup is the maximum elevation above still water level reached by the uprush of waves on the beach. Analytical approximations for runup are not available; however, empirical approximations are provided in the *Shore Protection Manual* (SPM 1984). Assuming the storm-associated period to be approximately 12 seconds, the deep-water wave equivalent of the 1.5-m near-shore wave height to be 0.84 m, and the slope of the beach to be milder than 1:5, the maximum runup should be approximately 2.0 m.

7. CONCLUSIONS

The risk of storm surge inundation has been determined for the site of Kivalina, Alaska, using the ADvanced CIRCulation model (ADCIRC) and a statistical procedure known as the Empirical Simulation Technique (EST). Thirty Chukchi Sea storms which occurred between 1954 and 1984 were considered in the data analysis. Sixteen of these produced positive surges at the Kivalina village site. Based on the combined analysis of these storms, the 100-year return period storm surge (*e.g.*, that

TABLE D-3.--*Frequency summary, Kivalina, Alaska*

Return period, years	Elevation, meters	Standard deviation, meters
5	1.68	0.21
10	2.29	0.14
15	2.49	0.17
20	2.61	0.18
25	2.70	0.17
50	2.96	0.23
75	3.14	0.28
100	3.23	0.36

6. WAVE SETUP AND RUNUP

Although an analysis of short waves, i.e., wind waves, is not a component of this project, an approximation of their magnitudes can be made to demonstrate their potential contribution to a total water surface elevation. Short waves contribute to total surface elevation in two ways: wave setup and wave runup. An approximation of each component is given below.

6.1 Wave Setup

Wave setup is a steady state super-elevation of the near-shore water surface as result of onshore mass transport of water by short waves. A relationship for wave setup can be derived from the equation for the conservation of linear momentum in which wave-induced forces are included in the formulation. For example, the momentum equation in the x direction can be written in the following Cartesian Coordinate form:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + g\frac{\partial \eta}{\partial x} + \frac{1}{\rho d}\frac{\partial S_{xx}}{\partial x} = 0$$

where U represents wave-induced currents, η represents setup and S_{xx} is the onshore component of the radiation stress defined as where the parentheses surrounding the subscript indicate that the data have been rank-ordered. The value $x_{(1)}$ is the smallest in the series and $x_{(n)}$n represents the largest. Let r denote the rank of the value $x_{(r)}$ such that rank 1 is the smallest and rank $r = n$ is the largest.

An empirical estimate of $F_X(x_{(r)})$, denoted by $\hat{F}_X(x_{(r)})$, is given by Gumbel (1954). (See also Borgman and Scheffner 1991 or Scheffner and Borgman 1992.)

$$\hat{F}_x(x_{(r)}) = \frac{r}{(n+1)} \tag{4}$$

for $\{x_{(r)}, r = 1, 2, 3, \ldots, n\}$. This form of estimate allows for future values of x to be less than the smallest observation $x_{(1)}$ with probability of 1/(n+1), and to be larger than the largest value $x_{(n)}$ also with probability 1/(n+1). In the implementation of the EST, tail functions (Borgman and Scheffner 1991) are used to define the cdf for events larger than the largest or smaller than the smallest observed event, so that there is no discontinuity in the cdf.

The cumulative cdf as defined by equation 4 is used to develop stage-frequency relationships in the following manner. Consider that the cdf for some storm impact corresponding to an n-year return period event can be determined from:

$$F(x) = 1 - \frac{1}{n} \tag{5}$$

where F(x) is the simulated cdf of the n-year impact. Frequency-of-occurrence relationships are obtained by linearly interpolating a stage from equation 4 corresponding to the cdf associated with the return period specified in equation 5.

Results of the 100 simulations for Kivalina are shown in figure 5. Note in the figure that all 100 simulations are shown with the curve composed of 0's representing the mean value.

For each return period year, a standard deviation, defined as:

$$\sigma = \sqrt{\left[(1/N)\sum_{n=1}^{n=N}(x_n - \bar{x})\right]}$$

(where $\bar{x}$ is the mean value), is computed to define an error band of ± one standard deviation (±σ) corresponding to each mean value curve. Figure 6 presents the mean and error bands associated with the mean value curve of figure 5. Results are summarized in table 3.

TABLE D-2.—*Maximum computed surge elevations at Kivalina*					
Storm number	**Start date YYMMDDHH**	**Maximum surge at Kivalina, m**	**Storm number**	**Start date YYMMDDHH**	**Maximum surge at Kivalina, m**
1	54100512	0.98	9	63082400	2.15
2	55072006	1.06	10	63100506	0.36
3	55072212	1.83	12	64102100	1.14
4	57071800	2.58	15	68092312	0.04
5	57091500	0.35	17	73080312	2.38
6	60092812	1.81	18	73101712	2.26
7	61061918	2.21	21	75082718	0.83
8	62090518	1.38	28	83100712	1.65

5. FREQUENCY COMPUTATIONS

Estimates of frequency-of-occurrence relationships require post-processing of each of the 100 life-cycle simulations generated by the EST. These computations begin with calculating a cumulative distribution function (cdf) for the response vector of interest, the maximum water surface elevation. Let X_1, X_2, X_3, ..., X_n be n identically distributed random response variables with a cumulative cdf

$$F_X(x) = Pr[X \leq x]$$

where $Pr[X \leq x]$ represents the probability that the random variable X is less than or equal to some value x, and $F_X(x)$ is the cumulative probability distribution function ranging from 0.0 to 1.0. The problem is to estimate the value of F_X without introducing some parametric relationship for probability. The following procedure is adopted because it makes use of the probability laws defined by the data and does not incorporate any prior assumptions concerning the probability relationship.

Assume that we have a set of n observations of data. The n values of x are first ranked in order of increasing size such that

$$x_{(1)} \leq x_{(2)} \leq x_{(3)} \leq \ldots \leq x_{(n)}$$

3.2 Storm Event Frequency

The second criterion to be satisfied is that the total number of storm events selected per year must be statistically similar to the number of historical events that have occurred at the area of concern. Given the mean frequency of storm events for a particular region, a Poisson distribution is used to determine the average number of expected events in a given year. For example, the Poisson distribution can be written in the following form:

$$Pr(s;\lambda) = \frac{\lambda^s e^{-\lambda}}{s!}$$

for s=0,1,2,3,... The probability $Pr(s;\lambda)$ defines the probability of having s events per year where λ is a measure of the historically based number of events per year.

A 10,000-element array is initialized to the above Poisson distribution. For example, the number corresponding to λ=0.32 and s=0 storms per year is 0.7261. Thus, if a random number selection is less than or equal to 0.7261 on an interval of 0.0 to 1.0, then no hurricanes would occur during that year of simulation. If the random number is between 0.7261 and 0.7261 + P[N=1] = 0.7261 + 0.2324 = 0.9585, one event is selected. Two events for 0.9585 + 0.0372 = 0.9957, etc. When one or more storms are indicated for a given year, they are randomly selected from the nearest neighbor interpolation technique described above.

4. ADCIRC MODELING RESULTS

Each of the events of table D-1 were simulated with maximum surge elevations archived for the Kivalina site. Of the 30 storm events provided in the Chukchi Sea data base, 14 events resulted in a draw-down condition (*e.g.*, offshore winds that caused the sea level to decrease) for the Kivalina site. Therefore, these conditions were not included in the training set of events. The final training set was, therefore, limited to the 16 events shown in table D-2 with λ=0.51613 (16 events/31 years). Included in the table are maximum computed surge elevations at Kivalina.

In addition to the surge elevations listed above, each storm was assumed to be independent of the tide phase. Therefore, a 64-event training set defined as the occurrence of each event at: (1) high tide, (2) MLLW at peak ebb, (3) low tide, and peak flood. Tidal elevation was taken as the RMS (0.707) value of the mean high tide at Shishmaref (Mason, *et al.* 1997). These data were used as input to the 1-D EST to generate 100 repetitions of a 100-year sequence of events at Kivalina. Post-processing to these multiple time series is described below.

Two criteria are required of the T-year sequence of events. The first criterion is that the individual events must be similar in behavior and magnitude to historical events. The second criterion is that the frequency of storm events in the future will remain the same as in the past. The following sections describe how these two criteria are preserved.

3.1 Storm Event Consistency

The first major assumption in the EST is that future events will be similar to past events. This criterion is maintained by using only historic events in the simulation process. Therefore, hypothetical events which have never occurred, or which have a minimal probability of occurrence, are not used in the frequency analysis.

The basic technique can be described in two dimensions as follows. Let X_1, X_2, X_3, ..., X_n be n independent, identically distributed random vectors (storm events), each having two components [$X_i = \{\underline{x}_i(1), \underline{x}_i(2)\}$; i=1,n].

Each event X_i has a probability p_i as 1/n, therefore, a cumulative probability relationship can be developed in which each storm event is assigned a segment of the total probability of 0.0 to 1.0. If each event has an equal probability, then each event is assigned a segment s_j such that s_j -> X_j. Therefore, each event occupies a fixed portion of the 0.0 to 1.0 probability space according to the total number of events in the training set.

$$[\ 0 < s_1 \le \frac{1}{n}\ ]$$

$$\cdot$$

$$[\ \frac{1}{n} < s_2 \le \frac{2}{n}\ ]$$

$$\cdot$$

$$[\ \frac{2}{n} < s_3 \le \frac{3}{n}\ ]$$

$$\vdots$$

$$[\ \frac{n-1}{n} < s_n \le .\ 1]$$

A random number from 0 to 1 is selected to identify a storm event from the total storm population. The procedure is equivalent to drawing and replacing random samples from the full storm event population.

Figure 1 shows the numerical grid used by ADCIRC for the present Kivalina study. As shown, the grid covers the Chukchi Sea and northern Bering Sea and is bounded by the 173° W. and 159° W. longitudes and the 75°N. and 63° N. latitudes (because the data base described above extended only to 64° N., the data at 64° was used to define conditions for 63° N.). Figure 2 shows the location of some communities within the computational domain boundaries. Figure 3 shows an enlarged portion of the grid including Kotzebue Sound with an inset showing high resolution within Kivalina Lagoon. Figure 4 shows the near-shore bottom contours near the Singauk Entrance to Kivalina Lagoon, where the minimum node-to-node distance is on the order of 400 m. The near-shore bathymetry needed to support the high-resolution grid offshore of Kivalina was supplied to CHL by the District.

3. EST MODELING

The EST (Empirical Simulation Technique) is based on a "Bootstrap" resampling-with-replacement, interpolation, and subsequent smoothing technique in which a random sampling of a finite length data base is used to generate a larger data base. The EST was first developed to model multi-parameter events such as tropical hurricanes in which the storm can be described in terms of defined storm parameters such as pressure deficit, radius to maximum winds, maximum winds, etc. For storm events not conducive to parameterization, such as extra-tropical events, a 1-dimensional version of the EST was developed. The present application uses this 1-D version of the EST.

The only assumption in the EST is that future events will be statistically similar in magnitude and frequency to past events. The EST begins with an analysis of historical events that have impacted a specific locale. For each event, a storm response is defined for which a frequency-of-occurrence analysis is performed. For the present application, the responses are the maximum storm surge which is computed via the ADCIRC for the 30 wind fields described in section 2.1.

Implementation of the 1D-EST begins with selection of a set of historic events referred to as a "training set" of events. Once the training set has been defined, with each event/station represented by an appropriate response vector, life cycle simulations via the EST can be generated. The goal of the EST can be summarized as:

1) given the following:
   a) the historical data $[\mathbf{v}_i \in \Re^{dv}; i=1,...,I]$
   b) the "training set" data $[\mathbf{v}^*_j \in \Re^{dv}; j=1,...,J]$
   c) the response vectors calculated from the training set $[\mathbf{r}^*_j \in \Re^{dr}; j=1,...,J]$

2) produce N simulations of a T-year sequence of events, each with their associated input vectors $\mathbf{v} \in \Re^{dv}$ and response vectors $\mathbf{r} \in \Re^{dr}$.

where t represents time, λ, ϕ are degrees longitude (east of Greenwich is taken positive) and degrees latitude (north of the equator is taken positive), ζ is the free surface elevation relative to the geoid, U, V are the depth-averaged horizontal velocities, R is the radius of the Earth, $H = \zeta + h$ is the total water column depth, h is the bathymetric depth relative to the geoid, $f = 2\Omega \sin\phi$ is the Coriolis parameter, Ω is the angular speed of the Earth, p_s is the atmospheric pressure at the free surface, g is the acceleration due to gravity, η is the effective Newtonian equilibrium tide potential, ρ_0 is the reference density of water, $\tau_{s\lambda,}\tau_{s\phi}$ is the applied free surface stress, and τ_* is given by the expression $C_f(U^2 + V^2)^{1/2}/H$ where C_f equals the bottom friction coefficient.

The momentum equations (equations 2 and 3) are differentiated with respect to λ and τ and substituted into the time-differentiated continuity equation (equation 1) to develop the following Generalized Wave Continuity Equation (GWCE):

$$\frac{\partial^2\zeta}{\partial t^2} + \tau_0\frac{\partial\zeta}{\partial t} - \frac{1}{R\cos\phi}\frac{\partial}{\partial\lambda}\left[\frac{1}{R\cos\phi}\left(\frac{\partial HUU}{\partial\lambda} + \frac{\partial(HUV\cos\phi)}{\partial\phi}\right) - UVH\frac{\tan\phi}{R}\right]$$

$$\left[-2\omega\sin\phi HV + \frac{H}{R\cos\phi}\frac{\partial}{\partial\lambda}\left(g(\zeta - \alpha\eta) + \frac{p_s}{[}p_0\right) + \tau_* HU - \tau_0 HU - \tau_{s\lambda}\right]$$

$$-\frac{1}{R}\frac{\partial}{\partial\phi}\left[\frac{1}{R\cos\phi}\left(\frac{\partial HVV}{\partial\lambda} + \frac{\partial HVV\cos\phi}{\partial\phi}\right) + UUH\frac{\tan\phi}{R} + 2\omega\sin\phi HU\right]$$

$$+ \frac{H}{R}\frac{\partial}{\partial\phi}\left(g(\zeta-\alpha\eta) + \frac{p_s}{\rho_0}\right) + \tau_* - \tau_0 HV - \frac{\tau_{s\lambda}}{\rho_0}]$$

$$- \frac{\partial}{\partial t}\left[\frac{VH}{R}\tan\phi\right] - \tau_0\left[\frac{VH}{R}\tan\phi\right] = 0 \tag{4}$$

The ADCIRC-2DDI model solves the GWCE in conjunction with the primitive momentum equations given in equations 2 and 3.

The ADCIRC model uses a finite-element algorithm in solving the defined governing equations over complicated bathymetry encompassed by irregular sea and shore boundary. This algorithm allows for extremely flexible spatial discretizations over the entire computational domain and has demonstrated excellent stability characteristics. The advantage of this flexibility in developing a computational grid is that larger elements can be used in the open-ocean regions where less resolution is needed, whereas smaller elements can be applied in the near-shore and estuary areas where finer resolution is needed to resolve hydrodynamic details.

a. Simulating tidal circulation and storm surge propagation over very large computational domains while simultaneously providing high resolution in areas of complex shoreline and bathymetry. The targeted areas of interest included continental shelves, near-shore areas, and estuaries.

b. Properly representing all pertinent physics of the three-dimensional equations of motion. These include tidal potential, Coriolis, and all nonlinear terms of the governing equations.

c. Providing accurate and efficient computations over time periods ranging from months to years.

The model includes depth-averaged shallow-water equations for conservation of mass and momentum, subject to incompressibility, Boussinesq, and hydrostatic pressure approximations. A standard quadratic parameterization for bottom stress is applied. Baroclinic, lateral diffusion, and dispersion effects are neglected. These assumptions form the following set of conservation equations in a spherical coordinate system, which are incorporated in the model (Flather 1988, Kolar *et al.* 1993):

$$\frac{\partial \zeta}{\partial t} + \frac{1}{R\cos\phi}\left[\frac{\partial UH}{\partial \lambda} + \frac{\partial (UV\cos\phi)}{\partial \phi}\right] = 0 \tag{1}$$

$$\frac{\partial U}{\partial t} + \frac{1}{r\cos\phi}U\frac{\partial U}{\partial \lambda} + \frac{1}{R}V\frac{\partial U}{\partial \phi} - \left[\frac{\tan\phi}{R}U + f\right]V =$$

$$-\frac{1}{R\cos\phi}\frac{\partial}{\partial \lambda}\left[\frac{p_s}{\rho_0} + g(\zeta - \eta)\right] + \frac{\tau_{s\lambda}}{\rho_0 H} - \tau_* U \tag{2}$$

$$\frac{\partial V}{\partial t} + \frac{1}{r\cos\phi}U\frac{\partial V}{\partial \lambda} + \frac{1}{R}V\frac{\partial V}{\partial \phi} - \left[\frac{\tan\phi}{R}U + f\right]U =$$

$$-\frac{1}{R}\frac{\partial}{\partial \phi}\left[\frac{p_s}{\rho_0} + g(\zeta - \eta)\right] + \frac{\tau_{s\lambda}}{\rho_0 H} - \tau_* V \tag{3}$$

TABLE D-1.--*Storm event data base for Chukchi Sea*

Storm number	Start date YYMMDDHH	Storm duration, hours	Storm number	Start date YYMMDDHH	Storm duration, hours
1	54100512	60	16	72101800	72
2	55072006	72	17	73080312	72
3	55072212	72	18	73101712	60
4	57071800	72	19	74100812	72
5	57091500	72	20	74102512	72
6	60092812	84	21	75082718	54
7	61061918	72	22	77101300	72
8	62090518	54	23	77102200	84
9	63082400	54	24	78101000	72
10	63100506	48	25	79100512	72
11	63100900	72	26	80100100	108
12	64102100	72	27	82092100	72
13	65090800	72	28	83100712	72
14	67092000	72	29	83101212	78
15	68092312	48	30	84100300	84

Each of the wind fields shown in table D-1 was provided in the form of: (1) wind direction from which the wind is blowing (degrees clockwise from North) and (2) windspeed in knots (nautical miles per hour). Data were provided at every 3 degrees longitude starting at 170° East (190° W.) and continuing to 245° East (115° W.) and every 1° latitude from 76° North to 64° North. All 30 events were simulated to generate a storm-specific surge data base for Kivalina.

2.2 Storm Surge Modeling

Storm surge computations were made by imposing the wind field conditions described above to the ADCIRC long-wave hydrodynamic model. The ADCIRC model was developed as a family of 2- and 3-dimensional finite element-based codes (Luettich *et al.* 1992, Westerink *et al.* 1992) with the capability of:

U.S. Geological Survey topographic maps, and survey data provided by the Alaska District.

The second phase of the study is the EST stochastic modeling, which generates multiple life-cycle simulations of storm event activity at user-selected locations. The EST accounts for an estimation of the possibility of storm surges which exceed historical levels but does not permit unrealistic hypothetical events to influence the frequency-of-occurrence relationship. Storm input to the EST are simulated surge conditions corresponding to historic events which occurred over the Chukchi Sea and impacted the Kivalina site. Post-processing of the simulations produces frequency relationships with error band estimates. Specifics of each task are described in the following section.

Before describing specifics of the present study, it should be noted that the effects of ice over the modeled area are not included in the hydrodynamic computations. For example, shelf ice impacts on storm surge suppression are not included as input to the ADCIRC model. Damage caused by the rafting of shorefast ice by surges will also not be included in the models. If impacts of ice cover are subsequently determined to be a significant factor in the success of the overall project, a followup study on the extent and influence of ice coverage can be conducted by the Coastal Hydraulics Laboratory in cooperation with the Cold Regions Research Environmental Laboratory (CRREL).

2. STORM SURGE MODELING

The surge component of the study requires the following two tasks: (1) identification of historic storm data, and (2) simulation of each event to generate a data base of historic surge information for the study area. These tasks are described in this section.

2.1 Storm Selection

The surge modeling component first requires the selection of a data base of historical events for which a corresponding storm surge is to be computed. Realism of the final computed frequency relationship is maintained by selecting only events that have actually impacted the study area. Therefore, only historically probable events are used in the frequency analysis so that the EST approach defines severe events which are specific to the study area.

This study was fortunate in that a data base of storm event wind fields impacting the study area had been generated previously by Oceanweather, Inc., under contract to Shell Development Corporation in 1987-1988. The study involved hindcasting (by Oceanweather, Inc.) of 30 historical storm events over the Chukchi Sea that occurred between 1954 and 1984, a 31-year time span. Table D-1 presents a tabulation of the storms' hindcast starting times and duration periods.

APPENDIX D
STORM SURGE RISK ANALYSIS

DEVELOPMENT OF WATER SURFACE ELEVATION FREQUENCY-OF-OCCURRENCE RELATIONSHIPS FOR KIVALINA, ALASKA

1. INTRODUCTION

The village of Kivalina, Alaska, is located on a narrow barrier island in the Chukchi Sea, about 130 km (81 miles) north of the Arctic Circle. The barrier is about 200 m (656 ft) wide and has a maximum elevation of just over 3 m (9.8 ft) above Mean Lower Low Water (MLLW). Astronomical (diurnal) tide range is less than 0.8 m, or 2.6 ft. The Chukchi Sea is to the west of the island and the Kivalina Lagoon is on the landward side to the east. The low-lying, unconsolidated gravel composing the island is subject to flooding from storm surge and erosion from wave attack. As a result of these risks to an increasing population, the Northwest Arctic Borough is considering the option of moving the village to a site on the mainland, possibly in the vicinity of the Wulik or Kivalina Rivers. Both of these rivers flow through low-lying permafrost tundra and drain into the Kivalina Lagoon. The surrounding area is also subject to the effects of storm surge from the Chukchi Sea and from run-off during the spring thaw or storms.

The purpose of the present investigation is to quantify the storm surge and wave risk at the present village site along the Chukchi Sea. The study will be conducted in a two-phase application of numerical models.

In the first phase, historical storm events will be simulated via the Advanced Circulation (ADCIRC) long-wave hydrodynamic model to compute storm surges at Kivalina for each of the historic events. The ADCIRC model is a finite element, two-dimensional, vertically integrated, time dependent model which has the capability to predict both water levels and currents on the gridded domain. The model was developed jointly by the Waterways Experiment Station, the University of North Carolina at Chapel Hill, and the University of Notre Dame. It has been extensively validated against storm surge and tidal data in studies along the east and gulf coasts of the United States and has been used to generate an extensive data base of storm surge responses for all significant east coast hurricanes (134 storms) beginning in 1889.

The first task in this phase of the study is the storm simulation, which requires development of a computational grid for the area of interest to include the Chukchi Sea, Kivalina Lagoon, and the low, threatened, shoreward area. Bathymetric and topographic data were obtained from navigational charts, standard digital data sets,

Figures (following the text)

Tables

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DEVELOPMENT OF WATER SURFACE ELEVATION FREQUENCY-OF-OCCURRENCE RELATIONSHIPS FOR KIVALINA, ALASKA

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APPENDIX D
STORM SURGE RISK ANALYSIS

DEVELOPMENT OF WATER SURFACE ELEVATION FREQUENCY-OF-OCCURRENCE RELATIONSHIPS FOR KIVALINA, ALASKA

SUMMARY

This report summarizes findings of a comprehensive storm surge frequency-of-occurrence study conducted for the U.S. Army Engineer District, Alaska, by the Coastal and Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. The goal of the study is to develop storm surge frequency relationships for the open coast region fronting the town of Kivalina, Alaska. Findings of this report are based on a one-dimensional application of the Empirical Simulation Technique (EST), a bootstrap-based statistical procedure for simulating multiple time sequences of non-deterministic systems such as storm events and their corresponding maximum water surface elevations. Because the approach is non-parametric and based on site-specific surge data, results are found to be more realistic than the parametrically based frequency approaches such as the Joint Probability Method. The following sections describe the project and the components of the study, and present results and overall conclusions.

DEVELOPMENT OF WATER SURFACE ELEVATION FREQUENCY-OF-OCCURRENCE RELATIONSHIPS FOR KIVALINA, ALASKA

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APPENDIX E

WULIK RIVER FLOOD RISK ANALYSIS

APPENDIX E
WULIK RIVER FLOOD RISK ANALYSIS

By Andrew Tuthill and Edward Chacho

1. INTRODUCTION

Flood stages were estimated along the lower Wulik River using the HEC-2 gradually varied flow model (U. S. Army 1990). River geometry data from a field survey taken August 8-9, 1997, were supplemented by flood plain elevations estimated from the 1-m contour interval aerial mapping. Based on the 12-year record from the gauge located on the Wulik River, 25 miles upstream of the study reach, the estimated 100-year discharge is 1,970 cubic meters per second (69,500 cubic feet per second). Depending on location, Wise *et al.* (1981) reported maximum storm surge elevations in the Chukchi Sea to be on the order of 3.4 m (11.2 ft). Much of the present Kivalina village site is at or below the 3.4-m level. The absence of serious flooding in recent memory suggests that the maximum storm surge water levels in the vicinity of Kivalina are somewhat less than at other locations along the coasts of the Chukchi Sea. Lacking more complete data when this work began, the analysis assumes a 3.4-m downstream (coastal) water surface elevation for the Wulik River HEC-2 backwater profiles. The coastal storm surge analysis (appendix D) later estimated the 100-year water surface elevation at 3.2 m. Therefore, the earlier 3.4-m estimate is slightly conservative, and no adjustment is necessary.

Storm surges which typically occur during ice-free conditions of late summer can coincide with heavy rainfall events that result in peak annual discharge on the Wulik River. Discharges in a range surrounding the estimated 100-year flow were then used as model inputs to develop stage discharge relationships at surveyed cross-section locations along the study reach. The model was initially calibrated to observed high water marks using estimated discharges from two recent floods.

Ice-affected stage was not considered in this analysis for a number of reasons. First, based on the Wulik River gauge record, the peak annual discharge does not occur during the ice season. Second, the presence of shorefast sea ice along the Alaskan coast of the Chukchi Sea significantly dampens the effect of wind set and storm surge water level rise (Wise *et al.* 1981). Finally, Kivalina residents reported that breakup on the lower Wulik and Kivalina Rivers is typically not a dynamic event: the ice either melts in place or moves as large broken sheets, without underturning to form thick jams.[1]

[1] Conversation with Caleb Wesley (8/7/97), who contrasted his observations of the mild breakups on the Wulik and Kivalina Rivers with the dynamic breakups he had witnessed on the Noatak River where he had lived previously.

2. FLOOD FREQUENCY

2.1 Historical Floods

The U.S. Geological Survey (USGS) has operated a discharge gauging station on the Wulik River below Tutak Creek (Station 15747000) from September 1984 to the present. The annual floods from the 13-year period of record are shown in table E-1. The flood of record occurred on August 17, 1994, with an instantaneous peak of 1,090 cubic meters per second (m^3/s). A large flood event also occurred on July 26, 1996, with an instantaneous peak of 878 m^3/s. Flood peaks in the intervening years were relatively low, such that the present high water evidence may be attributed to either of these recent large flood events, as discussed further below.

TABLE E-1.--*Annual flood peaks at Wulik River*

Year	Annual flood peaks at Wulik River below Tutak Creek (15747000) (m^3/s)	Estimated annual flood peaks at Wulik River near proposed townsite (m^3/s)
1985	442	562
1986	425	540
1987	264	336
1988	821	1,040
1989	889	1,130
1990	643	817
1991	391	497
1992	416	529
1993	521	663
1994	1,090	1,390
1995	365	465
1996	878	1,120
1997	371*	472

*Preliminary data through August 31, 1997.

The gauging station on the Wulik River is located approximately 35 km upstream of the proposed townsites. No precipitation data or other discharge data in the drainage is available to aid in transposing flood values from the gauging station to the proposed townsites. A uniform runoff method was used to perform the transposition. Flow data from the gauging station was transposed to the study site, assuming that the areal distribution of runoff between the proposed townsites and the gauging station was equal to the runoff distribution above the gauge station. The drainage area at the gauging station is 1,830 km^2, resulting in a runoff of 0.60 and 0.48 m^3/s per km^2 for the August 1994 and July 1996 flood events. The drainage area at the proposed townsites is 2,330 km^2. Using the runoff computed above results in flood peaks at the proposed townsites of 1,390 and 1,120 m^3/s for the August 1994 and July 1996 flood events. The estimated annual peaks at the proposed townsites for the period of record are included in table E-1.

2.2 Flood Frequency Analysis

Flood frequency analysis at the Wulik River was done using the HEC-FFA computer program (U.S. Army 1992). This program utilizes a log-Pearson Type III distribution in the computation of the frequency curve and follows techniques described in the revised "Guidelines for Determining Flood Flow Frequency," Bulletin 17B, Water Resources Council, September 1981. The 13-year record of annual peak floods (table E-1) was used in the computation of the frequency curve shown in figure E-1 and the exceedance values shown in table E-2. The 100-year (1-percent) flood is 1,550 m^3/s at the gauging station and 1,970 m^3/s at the proposed townsites.

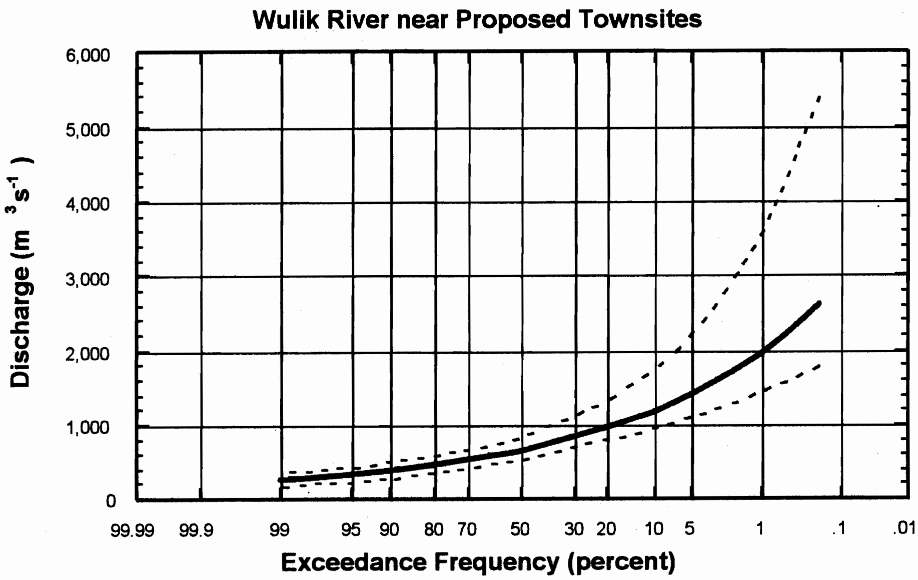

Figure E-1.--Estimated flood frequency for Wulik River near proposed townsites near Kivalina, Alaska, based on 13-year record, 1985-97. (Dashed lines are 0.05 and 0.95 confidence limits.)

TABLE E-2.--*Flood frequency analysis results*		
Percent chance exceedance	**Computed frequency curve at Wulik River below Tutak Creek (15747000) (m^3/s)**	**Estimated frequency curve at Wulik River near proposed townsite (m^3/s)**
0.2	2,050	2,610
0.5	1,760	2,230
1.0	1,550	1,970
2.0	1,350	1,720
5.0	1,110	1,410
10.0	932	1,180
20.0	759	965
50.0	521	664
80.0	365	466
90.0	306	390
95.0	266	338
99.0	206	262

3. NUMERICAL SIMULATION OF FLOODS

3.1 HEC-2 Model Setup

Ten river cross sections along a main channel length of 3.6 km were surveyed by Terra Surveys on August 8-9, 1997, using a real-time kinematic differential GPS system. The surveyed cross sections were extended using topographic data from the 1-m contour interval maps to achieve total cross-section widths of about 2,500 m. Figure E-2 shows cross-section locations. Cross-section numbers indicate the main channel distance upstream of the lowest cross section (0.01). Dashed lines indicate where cross section geometry was estimated from the maps rather than from field survey data. Table E-3 includes 10 high water elevations that were also surveyed during August 8-9, 1997.

The two downstream-most cross sections (0.01 and 425) were estimated from the topographic maps in order to extend the channel length of HEC-2 input file to the vicinity of the normal tide level of the lagoon. The cross-section plots (not included here) show the left-hand bank end points raised to 6 m MSL. (Note that 100 m was added to all field-surveyed elevations to avoid negative values in the HEC-2 model.) In reality, the unmapped portion of the flood plain extends beyond the left end point for some distance at an approximate elevation of 3 m. The HEC-2 model requires that the edges of the cross section be higher than the calculated water surface elevation (WSE), however. The raised end points reduce the flow area slightly, resulting in a conservative estimate of water surface elevation.

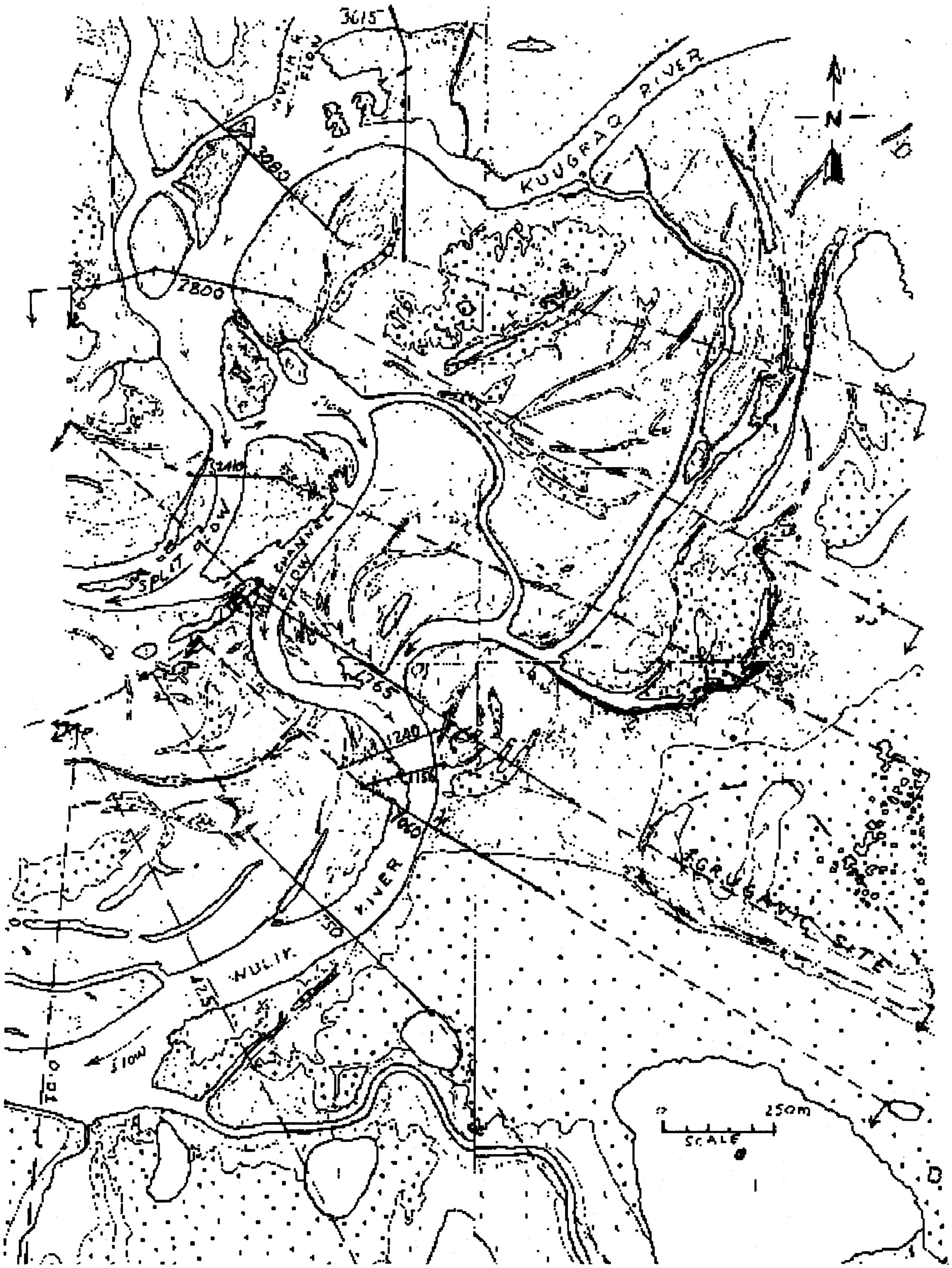

Figure E-2.—Map of Wulik River study reach. Solid lines indicate surveyed cross-section geometry; dashed lines indicate locations where geometry was estimated from 1-m contour interval maps.

TABLE E-3.--*HEC-2 calibration to High Water Marks*				
Cross section number	**Surveyed High Water Elevations (m MSL)**	**Channel Manning's n**	**HEC-2 calculated Water Surface Elevation (m MSL)**	
			Aug. 1994 1120 m^3/s	**July 1996 1390 m^3/s**
0.01		0.020	0.50	0.50
425.00		0.020	0.75	0.88
750.00		0.020	0.80	0.95
1060.00		0.020	1.33	1.59
1156.00	1.65	0.020	1.53	1.76
1240.00	1.92 1.80 1.52 1.80	0.020	1.75	2.00
1765.00		0.035	1.99	2.25
2410.00		0.035	2.04	2.29
2800.00	1.91	0.035	2.15	2.41
3080.00	2.35 2.39	0.035	2.44	2.72
3615.00	1.88 3.04	0.035	2.71	3.01

A major channel splits off to the right between cross sections 1765 and 2410. According to the 1:63,360-scale USGS topographic map, the distance to the Kivalina Lagoon by this channel is roughly equivalent to the distance by the main channel. The HEC-2 flow split option was used to divert flow out of the main channel at this point. The portion of the flow diverted is calculated by HEC-2 using the Manning equation, with cross-sectional geometry, bed roughness and water surface slope as inputs. It was assumed that during a flood situation, the average water surface slope in the channel that branches to the right would be roughly equivalent to the water surface slope in the main channel. Depending on total river discharge and lagoon WSE, between 20 and 40 percent of the total flow followed the right-hand branch in the model simulations.

3.2 Calibration to Recent Flood Events

The HEC-2 model was calibrated to the August 1994 flood of record, and the more recent July 1996 flood. Estimated discharges for these events, transposed from the gauge to the study reach, were 1,390 and 1,120 m^3/s respectively. Because the larger flood occurred first, high water debris would be expected to remain from both events. The model was calibrated to the flood of record (1,390 m^3/s) by adjustment of the channel Manning's "n" friction factor to match the highest of the surveyed high water marks (figure E-3 and table E-3). A Manning's "n" value of 0.05 was used for the overbank areas. The profile of the July 1996 flood also appears in figure E-3, roughly following the middle range high water marks. Due to lack of sea level information, the lagoon WSE was assumed to be 0.5 m for these calibration cases.

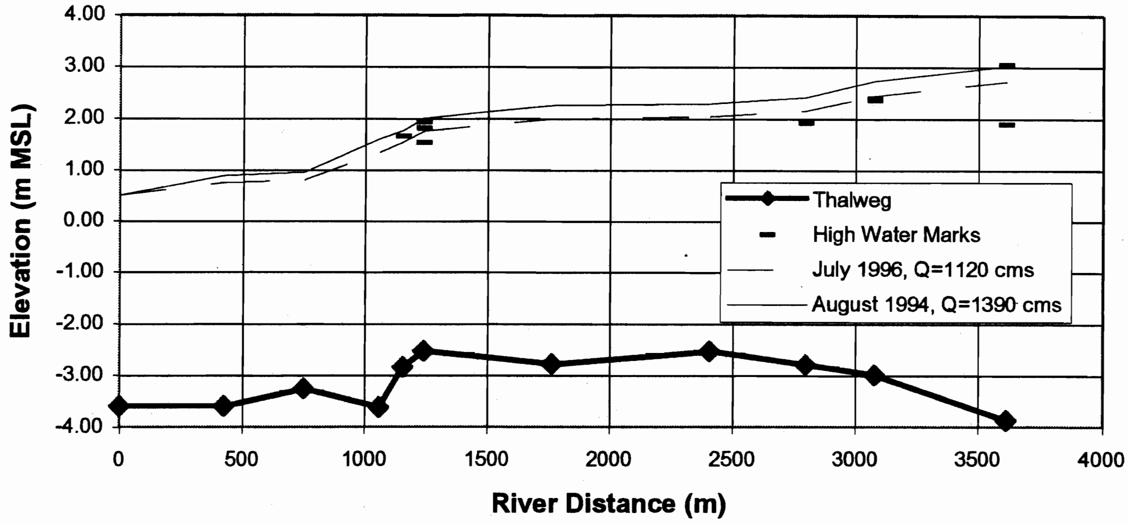

Figure E-3.--Calibration of HEC-2 model to recent flood events.

3.3 HEC-2 Water Surface Profiles and Stage Discharge Relationships

Using a range of discharges surrounding the estimated 100-year flow of 1970 m^3/s, water surface profiles were calculated using the HEC-2 gradually varied flow model. Two starting lagoon water levels were considered. The first lagoon water level of 0.5 m represented the non-storm surge case (figure E-4), and the second at 3.4 m represented the maximum storm surge case (figure E-5). The storm surge case produced the highest stages, particularly in the vicinity of the proposed Igrugaivik village site. Note that in the maximum storm surge case, the downstream water surface elevation is the predominant factor affecting water surface elevation at the village sites, and the river discharge is relatively less important. This finding is expected for such a wide flood plain area.

Stage-discharge relationships at all river cross-section locations appear in table E-4. Figure E-6 shows the stage-discharge relationship at cross section 1156, adjacent to the proposed Igrugaivik village site. Here the calculated 100-year flood level is 3.54 m. Figure E-7 shows the calculated rating curve for cross section 3080 in the vicinity of the Kuuguraq site, with a 100-year flood level of 3.75 m. For the maximum storm surge case, the rating curves are relatively flat, indicating that a large increase in river discharge will result in only a small additional rise in stage.

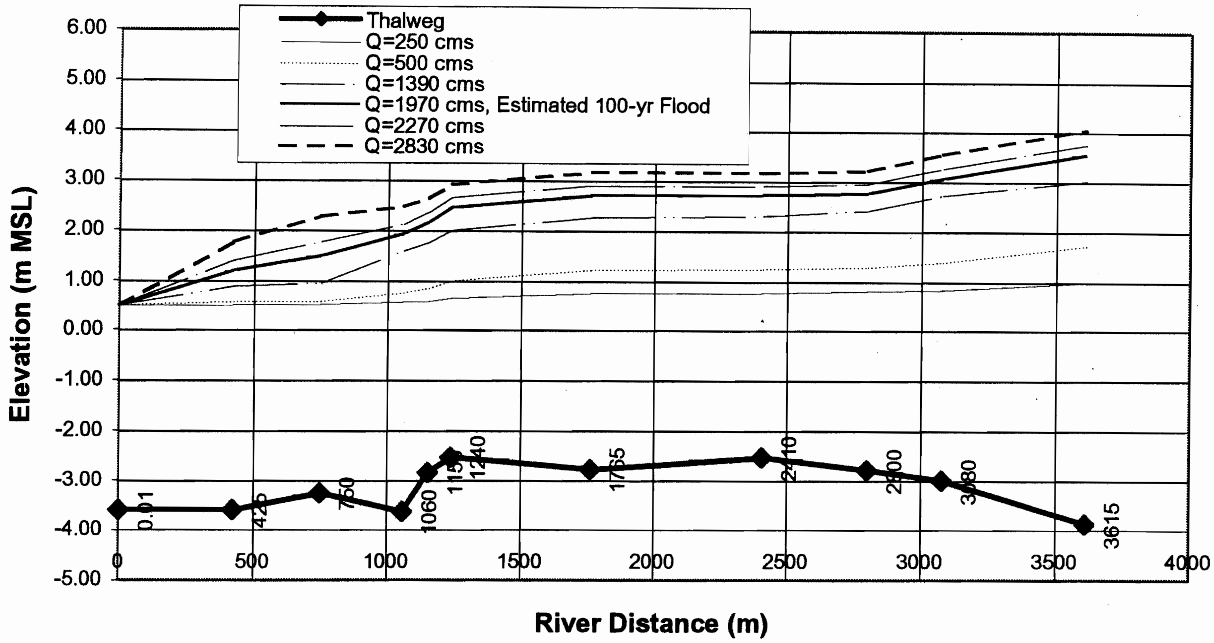

Figure E-4.--Wulik River water surface profiles for non-storm surge case.

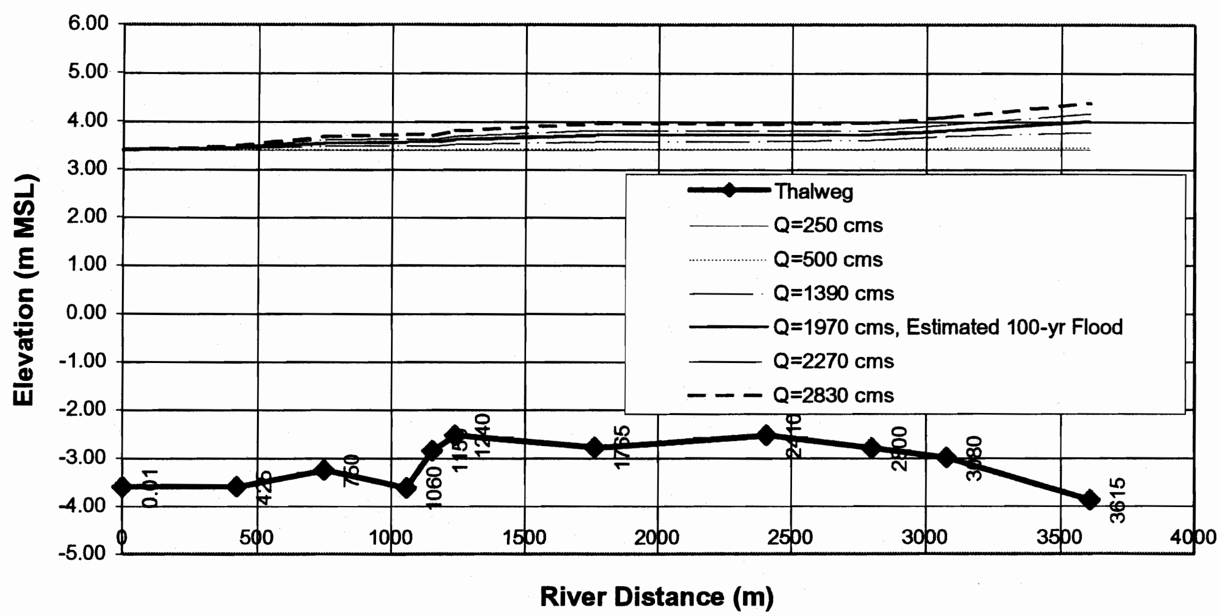

Figure E-5.--Wulik River water surface profiles for maximum storm surge case.

TABLE E-4.--*HEC-2 estimated Water Surface Elevations for Wulik River discharges*

Non-storm surge case: sea level at 0.5 m

Cross section	Discharges in cubic meters per second					
river distance (m)	**250**	**500**	**1,390**	**1,970**	**2,270**	**2,830**
0.01	0.50	0.50	0.50	0.50	0.50	0.51
425	0.52	0.57	0.88	1.20	1.40	1.77
750	0.53	0.59	0.95	1.50	1.77	2.28
1060	0.58	0.75	1.59	1.94	2.11	2.48
1156	0.60	0.84	1.76	2.17	2.36	2.64
1240	0.66	0.99	2.00	2.46	2.65	2.92
1765	0.76	1.21	2.25	2.71	2.90	3.17
2410	0.78	1.24	2.29	2.72	2.90	3.17
2800	0.81	1.28	2.41	2.77	2.95	3.22
3080	0.84	1.38	2.72	3.07	3.26	3.56
3615	0.99	1.71	3.01	3.56	3.75	4.06

Storm surge case: sea level at 3.4 m

Cross section	Discharges in cubic meters per second					
river distance (m)	**250**	**500**	**1,390**	**1,970**	**2,270**	**2,830**
0.01	3.40	3.40	3.40	3.40	3.40	3.40
425	3.40	3.40	3.43	3.45	3.47	3.50
750	3.40	3.41	3.48	3.55	3.61	3.69
1060	3.40	3.41	3.49	3.58	3.64	3.74
1156	3.40	3.41	3.48	3.57	3.63	3.71
1240	3.40	3.42	3.52	3.63	3.70	3.81
1765	3.41	3.43	3.58	3.72	3.81	3.96
2410	3.41	3.43	3.59	3.72	3.81	3.95
2800	3.41	3.43	3.61	3.73	3.82	3.97
3080	3.41	3.44	3.69	3.81	3.93	4.10
3615	3.41	3.46	3.78	4.02	4.16	4.39

Note: 1970 m^3/s is the estimated 100-year discharge.

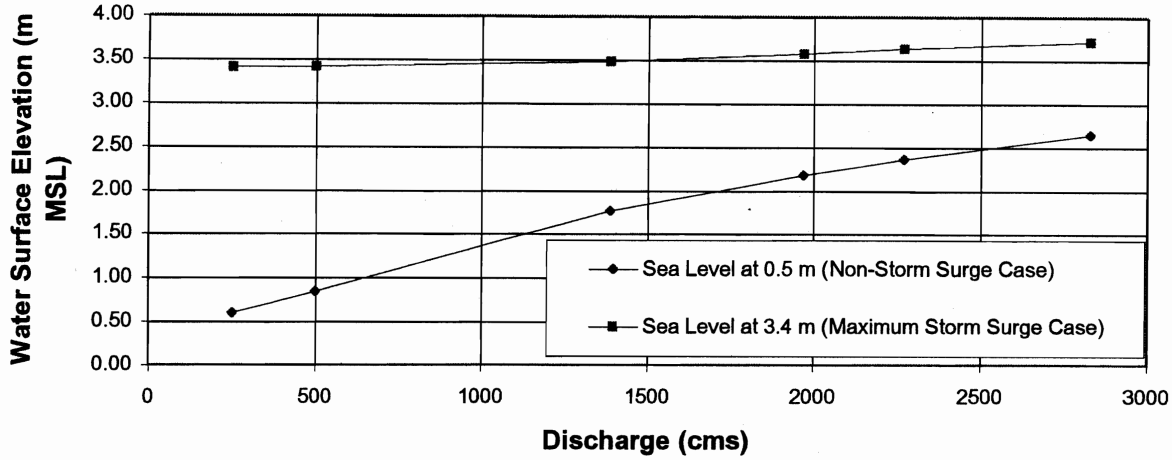

Figure E-6.--Stage-discharge relationship at cross section 1156, in the vicinity of the proposed Igrugaivik village site. The estimated 100-year flow is 1970 cubic meters per second.

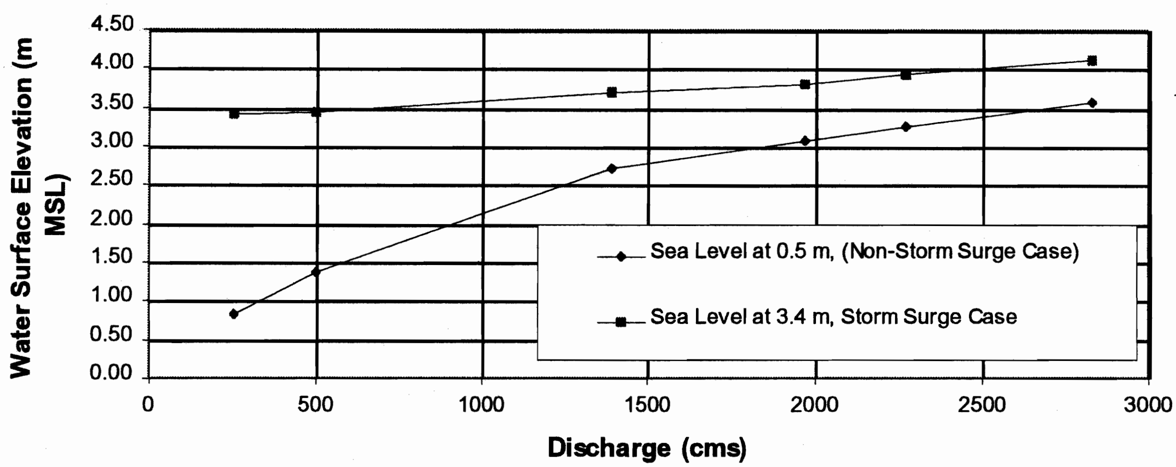

Figure E-7.--Stage-discharge relationship at cross section 3080, in the vicinity of the proposed Kuuguraq village site. The estimated 100-year flow is 1970 cubic meters per second.

4. SUMMARY

This analysis used the HEC-2 model to calculate 100-year flood water surface elevations adjacent to the proposed village sites on the lower Wulik River. A worst-case scenario was simulated, based on the coincidence in time of open-water season floods with an estimated peak storm surge water surface elevation in the Kivalina Lagoon of 3.4 m. In these simulations, the water surface elevation in the lagoon had a much greater effect on stage than river discharge. The 100-year water surface elevations on the Wulik River adjacent to the proposed village sites were found to be at or below 4 m MSL. HEC-2 backwater profiles were calculated using a range of flows surrounding an estimated 100-year discharge of 1970 m^3/s. Due to the vast storage area provided by the wide flood plains on the lower Wulik River, significant increases in river discharge in excess of the 100-year flow produced only minor additional increases in stage.

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APPENDIX F

ROAD TO WULIK RIVER RELOCATION SITE

APPENDIX F
ROAD TO WULIK RIVER RELOCATION SITE

By Stephen Walls, P.E.
Corps of Engineers, Alaska District, Civil/Sanitary Section

1. INTRODUCTION

Field investigations at Kivalina in August 1997 revealed an opportunity to connect the existing village by road to the proposed relocation site at Igrugaivik on the south bank of the lower Wulik River. The road would provide access by wheeled vehicles to a suitable landing for ocean barges and for commuting between the old and the new village site. No bridge is proposed across Singauk Entrance, the tidal inlet by the existing village, because of the high risk and expense of building and maintaining a rigid structure at this dynamic coastal site. The inlet is easily crossed by boat during summer and by snow machines and other vehicles in winter. Crossing the inlet would be difficult during only a few weeks each year. A road from the spit at Singauk Entrance to Igrugaivik would allow a gradual relocation of Kivalina. The school, other public buildings and facilities, and residences at the existing site could remain in use for a period of years, as new community infrastructure grows at Igrugaivik. This appendix describes the engineering considerations for constructing a road over the natural terrain between Singauk Entrance and Igrugaivik.

Similar considerations were applied for preliminary design of a road from the proposed relocation site on the north bank of the Kivalina River to the Chukchi Sea coast. Detailed maps and geotechnical information were not available for that 13.4-km route, so assumptions applied for the Kivalina River road design are more conservative.

2. MATERIALS

The roadbed must be constructed of materials that can be tightly compacted while retaining drainability. A well-graded sandy gravel, free of fine particles so that capillary rise of water will not occur (5 percent or less passing the #200 sieve) has proven to be an effective non-frost-susceptible material for road sub-bases in an arctic environment. The road structure must be able to support the traffic loads, transferring minimal forces to the subgrade materials, which are typically frost-susceptible and within the active layer. It is also standard practice to place a filter fabric on the sub-grade before placing the roadbed material, to prevent fine particles from migrating up into the sub-base.

3. ARCTIC CONSIDERATIONS

Disturbance of the original ground that is frost-susceptible should also be minimized. Vertical alignment of the road should be established so that the subgrade preparation requires fill rather than cut whenever possible. Another benefit of building the road on top of the existing ground is self-clearing from drifting snow. Portions of the road set below surrounding ground would become filled with drifting snow and require regular maintenance.

From the Igrugaivik site, the route to Kivalina is fairly flat. Therefore, filling up to the bottom of sub-base design elevation results in a fairly uniform total section (classified and unclassified material), with a minimum of cut. Unclassified fill is used to build the subgrade up to the required elevation and for constructing the side slopes. Classified fill is required for the road section, with dimensions as shown in figure F-1.

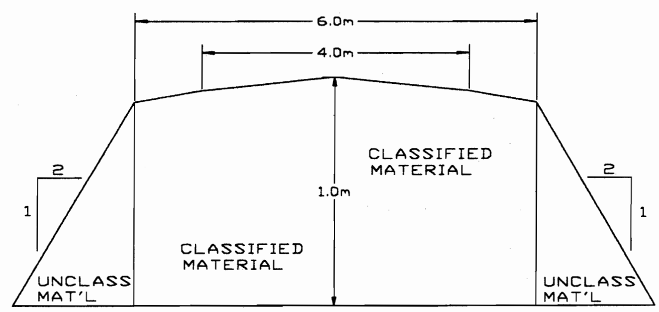


FIGURE F-1.—Proposed cross section of road from Singauk Entrance to Igrugaivik.

The selection in this analysis of a 1-meter depth of material is based on the "rule of thumb" of 3 to 5 feet depth for arctic conditions. The final constructed depth of roadbed should be determined through thermal analysis, which requires accurate local climatic data and subsurface investigation.

Three performance options were considered, which concern the degree of road maintenance required.

> **Option 1:** Provide a depth of roadbed that supports traffic loads, but ignores thermal considerations. This can lead to frost heave, as moisture in the frost-susceptible subgrade materials expands due to freezing. Also, if native vegetation is stripped away and replaced with a road, the active layer will extend deeper into the subgrade, thawing soil to a depth that does not freeze back in the winter. A thaw bulb begins to expand beneath the road, with result of subgrade failure.

Option 2: Provide a depth of roadbed and/or insulation that allows the subgrade materials beneath the road to thaw during the summer, but keeps the active layer at its pre-road depth. Heaving and cracking can result, increasing road maintenance, but the permafrost is not disturbed.

Option 3: Provide a depth of roadbed and/or insulation that prevents the active layer from penetrating to subgrade. By keeping the freeze and thaw within the road fill, the road is unaffected by frost heaving. The permafrost is not disturbed, and may even extend upward due to the additional insulation.

For the situation at Kivalina, option 2 appears the most practical. Analysis based on very general climatic data and other unverified assumptions predicts an active layer up to 1 meter (3.5 feet) thick. The portion of the proposed road alignment where the active layer is thickest lies between stations 2+200 and 4+500 (2.2 to 4.5 km from the roadhead at Singauk Entrance). Between these stations a road section consisting of 1.5 meters of classified material is recommended. This portion of the road also requires insulation. With a width of insulation of 6 meters, total area of insulation is 13,800 square meters of 2-inch extruded polystyrene (blue board). Also, the entire length of road should have a geotechnical filter fabric placed between the existing subgrade and the fill material.

4. CONSTRUCTION MATERIAL QUANTITY ESTIMATE

A relatively narrow road section could be used to minimize the total material needed to construct the road. A 4-meter-wide road would be constructed with 1-meter shoulders on each side and with minimum-width side slopes of 2H:1V (see figure F-1). This geometry is adequate for two-way traffic of four-wheelers and snowmobiles and for full-sized automobiles to pass at slow speeds. Construction material quantities for this design, placed along the proposed 5.3-km (3.3-mile) alignment from Singauk Entrance to Igrugaivik, are estimated below.

Total Cut	1,885 m^3
Total Unclassified Fill	19,312 m^3
Total Classified Fill	38,940 m^3

Total area of extruded polystyrene insulation: 13,800 m^2

Total area of geofabric: 32,000 m^2

APPENDIX G

WATER SUPPLY AT RELOCATION SITES

APPENDIX G
WATER SUPPLY AT RELOCATION SITES

By Steven M. Geppert, P.E.
Corps of Engineers, Alaska District, Civil/Sanitary Section

1. OVERVIEW

Water supply in cold climates requires special considerations. Hydrologic conditions in the northern latitudes differ from those in the continental United States. Precipitation is light, with a majority of the runoff concentrated during the spring breakup. The land near Kivalina is covered with small lakes, ponds, rivers, and creeks, but they are covered with thick layers of ice that last for most of the year. Hydrologic and geotechnical data for this area is limited, which makes it difficult to predict reliable quantities of available water for water supply.

Permafrost inland of Kivalina is estimated to be about 600 feet deep. Although permafrost generally exists within a few feet of the ground surface, thaw bulbs typically develop under larger lakes and rivers. The horizontal and vertical extent of thaw bulbs associated with rivers depends primarily on the size of the river and the history of the river's migration across the floodplain. Golder Associates conducted a geophysical ground water source investigation to determine the best sites for drilling wells along the Wulik and Kivalina Rivers to use the rivers' thaw bulbs as a source of water. (See Appendix B.) Test well sites for the Igrugaivik location are shown in figure G-1.

2. WATER SOURCES

Alternative water sources also include existing surface ponds, rivers, or the ocean. Surface sources are seasonal and require storage during the nonproductive months. Ocean sources require desalination, which is costly. At the Imnakuk and Igrugaivik sites, wells are the recommended solution. A well at the existing Kivalina site does not appear practical, since an earlier attempt encountered salt-water contamination.

Wells are typically the most expensive of basic water sources, and production rates can vary. In permafrost areas, wells are impractical unless areas free of permafrost can be located. When the conditions are favorable, a well can provide a year-round water supply that is convenient to the treatment, storage, and distribution systems. The well must be located a safe distance from potential sources of pollution. State of Alaska Drinking Water Regulations specify minimum requirements for water wells.

A well at either relocation site must be located in a well house to protect it from freezing. Water treatment and storage facilities should be located as close as possible to the well to limit the length of water supply lines that are prone to freezing. A seal is

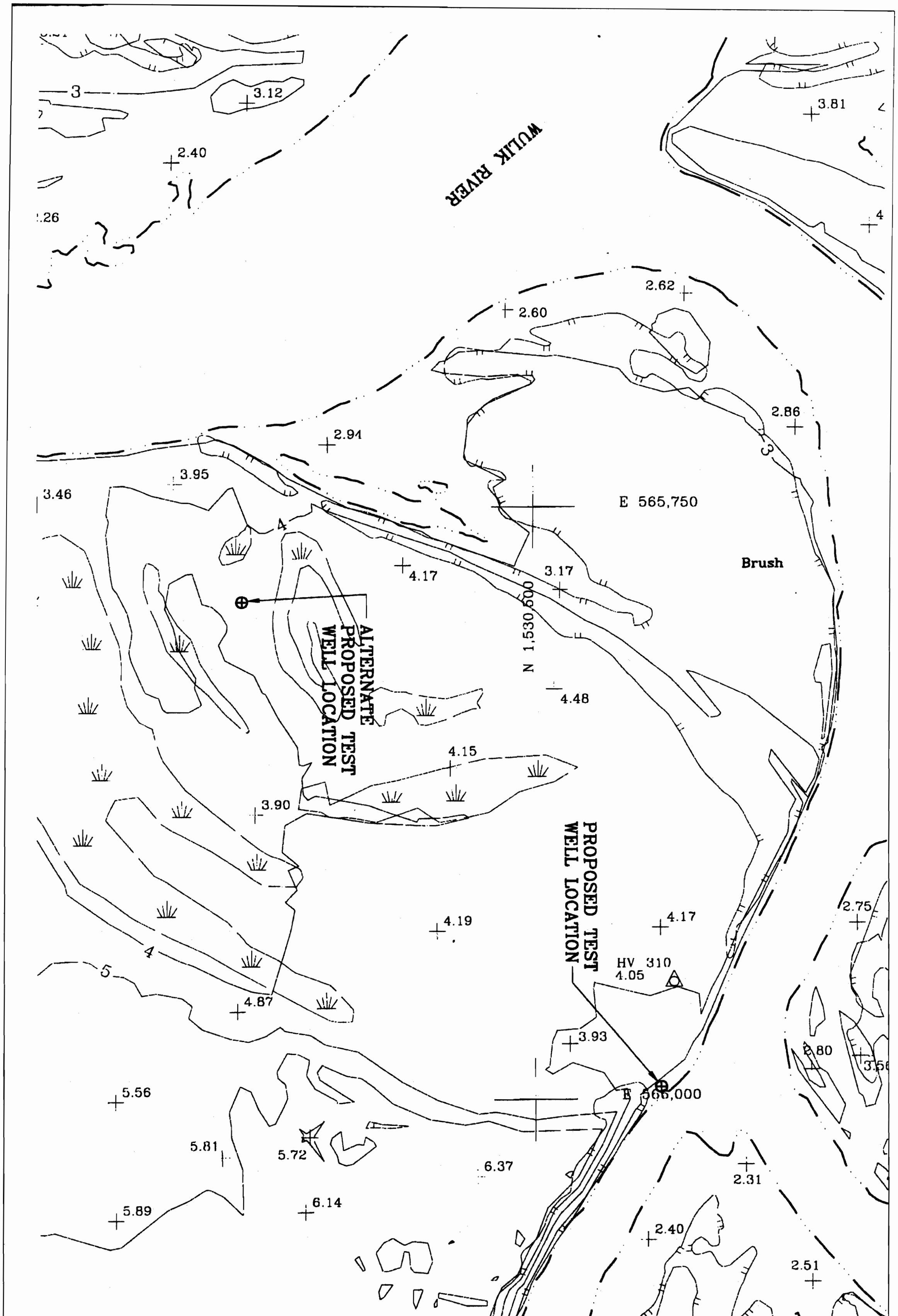


FIGURE G-1.--Test well locations for the Igrugaivik relocation site.

required around the casing to minimize the possibility of contamination by intrusion of surface water. The well must be kept open by pumping continuously at low flows and with backup electrical heat tracing.

3. WATER REQUIREMENTS

The consumption of water at Kotzebue, which has a circulating distribution system, is about 66 gallons per person per day. Assuming Kivalina's population grows to 600 persons, the required flow would be 40,000 gallons per day, with a storage requirement for a 2-week period of 555,000 gallons. Relocation of the existing 692,000-gallon storage tank to the new site would satisfy this requirement. The second older tank and the present treatment system could continue to serve residents at the existing site during the period of transition.

Fire departments on standby are costly and generally not feasible in remote communities. Unless a fire is controlled within minutes after it has started, usually little can be done to save a burning building. Therefore, the design of new buildings must emphasize fire-resistant construction, early fire detection, and rapid response, preferably by automatic means. Although not required by code for residences, sprinkler systems connected to the water storage tank or a small pressure system would be the safest arrangement. It is often difficult to meet strict design code requirements for pressure and flow for sprinklers, but even minimum sprinkler systems can save a building. The proposed relocated storage tank is sufficient in volume to handle fire protection, if adequate pressure is provided to meet the needs of extinguishing a fire.

4. WATER TREATMENT

The exact level of treatment required to meet the State of Alaska Drinking Water Regulations will not be known until the water quality of the supply is known. The water is assumed to require removal of iron and manganese, filtration, fluoridation, and disinfection. These processes are briefly described here.

4.1 Removal of Iron and Manganese

Dissolved iron and manganese are encountered principally in ground water with low dissolved oxygen, but may also be found in stagnant waters of thermally stratified lakes. Dissolved iron in excess of 1 or 2 mg/L will cause an unpleasant taste, and concentrations greater than 0.3 mg/L will cause red stains on plumbing fixtures and laundry. Similarly, manganese will cause black stains if present in concentrations greater than 0.05 mg/L. When the iron is in the ferrous state and the concentration is no more than 3mg/L, the most convenient treatment method is to add a polyphosphate, such as sodium hexamethaphosphate. This prevents iron precipitation without removing the iron. Polyphosphate doses of 1 mg/L to 5 mg/L per mg/L of iron present are typical.

Small amounts of ferrous iron may be removed by ion exchange-type water softeners. If the iron is in the ferric state, severe fouling of the exchange media will occur. Manufacturers' recommendations should be followed.

The most popular method of iron removal involves oxidation of the iron by treatment with potassium permanganate followed by filtration. The filter consists of natural green sand zeolite coated with oxides of manganese.

4.2 Filtration

Because the well would be located close to the surface of the river, surface water treatment requirements are assumed, which include filtration.

4.3 Fluoridation

Fluoridation of water supplies to an optimum concentration of about 1.2 to 1.4 mg/L in northern communities is considered to be an effective practice to improve dental health.

4.4 Disinfection

Disinfection involves the removal, destruction, or inactivation of pathogenic organisms. Methods of disinfection include the application of heat, radiation, heavy metals, or oxidizing chemicals. The application of chlorine to water is the preferred method of disinfection for water supplies. The chlorine dosage is regulated to maintain a free chlorine residual of 0.2 mg/L in all parts of the distribution system.

Chlorine is available in several forms, including chlorine gas, calcium hypochlorite, and sodium hypochlorite. Chlorine gas, used at larger water treatment plants, is extremely hazardous and often unsuitable for small water systems. Calcium hypochlorite is a dry powder or granular material that has a long shelf life. The disadvantage is that it contains a significant insoluble portion that must be settled out before disinfection or it will clog the chlorination equipment. This requires significant operator time. Sodium hypochlorite is probably the best form of chlorine for small systems. It is available as a clear liquid containing between 12 and 17 percent available chlorine. Its disadvantage is that it has a half-life of approximately 90 days. The hypochlorite solution is injected into the system with a positive displacement pump called a hypochlorinator.

5. RECOMMENDED WATER DISTRIBUTION SYSTEM

A well with a pumping rate of 30 gallons per minute can supply enough water to the storage tank. The well should be located in a new well house and protected from freezing. An 8-inch well casing to a depth of approximately 15.2 m (50 feet) is recommended, based on the findings of Golder Associates (1997). A vertical turbine pump is recommended, with a backup pump on hand.

The domestic water distribution should be through an aboveground forced circulation system. Constant pressure pumps maintaining about 50 pounds per square inch should be used to pressurize the domestic water system. The arctic pipe should be insulated with high-density polyethylene (HDPE) carrier pipe and a corrugated aluminum outer jacket with a continuous glycol heat trace. The insulation between pipes should be low-density closed-cell rigid urethane. Any fire protection requirements should come from the domestic water distribution system. A typical pump pressure system is shown in figure G-2.

6. RECOMMENDED TREATMENT

Treatment should consist of pressurized green sand filtration for iron and manganese removal, and chlorination for disinfection. All water treatment equipment should be housed in a heated building intended for this purpose, located beside the storage tank. Converting the soluble (dissolved) element to an insoluble form will reduce iron and manganese concentrations by oxidation, followed by filtration to remove the resulting precipitate. Zeolite ("green sand") activated with manganese chloride should be used as the filter material, due to its catalytic effect in this reaction. The filter bed should be continuously regenerated with potassium permanganate to maintain the process. A filter bed of anthracite coal should be used ahead of the green sand to remove particulates.

Raw well water should be treated with potassium permanganate as an oxidation agent, followed by a static mixer, just prior to the green sand filter. The water should be chlorinated prior to its discharge into the storage tank. The chlorination should meet Alaska Department of Environmental Conservation requirements. Specifications follow. Schematics are shown in figures G-3, G-4, and G-5.

7. SPECIFICATIONS

Specifications for Water Supply Equipment
at the Wulik and Kivalina River Relocation Sites:

8" well casing to a depth of 50 feet
4" water line inside casing
2 – vertical turbine pumps, 30 gpm and 70 foot each
Heated 10' × 10' well house
Elevate and protect well house from flooding
Heat trace for well casing

20' × 20' pump house
Filtration tank
50-gal potassium permanganate solution tank
2 – 0.32 gpm injector pumps for potassium permanganate
100-gal chlorine solution tank
2 – 0.48 gpm injector pumps for chlorine

50-gal contact tank
Static tank
Green sand filter tank (*e.g.,* Culligan HG-36, 36”×60”)
Fluoridation unit

Relocated water storage tank (750,000 gal)
2 - 75 gpm peak constant pressure pumps, 50 pounds per square inch
Flow valve from domestic line to tank

Preinsulated pipe above ground from well house to pump house:

- 4” carrier pipe with 6” of insulation
- 16” corrugated aluminum outer pipe
- Glycol heat trace system

Preinsulated pipe above ground from tank to housing:

- 6” carrier pipe with 6” of insulation
- 18” corrugated aluminum outer pipe
- Glycol heat trace system

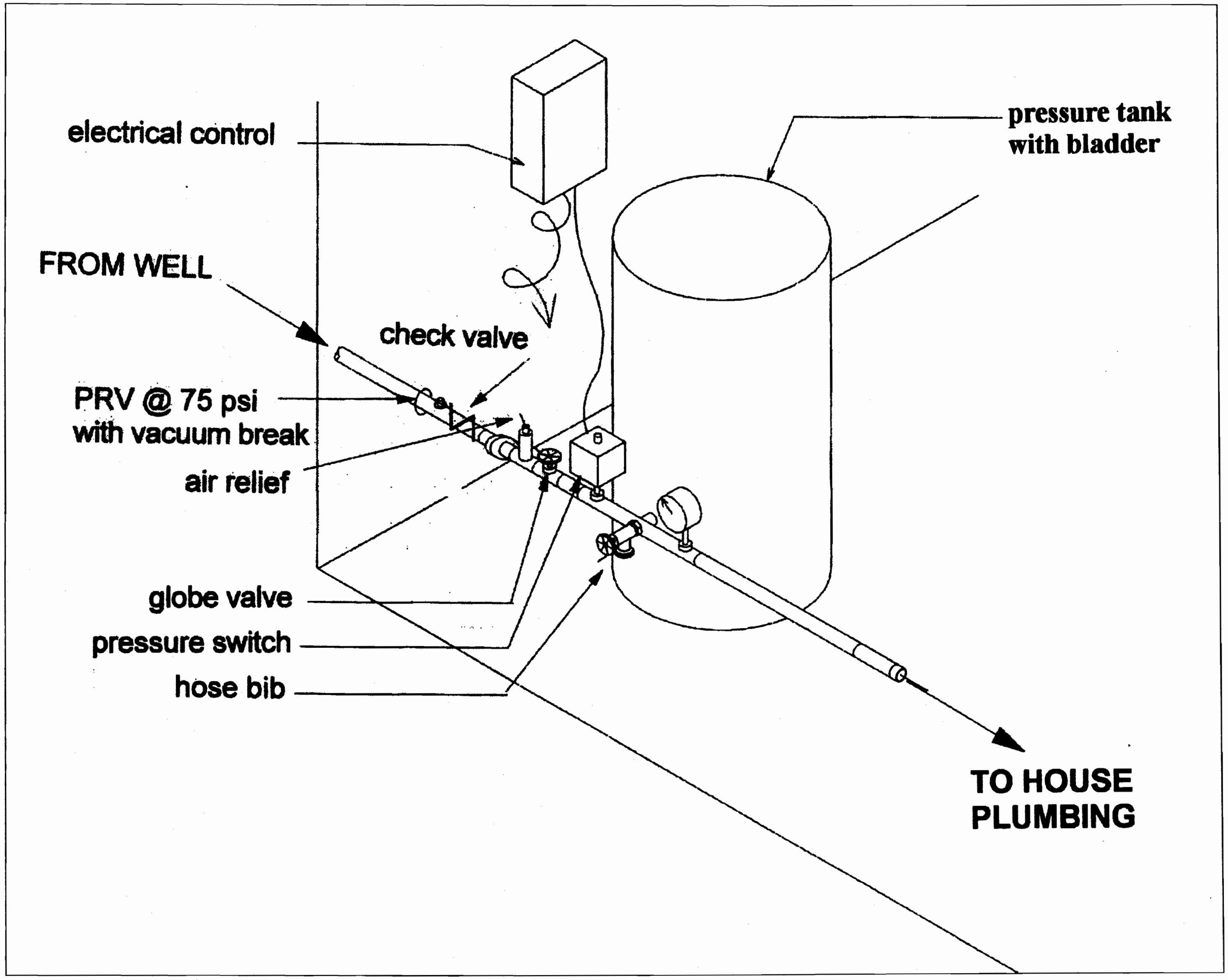
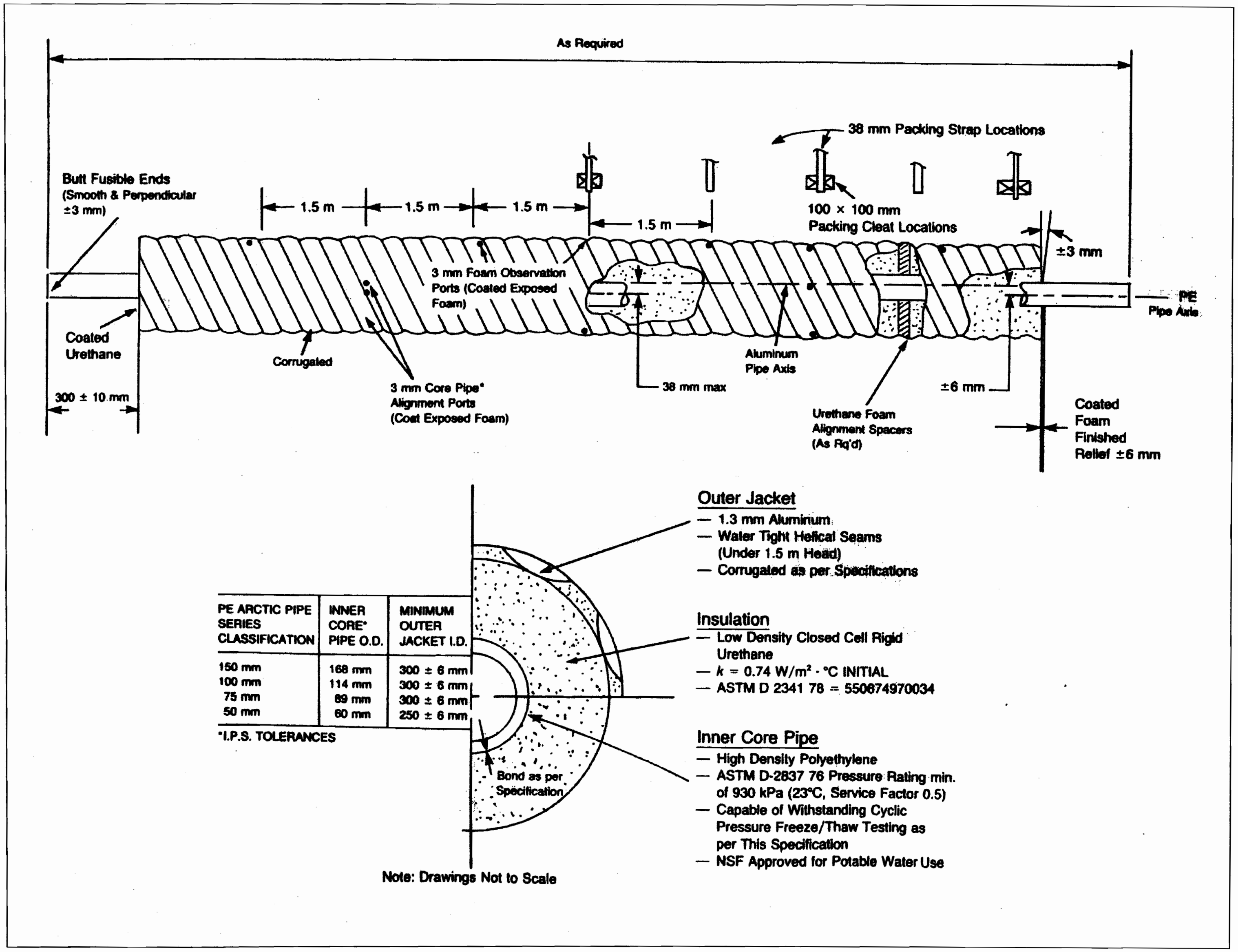


FIGURE G-2.—*Typical pump pressure system with well line drainback.*



PE ARCTIC PIPE SERIES CLASSIFICATION	INNER CORE* PIPE O.D.	MINIMUM OUTER JACKET I.D.
150 mm	168 mm	300 ± 6 mm
100 mm	114 mm	300 ± 6 mm
75 mm	89 mm	300 ± 6 mm
50 mm	60 mm	250 ± 6 mm

*I.P.S. TOLERANCES

FIGURE G-3.—Arctic pipe specifications for Kivalina water system.

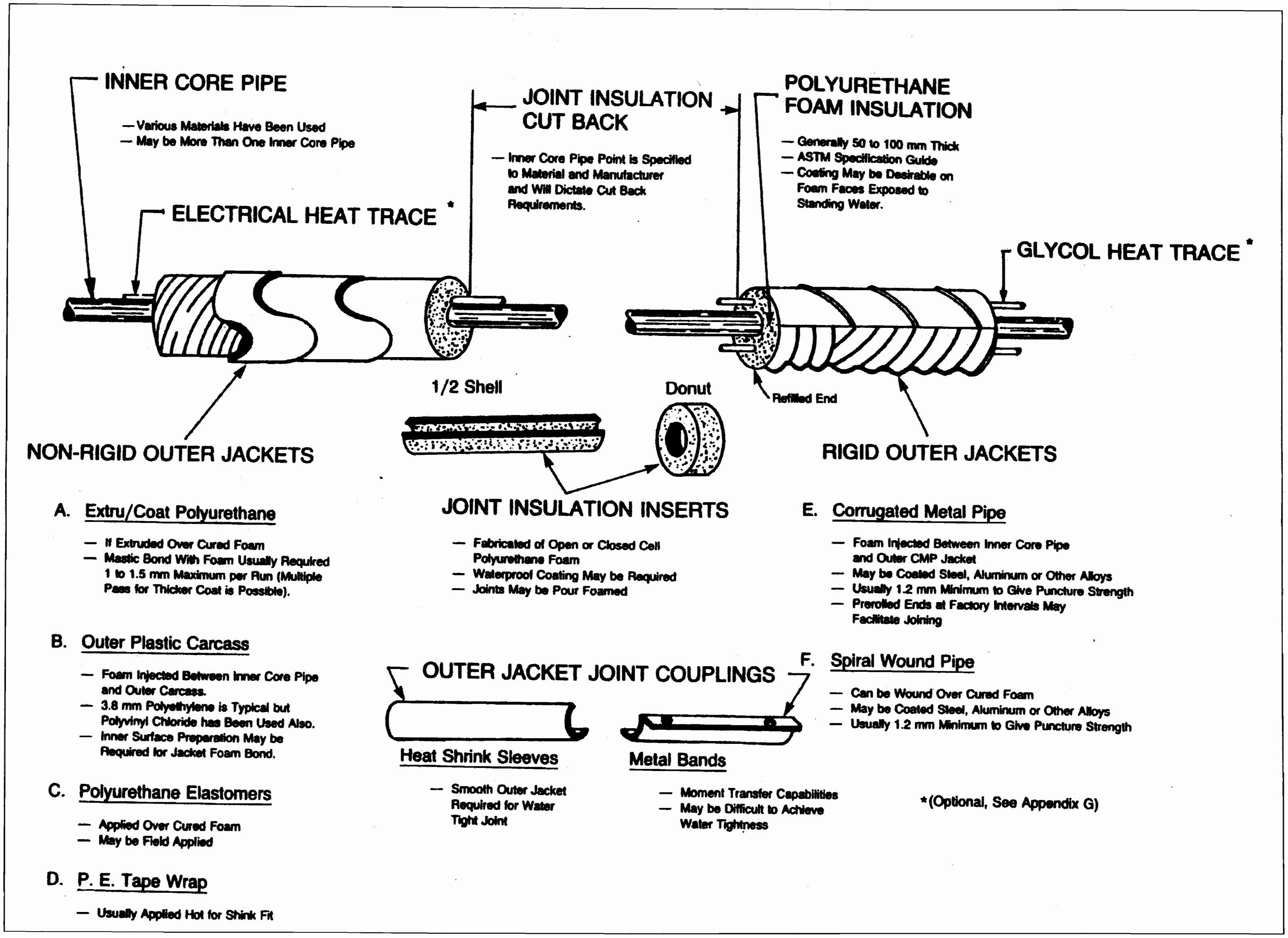


FIGURE G-4.—Preinsulated pipe: a common system configuration.

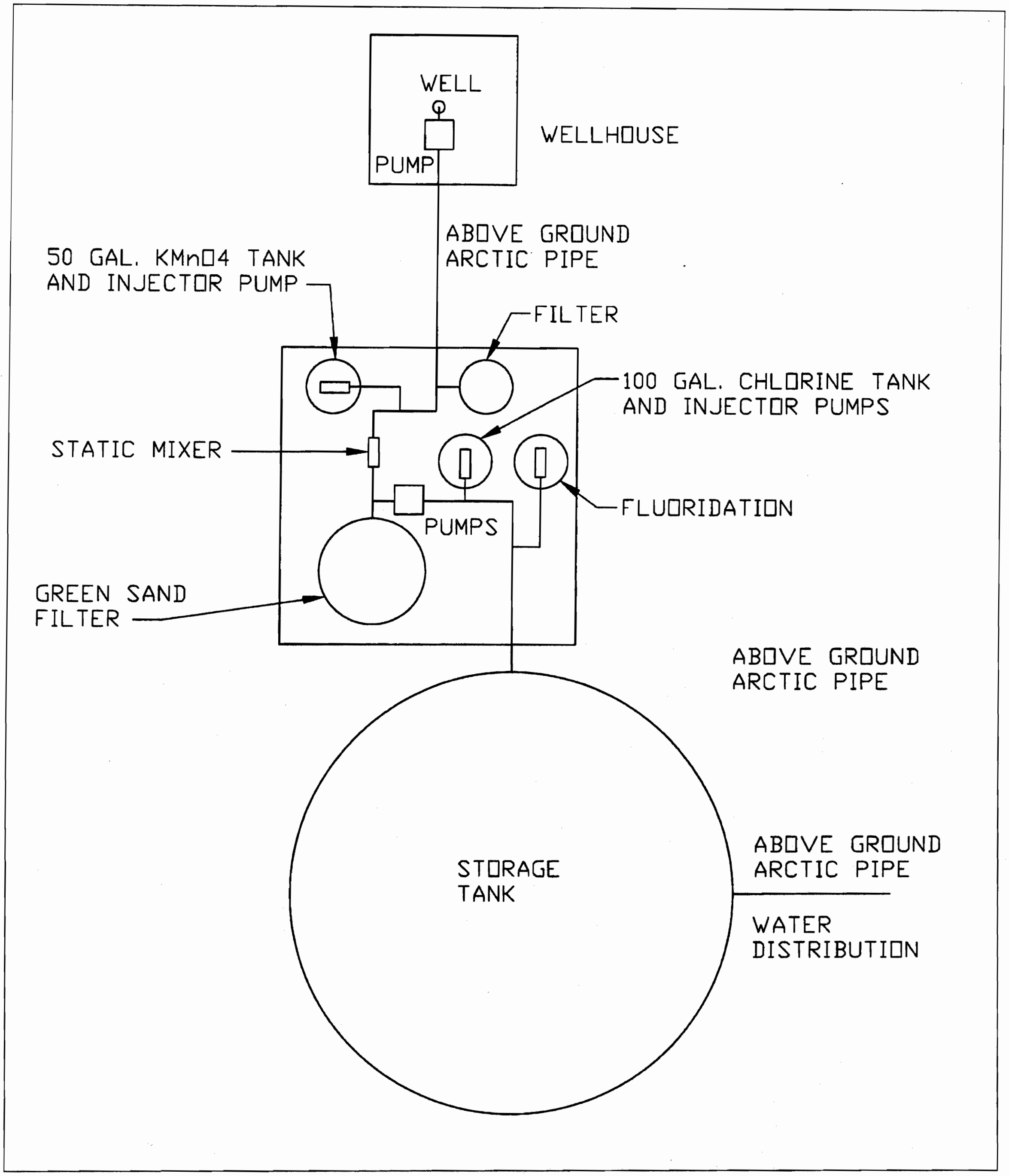


FIGURE G-5.—Water supply schematic for Kivalina.

APPENDIX H

WASTEWATER COLLECTION AND TREATMENT AT RELOCATION SITES

APPENDIX H
WASTEWATER COLLECTION AND TREATMENT AT RELOCATION SITES

By C. James Martel, Ph.D., P.E.
U.S. Army Cold Regions Research & Engineering Laboratory, Hanover, NH

1. INTRODUCTION

The volume of wastewater that will be produced by the new village of Kivalina is estimated to be 24,000 gallons per day, based on a population of 600 and a usage rate of 40 gallons/person/day. Various methods for collection and treatment of this wastewater were considered based on recommendations of the American Society of Civil Engineers' Cold Regions Utilities Monograph and the experience of the Army Cold Regions Research and Engineering Laboratory and the U.S. Public Health Service. These methods and their applicability at each of the proposed sites are listed in tables H-1 and H-2 at the end of this appendix. The sites considered in the relocation plan are the present site, Imnakuk (Kivalina River), and Igrugaivik (Wulik River).

The strong preference of the community is to have piped water and sewerage. Residents consider the present system, self-haul of water and honeybuckets, to be totally inadequate and inconsistent with the rest of the world. Consequently, any option that is not a piped water and sewerage system, no matter how cost-effective, will probably not be acceptable.

2. PRESENT SITE

The soils at the present site consist of black beach sand typical of barrier islands in the area. According to the ground-penetrating radar (GPR) survey taken by Golder Associates, the top of the permafrost is approximately 3.7 m (12 feet) below the surface. Also, a well log taken in 1976 indicates a layer of frozen beach sand at 1.8 to 3 m (6-10 feet) followed by a layer of unfrozen beach sand at 3 to 5.5 m. Permafrost was found between 5.5 and 17.7 m (18 and 58 feet).

Because of the high permeability of these sands and the considerable depth to permafrost, it appears that a community subsurface disposal system should be possible. This type of system would be simpler to operate and maintain than the other options. The washeteria already has a subsurface disposal system that has operated satisfactorily for several years.

The treatment process would include a bar screen, an Imhoff tank or large septic tank, and a subsurface disposal field. The purpose of the bar screen is to remove large objects such as bones, rocks, or rags. The purpose of the Imhoff tank is to provide primary treatment and to digest the sludge. However, the Imhoff tank is usually 7.3 to 9.8 m (24 to 32 feet) deep because of the volume needed to store and digest the sludge. Permafrost may be present at this depth. Depending on the stability of the soil, this permafrost could preclude the use of an Imhoff tank. If this were the case, a large septic tank could be used. Sludge would have to be pumped out of the tank two or three times a year. Assuming approval from the Alaska Department of Environmental Conservation (ADEC), sludge from either the Imhoff tank or the septic tank would be discharged to the present honeybucket disposal site.

The size of the disposal field would depend on the infiltration capacity of the soil. Assuming that the soil has a percolation rate similar to a coarse to medium sand, the application rate recommended by the Environmental Protection Agency is 1.2 gal/ft^2 of bottom area/day. For a flow of 24,000 gal/day, the disposal field would be 20,000 ft^2 or approximately one-half acre. It is recommended that the system be located in the northern half of the proposed new landfill. This part of the landfill would be dedicated to airport operations and would not be available for residential development. This location would be far enough from proposed residences not to present an odor problem in the prevailing onshore winds.

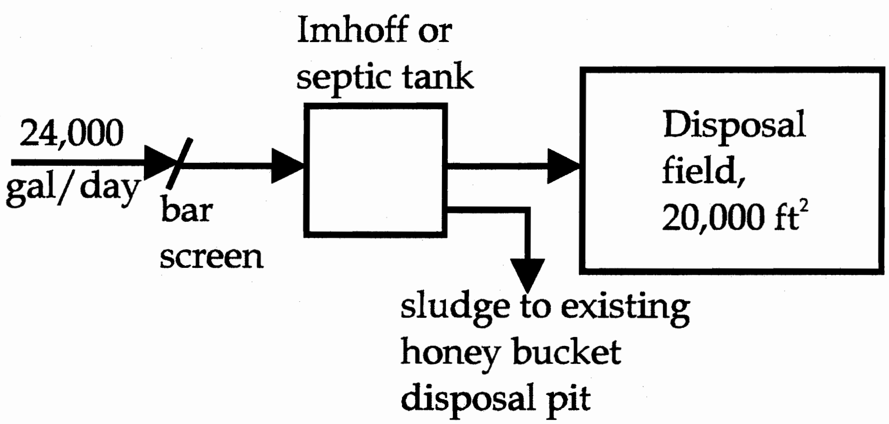


FIGURE H-1.--Schematic flow diagram for sewage treatment at the existing village site.

The recommended wastewater collection method is gravity flow from each building to a central pump station. The gravity flow method should be possible because of the granular, well-drained soils and the absence of permafrost. Since the project involves a water distribution system and possibly a centralized heat distribution system, it may be advantageous to use a shallow buried utilidor. This would allow easier maintenance of all utilities and thawing of pipelines, if necessary.

3. IMNAKUK

The Imnakuk site is located about 6 miles north of Kivalina along the north bank of the Kivalina River. It is characterized by a south-facing, tundra-covered hillside that slopes down to the river. Clayey marine deposits that appear to be several feet deep mantle the bedrock on the slope. Based on visual observations in August, these deposits were frozen within 0.9 m (3 feet) of the ground surface.

Because of the gentle slope of the land, a gravity collection system seems to be the best alternative. However, the permafrost at the site would make burial very expensive. Instead, the pipes could be placed in an aboveground utilidor. A single pump station located at the base of the slope would probably be sufficient to collect all the wastewater.

Since there is plenty of land area at this site, it seems that a stabilization pond would be the best alternative for wastewater treatment. This is one of the simplest and least expensive methods to operate and maintain. Several of these systems have been installed in Alaska and Canada. Pretreatment would consist of a simple bar rack and flow measurement structure. The screening would be taken to the landfill. The best place to locate the ponds is on the northwest corner of Section 21, which is near a small creek that empties into the lower Kivalina River.

Based on figure 10.3 in the Cold Regions Utilities Monograph, the area required for a series of stabilization ponds to serve 600 people at 40 gal/person/day and 10 months of storage is approximately 4.5 acres. A two-cell system would be best to conserve heat and thus maintain a thawed flow path. Discharge would be to the small creek during July and August. ADEC may not require disinfection because the creek is not near the village or a potential water supply.

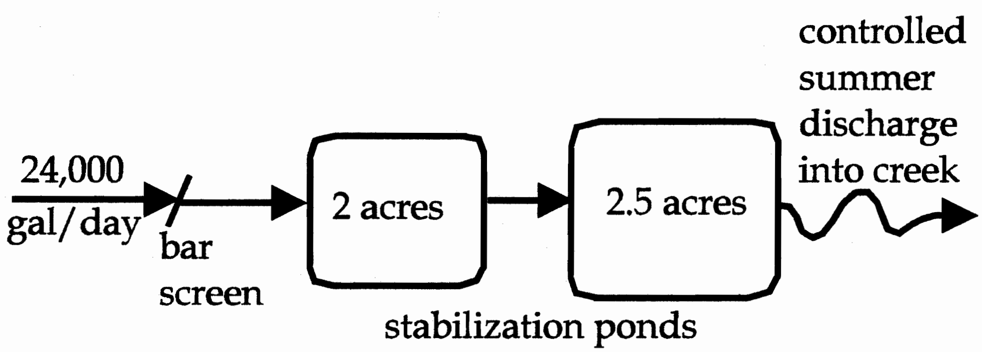


FIGURE H-2.--Schematic flow diagram for sewage treatment at the Imnakuk site.

4. IGRUGAIVIK

The Igrugaivik site is located about 2.5 miles east of Kivalina on a main channel of the Wulik River. It is a relatively flat site, underlain with permafrost. Two tundra ponds are in the immediate vicinity.

Because of the flat terrain and permafrost, it appears that a gravity collection system is not feasible. The alternatives are pressure or vacuum collection systems. Although either system could be used, the pressure system would probably suffer more damage during an accidental freezeup because the pipelines are normally filled with water. Also, special vacuum toilets are available that can reduce water consumption by 90 percent compared to conventional toilets. Therefore, it appears that a vacuum collection system would be the best alternative. The village of Noorvik, another village in the Northwest Arctic Borough, has successfully operated a vacuum collection system for several years.

Wastewater treatment could be accomplished in one of the tundra ponds. According to State regulations, the use of tundra ponds is allowed if there is no other viable means of treatment and the village has a population of less than 1,000. Also, the pond must be fenced and have warning signs. A simple bar rack would be the only pretreatment process.

The most favorable tundra pond for wastewater treatment would be the one at the southern boundary of the site. The size of this pond is approximately 6 acres. Discharge appears to be to a minor channel of the Wulik River. This pond would be easier to get to than the large tundra pond that lies on the east boundary of the site. Also, the 6-acre pond should be far enough from the town that it would not cause an odor problem.

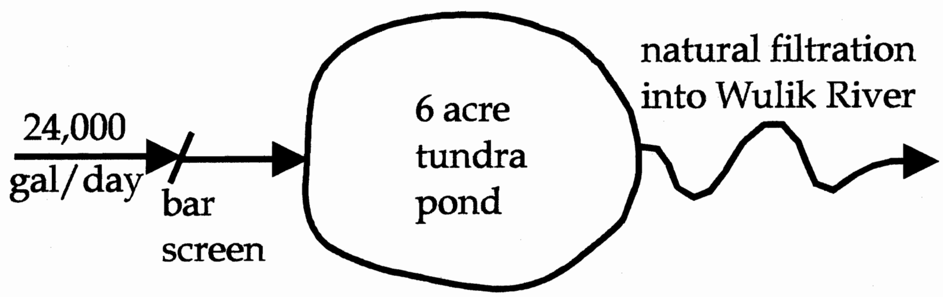


FIGURE H-3.--Schematic flow diagram for sewage treatment at Igrugaivik site.

TABLE H-1.--*Evaluation of wastewater collection options*

Wastewater collection option	Present site	Imnakuk	Igrugaivik
Gravity: High initial cost but low O&M costs. High health protection and convenience.	May be possible to bury below frost line. Alternative would be to use insulated pipe.	Attractive option because of sloping terrain. However, pipe could not be buried because of permafrost.	Very difficult and expensive to install because of relatively flat terrain and permafrost.
Vacuum: Can be used in any soil and in gently sloping terrain. Moderately high installation and O&M costs. High health protection and convenience.	Possible. Would be easy to install because of sandy soil.	Possible. Could run insulated pipe in shallow trenches or utilidor.	Possible. Could run insulated pipe in shallow trenches or utilidor.
Pressure: Good in hilly terrain. Moderately high installation and O&M costs. High health protection and convenience.	Possible. Would be easy to install because of sandy soil.	Possible. Could run insulated pipe in shallow trenches or utilidor.	Possible. Could run insulated pipe in shallow trenches or utilidor.
ATV Haul: Often used in poor soil areas with boardwalks. Low initial cost but high O&M cost. Moderate health protection and convenience.	Possible. Roads already in place.	Possible. Would be easy to implement on new roads and boardwalks.	Possible. Would be easy to implement on new roads and boardwalks.
Truck Haul: Most useful for frost susceptible or bedrock soils. Low initial cost but high O&M cost. Moderate health protection and convenience.	Possible. Roads already in place.	Possible. Would be easy to implement on new roads and boardwalks.	Possible. Would be easy to implement on new roads and boardwalks.
Individual Haul: Can be used in any soil condition. Very low initial and O&M cost. Low health protection and convenience.	Presently being used.	Technically possible but unacceptable to residents.	Technically possible but unacceptable to residents.

TABLE H-2.--*Evaluation of wastewater treatment options*

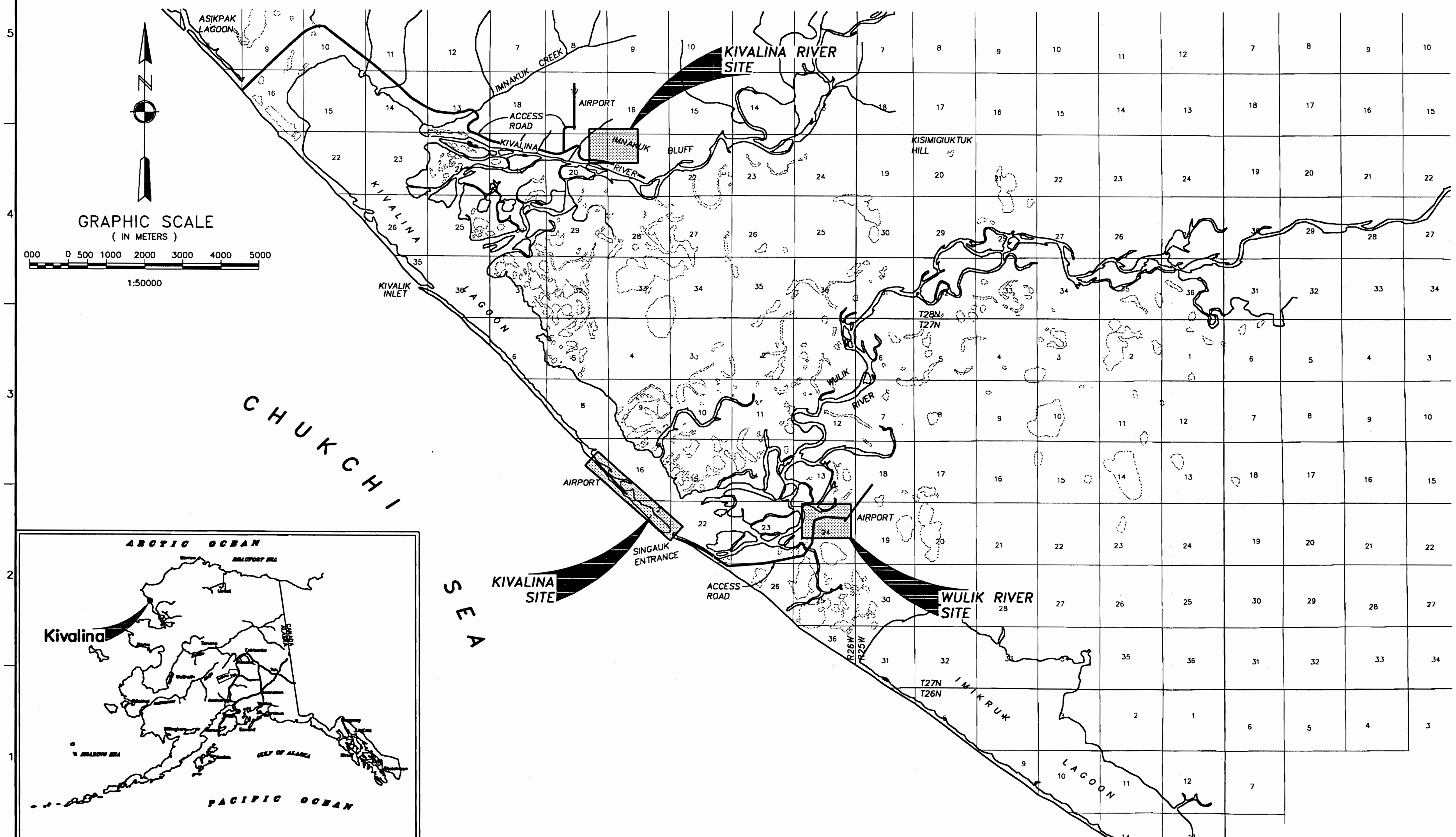
Wastewater treatment option	Present site	Imnakuk	Igrugaivik
Stabilization Pond: Most common method in cold regions. Simple to operate and maintain but requires a large land area. High installation cost but low O&M cost	Easy to construct because of sandy soils. Significant portion of available land would by used by the lagoon. Seasonal discharge to infiltration basin or surface water.	Difficult and expensive to construct because of permafrost. Plenty of land available. Seasonal discharge to Kivalina River.	Construction difficult because of permafrost. Large tundra pond available which could be converted to a stabilization pond. Seasonal discharge to Wulik River.
Aerated Lagoon: Widely used in cold regions. Requires less land than facultative lagoons but more difficult to operate and maintain. High installation and O&M cost.	Easy to construct because of sandy soils. Would use less land than facultative lagoon. Seasonal discharge to infiltration basin or surface water.	Difficult and expensive to construct because of permafrost. Plenty of land available. Seasonal discharge to Kivalina River.	Difficult and expensive to construct because of permafrost. Seasonal discharge to Wulik River or tundra pond.
Package Plant: Must be enclosed. Land requirement is minimal. Requires skilled operator. High installation and O&M cost.	Possible location near village because of small size. Wastewater from school is treated with a package plant. Submerged pipe discharge to Kivalina Lagoon.	Above ground installation probably required because of permafrost. Freefall discharge to Kivalina River.	Above ground installation probably required because of permafrost. Freefall discharge to Wulik River.
Rotating Biological Contactors (RBC's): Must be enclosed. Land requirement is minimal. Simple O&M and low energy consumption. High installation but moderate O&M cost.	Possible location near village because of small size. Submerged pipe discharge to Kivalina Lagoon.	Not affected by permafrost because normal installation is above ground. Freefall discharge to Kivalina River.	Not affected by permafrost because normal installation is above ground. Freefall discharge to Wulik River
Imhoff or septic tank with sand filter: Imhoff tank requires 30 ft depth; septic tank only 10 ft. Moderate land requirement for filter. Simple operation and maintenance. Moderate installation but low O&M cost.	Possible use of existing material for sand filter or subsurface drain field. Discharge to drain field or Kivalina Lagoon.	System tank would be difficult to construct on permafrost soils. Plenty of room for constructed sand filter. Freefall discharge to Kivalina River.	System would be difficult to construct on permafrost soils. Plenty of room for constructed sand filter. Freefall discharge to Wulik River.

APPENDIX I

COMMUNITY LAYOUT ALTERNATIVES

KIVALINA RELOCATION PROJECT

KIVALINA, ALASKA



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CORPS OF ENGINEERS
ANCHORAGE, ALASKA

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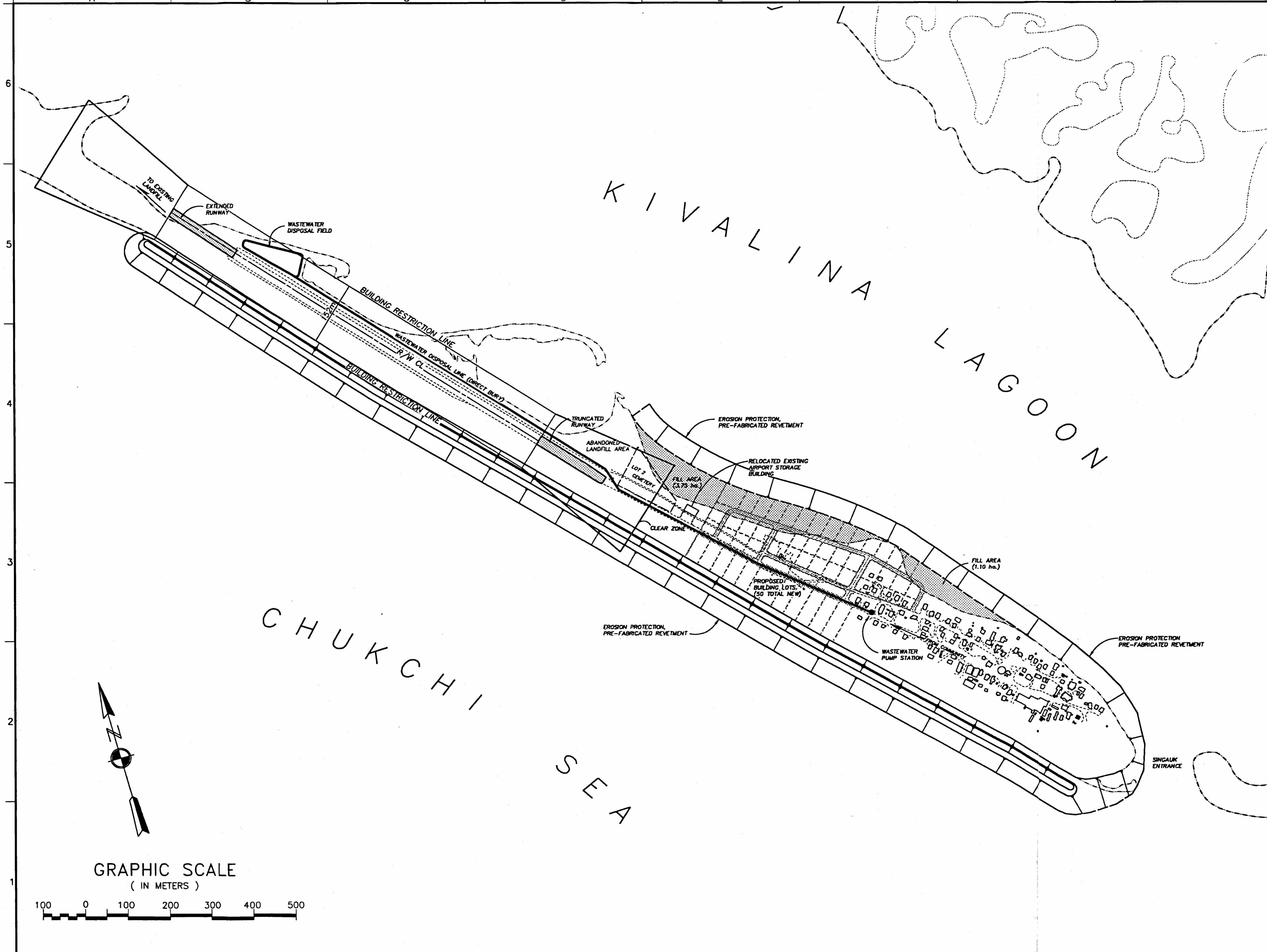
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953

KIVALINA RELOCATION PROJECT
SITE LOCATION MAP

Reference number:
I–1
Sheet 1 of 7



ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

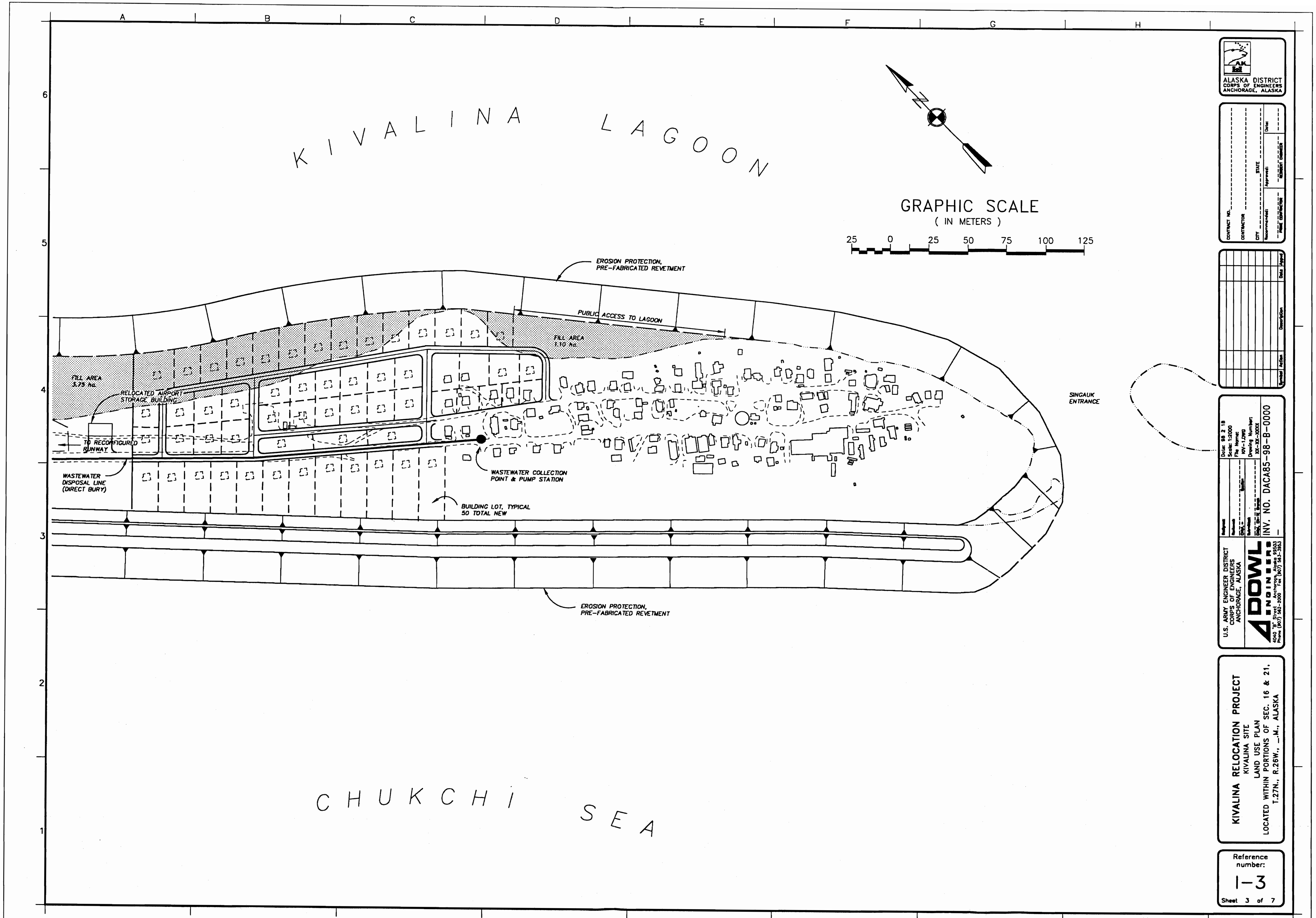
DOWL ENGINEERS

INV. NO. DACA85-98-B-0000

KIVALINA RELOCATION PROJECT
KIVALINA SITE
CONCEPTUAL SITE PLAN
LOCATED WITHIN PORTIONS OF SEC. 16 & 21.
T.27N., R.26W., _M., ALASKA

Reference number:
I-2

Sheet 2 of 7


KIVALINA LAGOON
GRAPHIC SCALE
(IN METERS)
25 0 25 50 75 100 125
EROSION PROTECTION, PRE-FABRICATED REVETMENT
PUBLIC ACCESS TO LAGOON
FILL AREA 1.10 ha.
FILL AREA 3.75 ha.
RELOCATED AIRPORT STORAGE BUILDING
TO RECONFIGURED RUNWAY
WASTEWATER DISPOSAL LINE (DIRECT BURY)
WASTEWATER COLLECTION POINT & PUMP STATION
BUILDING LOT, TYPICAL 50 TOTAL NEW
SINGAUK ENTRANCE
EROSION PROTECTION, PRE-FABRICATED REVETMENT
CHUKCHI SEA
ALASKA DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA
DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953
Date: 98 2 18
Scale: 1:2000
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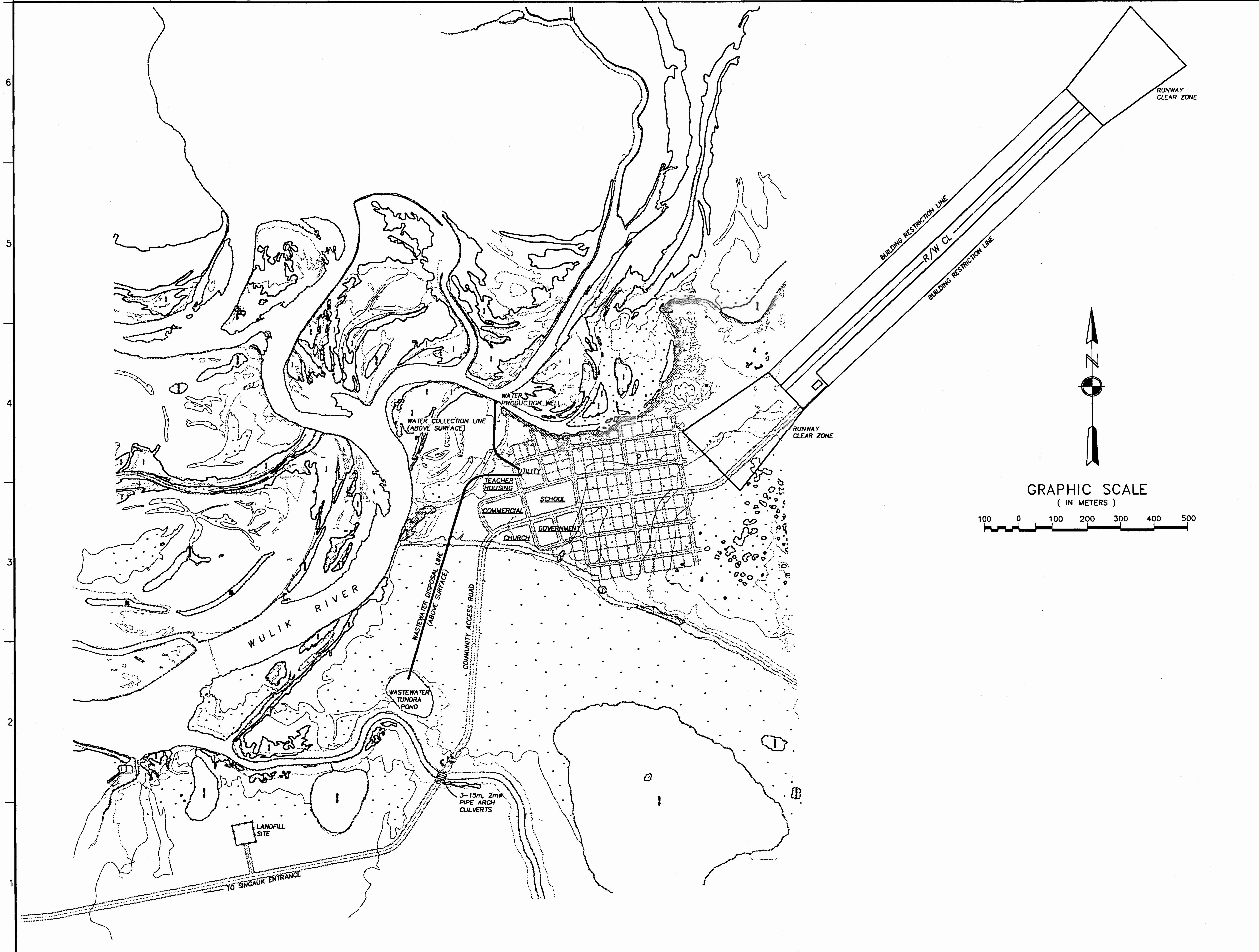
Drawing Number: XX-XX-XXXX
INV. NO. DACA85-98-B-0000
KIVALINA RELOCATION PROJECT
KIVALINA SITE
LAND USE PLAN
LOCATED WITHIN PORTIONS OF SEC. 16 & 21, T.27N., R.26W., __M., ALASKA
Reference number:
I-3
Sheet 3 of 7



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ANCHORAGE, ALASKA

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CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953

Date: 98 2 18
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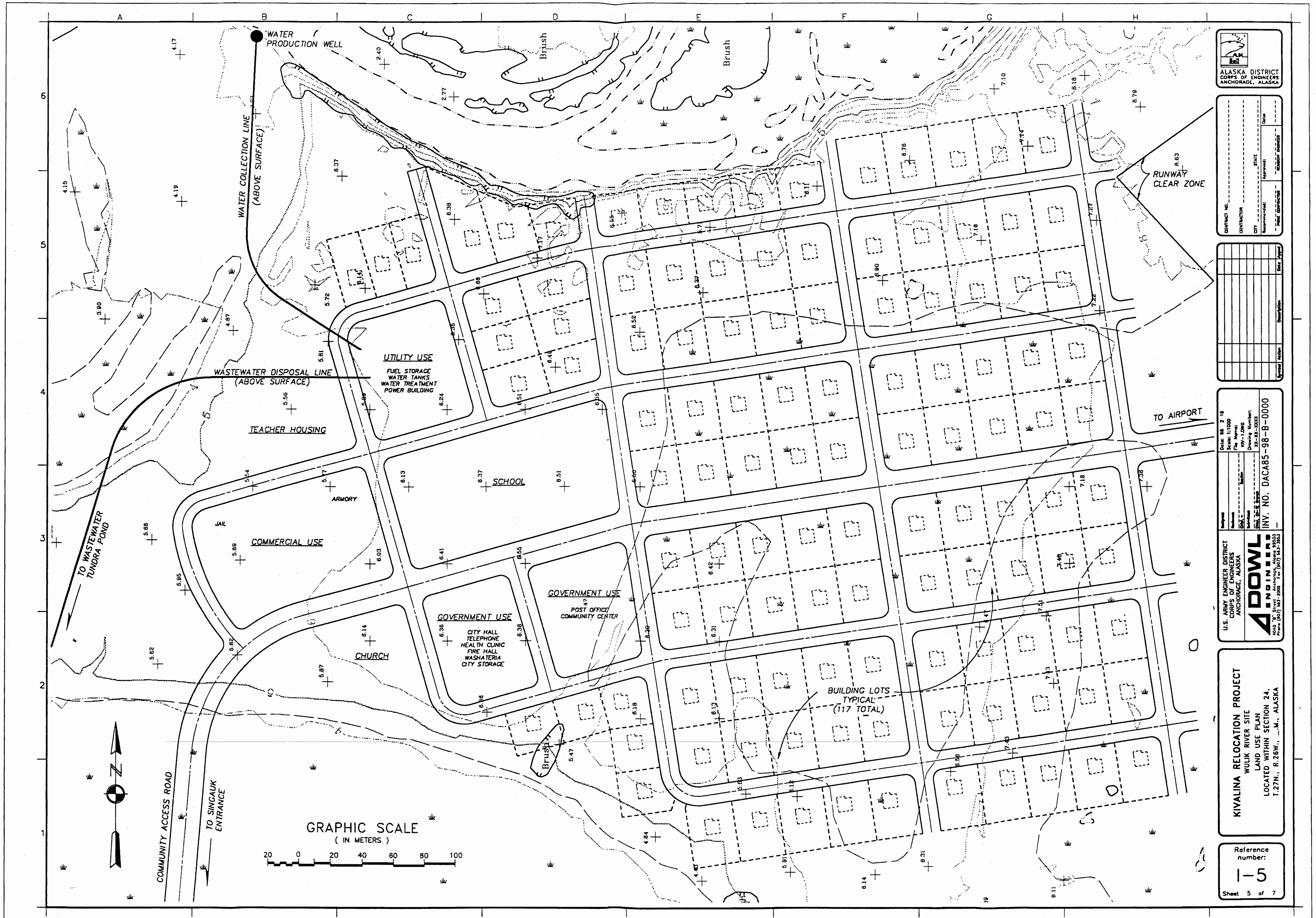
INV. NO. DACA85-98-B-0000

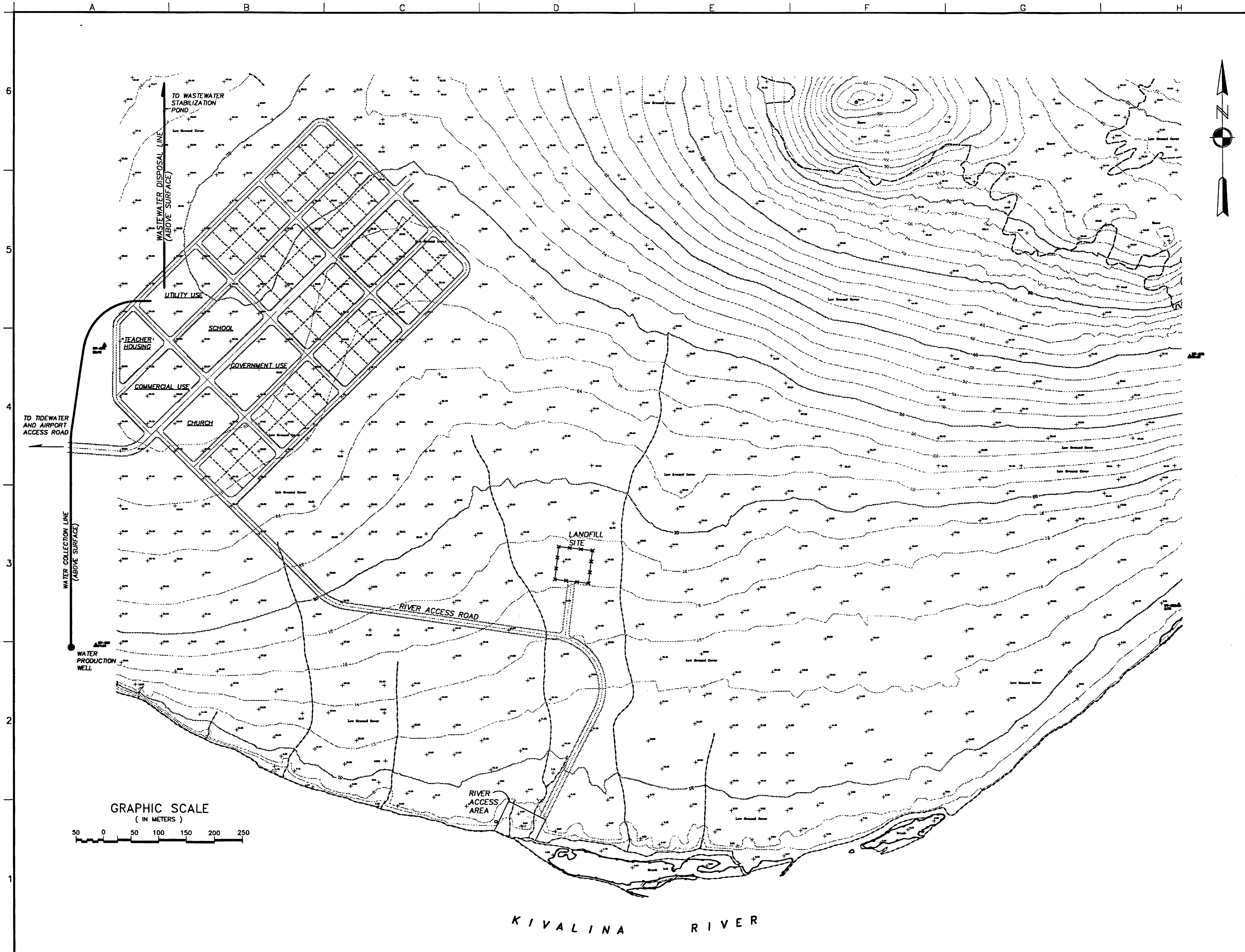
KIVALINA RELOCATION PROJECT
WULIK RIVER SITE
LAND USE PLAN
LOCATED WITHIN SECTION 24,
T.27N., R.26W., _.M., ALASKA

Reference number:
I–4

Sheet 4 of 7



WATER PRODUCTION WELL
WATER COLLECTION LINE (ABOVE SURFACE)
Brush
Brush
RUNWAY CLEAR ZONE
UTILITY USE
FUEL STORAGE
WATER TANKS
WATER TREATMENT
POWER BUILDING
WASTEWATER DISPOSAL LINE (ABOVE SURFACE)
TEACHER HOUSING
TO AIRPORT
SCHOOL
ARMORY
JAIL
COMMERCIAL USE
TO WASTEWATER TUNDRA POND
GOVERNMENT USE
POST OFFICE
COMMUNITY CENTER
GOVERNMENT USE
CITY HALL
TELEPHONE
HEALTH CLINIC
FIRE HALL
WASHATERIA
CITY STORAGE
CHURCH
BUILDING LOTS TYPICAL (117 TOTAL)
Brush
COMMUNITY ACCESS ROAD
TO SINGAUK ENTRANCE
GRAPHIC SCALE
(IN METERS)
20 0 20 40 60 80 100
N
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953
Date: 98 2 18
Scale: 1:1000
File Name: KIV-1.DWG
Drawing Number: XX-XX-XXXX
INV. NO. DACA85-98-B-0000
KIVALINA RELOCATION PROJECT
WULIK RIVER SITE
LAND USE PLAN
LOCATED WITHIN SECTION 24,
T.27N., R.26W., _M., ALASKA
Reference number:
I-5
Sheet 5 of 7



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ANCHORAGE, ALASKA

DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953

Date: 98 2 18
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Drawing Number: XX-XX-XXXX

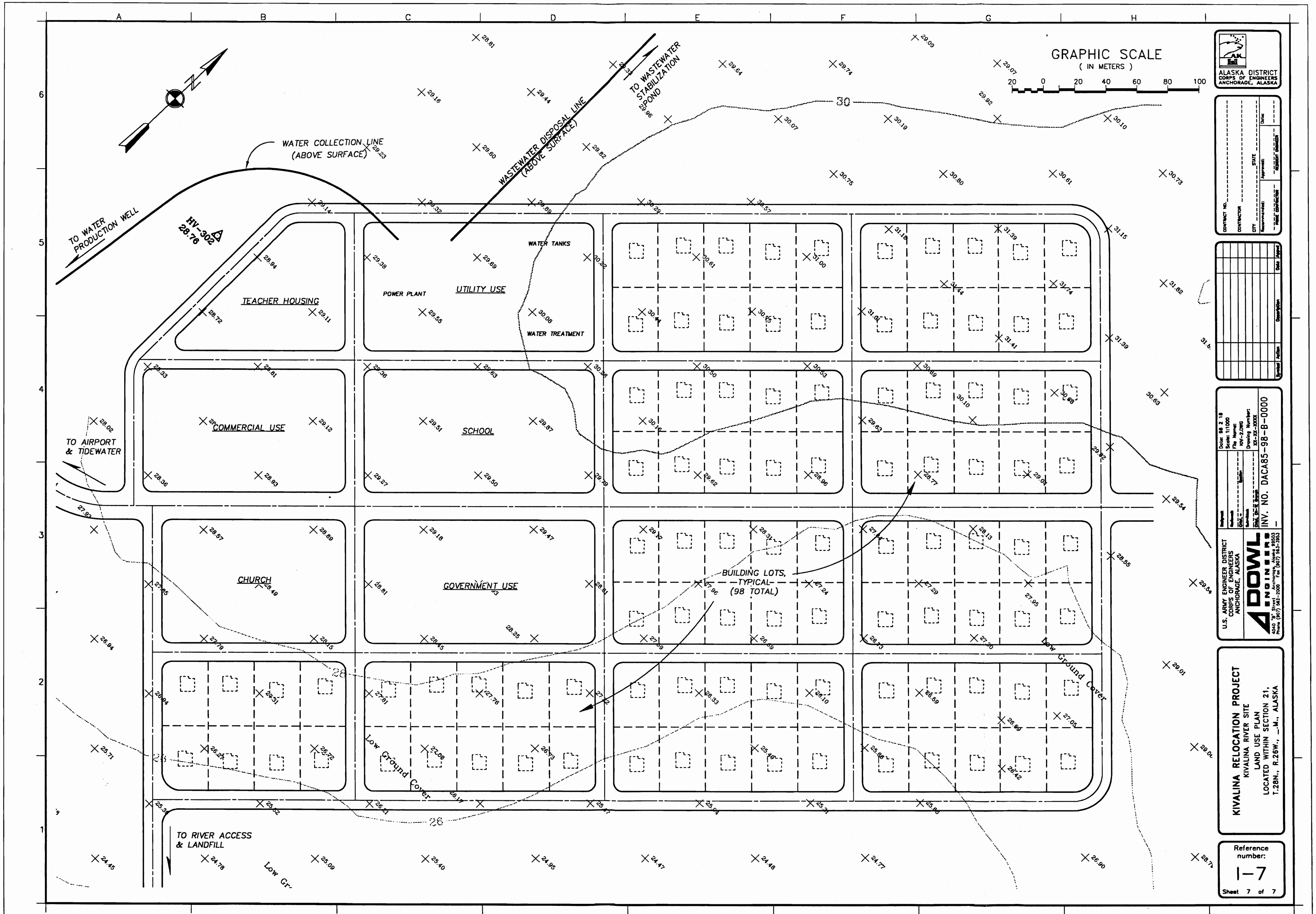
INV. NO. DACA85-98-B-0000

KIVALINA RELOCATION PROJECT

KIVALINA RIVER SITE
CONCEPTUAL SITE PLAN
LOCATED WITHIN SECTION 21
T.28N., R.26W., _M., ALASKA

Reference number:
I-6

Sheet 6 of 7


GRAPHIC SCALE
(IN METERS)
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WATER COLLECTION LINE
(ABOVE SURFACE)
WASTEWATER DISPOSAL LINE
(ABOVE SURFACE)
TO WASTEWATER
STABILIZATION
POND
TO WATER
PRODUCTION WELL
HV-302
28.76
TEACHER HOUSING
POWER PLANT
UTILITY USE
WATER TANKS
WATER TREATMENT
COMMERCIAL USE
SCHOOL
TO AIRPORT
& TIDEWATER
CHURCH
GOVERNMENT USE
BUILDING LOTS,
TYPICAL
(98 TOTAL)
Low Ground Cover
TO RIVER ACCESS
& LANDFILL
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
Date: 98 2 18
Scale: 1:1000
File Name: KIV-2.DWG
Drawing Number: XX-XX-XXXX
INV. NO. DACA85-98-B-0000
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DOWL ENGINEERS
4040 "B" Street Anchorage, Alaska 99503
Phone (907) 562-2000 Fax (907) 563-3953
KIVALINA RELOCATION PROJECT
KIVALINA RIVER SITE
LAND USE PLAN
LOCATED WITHIN SECTION 21,
T.28N., R.26W., _.M., ALASKA
Reference number:
I-7
Sheet 7 of 7

APPENDIX J

A VISIT TO OUJE-BOUGOUMOU, A MODEL NATIVE VILLAGE

APPENDIX J
A VISIT TO OUJE-BOUGOUMOU, A MODEL NATIVE VILLAGE

By C. James Martel and Rosa T. Affleck
U.S. Army Cold Regions Research & Engineering Laboratory, Hanover, NH

1. INTRODUCTION

On September 24 and 25, 1997, the authors visited Oujé-Bougoumou, a Cree village of about 650 people in northern Quebec. The purpose of the visit was to obtain firsthand information on how the village was sited and planned. The United Nations recently recognized this village as a model human settlement. Information from their experience could be useful in building a new village or modernizing the existing Kivalina.

Oujé-Bougoumou comes from the Cree word meaning “the place where people gather.” It is located in the James Bay Territory at approximately 50° N. and 74° W. on the shores of Lake Opemiska (figure J-1). About 45 miles away is the town of Chibougamau, and the nearest airport is about a 25-minute drive. The village is 630 miles from Hanover, New Hampshire, which turned out to be a 12-hour drive. We stayed at the Capisissit Lodge, which has very pleasant accommodations and a nice restaurant.

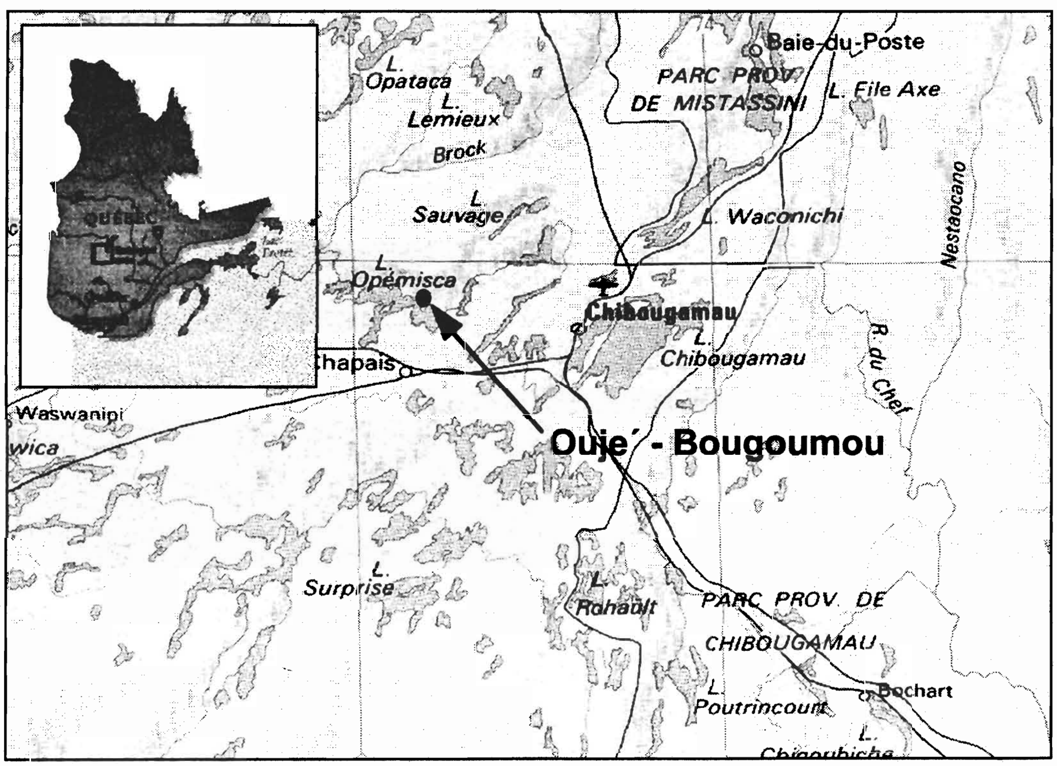

FIGURE J-1.–Location of Oujé-Bougoumou.

During our visit we met with Chief Abel Bosum; Paul Wertman, Advisor to the Oujé-Bougoumou Crees; and Sidney Coonishish, Project General Manager. The Chief and Mr. Wertman recounted the history of the Oujé-Bougoumou Cree and explained how the village was planned, designed, and constructed. The Chief and Mr. Coonishish took us on a tour of the village, including the cultural village. On Thursday, Mr. Coonishish took us to the wastewater treatment facility and to his home, a typical single-family residence.

General information about Oujé-Bougoumou can be found on the community's excellent web site (*http://www.ouje.ca/index.htm*). Another source of information is an article by John Goddard called "In From the Cold" in the July/August 1994 issue of *Canadian Geographic*.

2. HISTORY

The history of the Oujé-Bougoumou Crees is a sad story of deprivation and neglect. Since the 1920's, they have been relocated seven times in favor of forest and mining interests. During the last relocation, they became dispersed into several small camps built along logging roads. They became squatters on provincial lands, living in shacks with no heat or running water. Children became sick with gastrointestinal infections from drinking polluted water. The crude and overcrowded shacks proved to be an ideal breeding ground for all sorts of diseases. In 1986 a report commissioned by the Grand Council of the Crees of Quebec called the living conditions the worst in the developed world.

In spite of these hardships, the Oujé-Bougoumou Cree kept the dream alive for a village of their own. Under the leadership of Chief Bosum, they began to organize and formulate a plan. With the help of Paul Wertman, they began a campaign to acquire land for the new village. After several years of negotiating with both Federal and provincial authorities, an agreement was reached in 1989 whereby Quebec agreed to contribute money for the construction of a new village. This was followed by the Oujé-Bougoumou/Canada Agreement in 1992 whereby the Federal Government also agreed to contribute, giving the Cree 2.7 square kilometers on which to build the village. Chief Bosum credits the wisdom of the elders and the perseverance of the people for getting them through this long ordeal.

The traditional economic base is hunting, fishing, and trapping. These activities continue, and some effort is being made to market them to tourists. The main source of income is the jobs provided by the forestry and mining industries. Also, now that the village is a reality, some members are employed in the administration offices, in the operation and maintenance of the facilities, in construction, and in other seasonal employment.

3. SITE SELECTION

Much of the land in northern Quebec is owned or controlled by mining and forestry companies. Other lands are under the control of the park service and individual landowners. The only land available for a new village was under the control of the provincial government. Under the terms of the agreement, the community was given exclusive surface rights to 167 square kilometers of land around Lake Opemisca.

According to Chief Bosum, the people identified seven criteria for the new site:

1. The land must be suitable for construction, not swampy or poorly drained.
2. It must have access to a good source of drinking water.
3. The site must be large enough for expansion.
4. It must not be too close or too far from other municipalities.
5. It must have access to a main highway.
6. The views from the site must be esthetically pleasing.
7. It must have access to hunting territories.

Approximately 20 potential sites were initially selected. This list was gradually reduced to six. The present site was third on the list. This site faces south, which allows more solar energy in the winter. In the summer, a breeze from the southwest cools the site. The land slopes down to the lake, which allows gravity flow of water and sewage. The sewerage system has only one pump station. The south-facing slope also shields buildings from cold north winds. Although the depth of frost penetration can be up to 3 meters in some areas, there is no permafrost. The site had been clear-cut by the forestry industry prior to selection. As a result, there are few large trees on the site.

4. SITE PLAN

As explained on the web site, the site plan for the new village began with the vision of re-creating the well-being of traditional village life with modern facilities and contemporary institutions. Three major objectives were defined:

1. The village had to be constructed in harmony with the environment and with the traditional Cree philosophy of conservation.

2. The village had to provide for the long-term financial requirements of the people. They did not want it to become a "welfare enclave."

3. The village had to reflect Cree culture in its physical appearance and function. They did not want a conventional planned unit subdivision.

These objectives are essentially the credos of what we now call "sustainable development."

To ensure that the physical appearance of the village reflected Cree culture, they hired Mr. David Cardinal, a renowned aboriginal architect who has designed several museums with Native themes. Mr. Cardinal took the concept of the *astchiiugamikw*, a teepee-like dwelling where the ceiling is also the wall of the structure. In Mr. Cardinal's rendition of this design, the roof becomes the dominant feature and the side walls are rounded. This architecture was used on the major public buildings like the municipal building, school, elders' homes, business center, and others (figure J-2).

FIGURE J-2.—Healing Center.

The village is laid out in a circular fashion, with the *septuan*, a traditional meeting place for feasts, in the middle (figure J-3). Community buildings, including the church, business office, and municipal building, are located in the inner circle along with the *septuan*. The next circle contains other community buildings such as the school, teachers' residences, and elder residences. Radiating out from the two circles are residential buildings including apartments, duplexes, and single-family homes. This compact arrangement of buildings results in lower utility costs because of shorter pipeline and electrical distribution systems. The village maintenance garage, police station, fire station, heating plant, and various retail establishments are all located on the road in and out of town. A lodge for visitors and a cultural village are located at the far end of the village near the lake. There appears to be plenty of area around the village available for future expansion. The birth rate in the village is 2.5 to 3.0 percent annually.

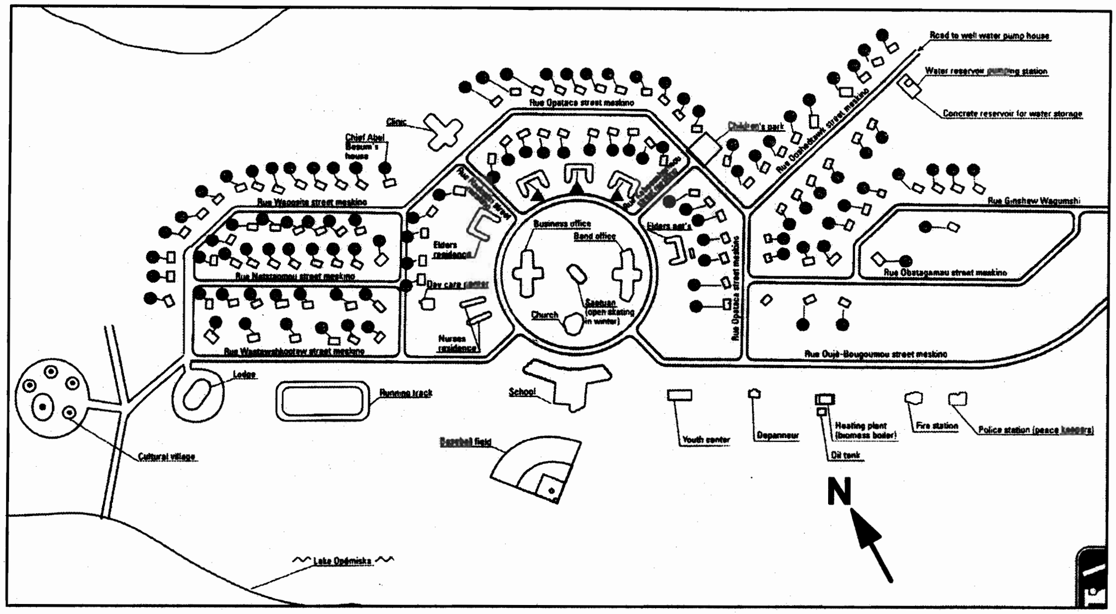

FIGURE J-3.–Oujé-Bougoumou site plan.

5. HOUSING

Before the construction, each household selected the specific location where their home was going to be built and picked out their own house layout or model. It was important to them to participate during construction of the village and to gain the training. Oujé-Bougoumou constructed 125 units during the first year of the construction, and 5 to 10 units have been added each year thereafter.

Mr. Sidney Coonishish took us on a tour of his house, a typical single-family residence in Oujé-Bougoumou (figure J-4). This single-story wooden structure has approximately 1,100 square feet of usable space. To conserve energy, the house was designed to meet the R-2000 standard.

However, tests have shown that these houses are rated at almost R-3000. The walls are more than 9 inches thick, consisting of a sheeting of plastic composite material, 6 inches of insulation, a vapor barrier, another 3 inches of insulation, and finally the wallboard. The foundation is made from pressure-treated lumber rather than concrete to reduce cost. The basement floor is also wood. Both heat and hot water are derived from the district heating system. This house has a modern kitchen and dining area (figure J-5). One concession made to Native lifestyle was the inclusion of an air exchanger to get rid of large amounts of water vapor generated during cooking. Mr. Coonishish explained that the preferred method of cooking is boiling.

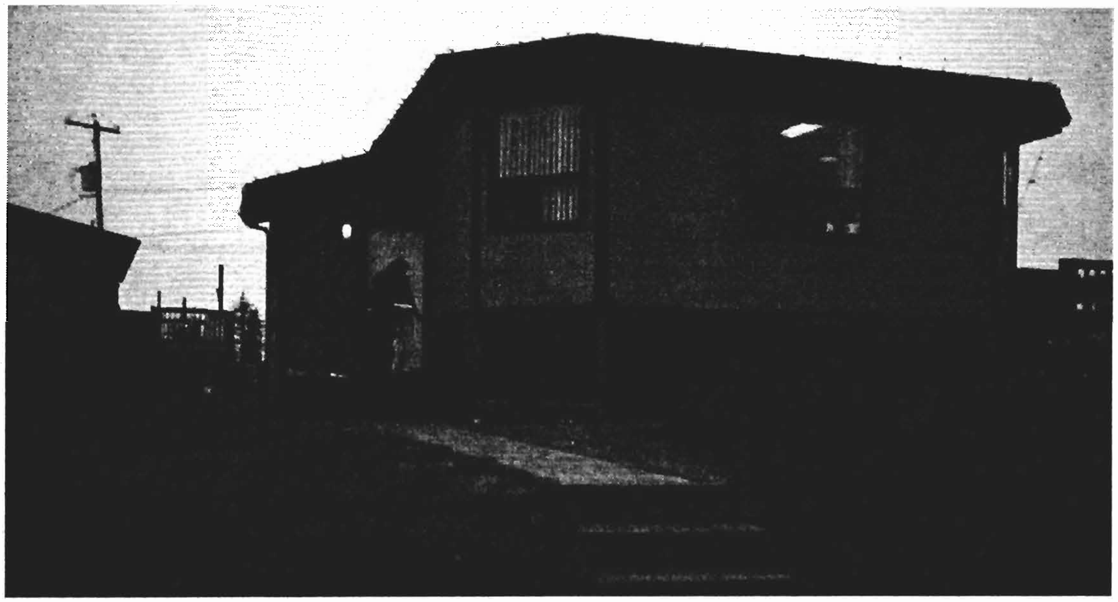

FIGURE J-4.—Typical single-family home.

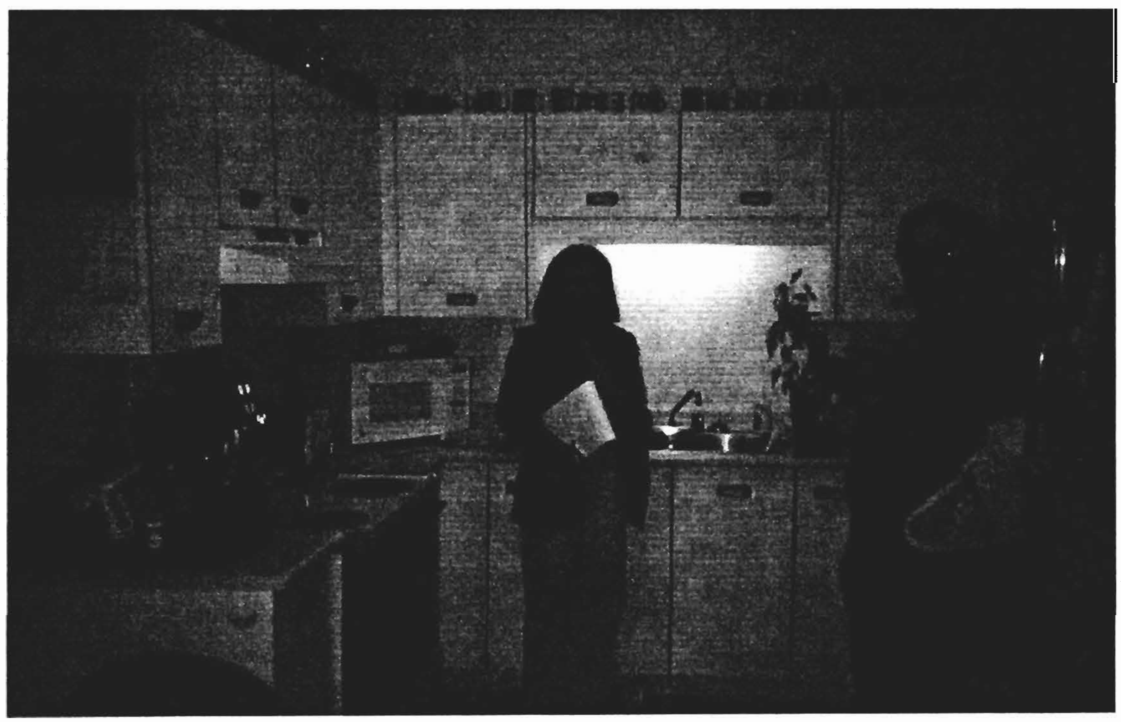

FIGURE J-5.—The co-author and Mr. Coonishish in his kitchen.

One of the key elements of the Oujé-Bougoumou/Canada Agreement was the granting of funds for housing purposes. These funds were used to set up a Housing Program that provides affordable and good-quality housing to as many residents as possible. The Housing Program is split into two components: a Home Ownership Program and a Rental Program.

The Home Ownership Program was based on guidelines developed by a local housing committee from input received at several meetings and workshops. Some of these guidelines are:

1. The houses should be built in such a way that the people can build a house themselves. Voluntary labor provided by the prospective homeowner can be applied to reducing the amount paid back to the program.

2. The houses should be designed to accommodate Cree culture and lifestyle.

3. The houses should be easy to maintain and inexpensive to operate. In a cold climate like northern Quebec, this meant that the houses had to be well insulated to reduce heating costs.

4. The houses had to be affordable without sacrificing quality.

The average cost of a new home is approximately $95,000 Canadian. The minimum annual income to qualify for home ownership is $22,000. The homeowner is expected to pay about 50 percent of the construction costs as well as the cost of maintenance and utilities, which is approximately $125/month. The amount paid each month depends on the family's income. The program is set up so that no more than 25 percent of the family's income goes to housing costs. However, the more that is paid on a monthly basis, the quicker the construction loan is paid off and the family owns the house. Part of the housing payments go into a revolving fund so that other families can obtain a construction loan.

The Rental Program offers individuals the option to rent a house or apartment. Because of a large variation in income among renters, three categories of rental rates were established. One of the rates allows a family to regularly set aside an amount of money that can be credited to a home ownership account. This option makes it easier for renters eventually to become homeowners.

6. UTILITIES

Unlike in Kivalina, there is no permafrost in Oujé-Bougoumou. Therefore, all utilities, including electrical, are buried. Frost depth can be up to 9 feet in some places, according to Mr. Coonishish. The soils at the site are sandy and well drained, making them less frost-susceptible.

7. HEATING SYSTEM

One of the most innovative and interesting aspects of the Oujé-Bougoumou village is the installation of a district heating system that uses sawdust from nearby sawmills as the fuel source. The district heating system also provides heat for domestic hot water. According to Mr. Duncan Varey, the District Heating Coordinator, the cost of producing 1.0 MW of heat is only $2.44. In comparison, the cost of producing the same amount of heat using electricity or oil is $71.80 and $30.64, respectively.

Before deciding to adopt a district heating system, community members made a concerted effort to learn all they could about the system. Some of their concerns were the continuing availability of sawdust, the effect of emissions on air quality, and the skill level needed to operate and maintain the system. To investigate these concerns, they sent a four-person delegation to visit a similar biomass-fueled heating system in Charlottetown, P.E.I. The delegation came back to Oujé-Bougoumou very enthusiastic about district heating and was able to give community members very detailed information about it. Some of the long-term benefits that the community foresaw in adopting this system are retaining money spent on heating energy within the community; local control over heating costs; and creation of local employment.

During our visit to the heating plant, we were shown how sawdust is dumped into a large hopper where an auger transports it to the sloping grate combustion chamber (figure J-6). The boiler burns approximately 2,000 tons/year at a cost of $6.00/ton. The combustion chamber is heavily insulated and lined with refractory material to allow use of high-moisture-content fuel. Ash produced by the plant is spread on reforested land. The hot water produced by the plant is pumped through the distribution system at various temperatures, depending on the weather. The design temperature is 194 °F, but the system produced only 150-°F water during our visit

FIGURE J-6.—Truckload of sawdust outside heating plant.

because of the relatively warm temperatures. The return water was at 140 °F. The system has a second oil-fired boiler that is used to augment the sawdust-fueled boiler during peak demand periods to provide emergency backup heat in case the primary boiler fails.

8. WATER SUPPLY

Oujé-Bougoumou has a conventional piped water supply system. The source of water is a drilled well located outside the village. Water is pumped to a concrete reservoir that supplies the distribution system. No mention was made of a water treatment system. Based on our taste test, the quality of the water was excellent.

9. WASTEWATER TREATMENT

Oujé-Bougoumou has a conventional gravity sewage collection system. Since the village is located on terrain that slopes toward the lake, all sewage can be collected in a single pump station at the base of the slope. Sewage is then pumped to a pair of aerated lagoons (figure J-7). According to Mr. Coonishish, the lagoons are 100 feet square by 20 feet deep. The lagoons are aerated with submerged aerators. No information was available on the design flow. Effluent from the lagoons is chlorinated and discharged into a receiving stream that flows into the lake.

FIGURE J-7.—Aerated lagoon for wastewater treatment.

10. CONCLUSIONS

As a result of our visit to Oujé-Bougoumou, we conclude that:

1. The village is well planned and sustainable. The people we met appear to be happy and gainfully employed.

2. One of the keys to their success was the continuous involvement of the villagers in all the planning steps. This approach built consensus among the members.

3. All buildings, facilities, and utilities were well operated and maintained. Part of the reason may the money provided by the Federal Government for operation and maintenance.

4. If the village of Kivalina decides to relocate to a new site, it would be worthwhile for some of the villagers to visit Oujé-Bougoumou. They would gain valuable information on how to organize their committees and manage the project.

APPENDIX K

JOURNAL OF THE KIVALINA FIELD MEASUREMENT EXPEDITION, AUGUST 4-11, 1997

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JOURNAL OF THE KIVALINA FIELD MEASUREMENT EXPEDITION, AUGUST 4-11, 1997

By Orson P. Smith, Ph.D.
U.S. Army Cold Regions Research & Engineering Laboratory, Anchorage, AK

1. The following paragraphs document the sequence of events at Kivalina, Alaska, during eight days of intense field investigations by the Corps of Engineers and others involved in the Kivalina Community Improvement Study of 1997. This account is based on my notes and does not include the technical details of the wide range of observations and measurements that were made during this time in Kivalina.

2. Monday, August 4

a. We reported to the school and were met by Tom Hanifan, principal, and were shown the classrooms available for our use. Ron Cothren and I were billeted in the "BOQ," a small outbuilding of the school's compound. Most of the Corps gear was stockpiled in the BOQ, and the Corps radio base station was installed there.

b. We met Leona Baldwin and Anita Adams at the school kitchen. These two were scheduled the previous week to cook for our team. Leona had already purchased food from the Kivalina Store on the Corps account opened the previous week. Lunch preparations were underway. I visited the store to confirm the account was in order and to review the purchases to date. The store clerks showed me the tally sheet that would become the invoice for our purchases. Much of the week's food supply had already been purchased and stored at the school.

c. Ron Cothren, Jim Martel, James Sauceda, and I checked in with Betty Swan, city administrator, at the city building. We confirmed the schedule for the public meeting to be held the next day (August 5) at 1:00 p.m. We asked her to contact the Kivalina Relocation Committee and schedule a meeting with us before the public meeting. She suggested 10:00 a.m. and promised to make the arrangements.

d. Ron Cothren and Tim Reed set up the DGPS base station on the roof of the school, recovered survey monuments in the town, and set up the survey baseline through town.

e. Jim Martel, Mark Anderson, and James Sauceda went to both the Kivalina and Wulik River sites, piloted in Caleb Wesley's outboard jet-powered flat-bottomed 22-foot aluminum riverboat. The trip lasted from 1:00 to 4:00 p.m. The high water made it easy to enter the Kivalina River. We had feared this would not be possible in August.

f. Sam Denny of Terra Surveys arrived in Kivalina Monday evening with additional instruments and equipment for the project.

g. Tom Hanifan showed us his draft video production of life in Kivalina that evening. The winter scenes were memorable with images of fierce winds and high snowdrifts on the buildings.

3. Tuesday, August 5

a. Greg Carpenter of DOWL Engineers and Howard Holton of USKH arrived on an early flight. Tom Newman of Terra Surveys also arrived early Tuesday with hydrographic surveying instruments and equipment. CPT Bob Pawlowski, NOAA/NOS, arrived to observe the surveys and attend the afternoon public meeting.

b. The Terra Surveys team, assisted by Ron Cothren, continued recovering existing monuments and establishing the village baseline. A tide gauge was deployed in Kivalina Lagoon at the village.

c. The Relocation Committee met with Jim Martel, Greg Carpenter, Howard Holton, and me at 10:00 a.m. I reviewed the field work planned for the week and milestones scheduled for the remainder of the entire study. Committee members present were Austin Swan, Chair, Joe Swan, Andrew Koenig, Enoch Adams, David Swan, Caleb Adams, and Fred Swan.

(1) The meeting previously scheduled for early October in Anchorage in conjunction with the American Federation of Natives Conference was discussed at some length. The AFN Conference was postponed a week, which called for rescheduling the Kivalina project meeting. The committee noted that means for their attendance were not assured and that some request must be made.

(2) Mark Anderson reviewed the Native Health Service (NHS) goals and Golder Associates contract scope. The Golder contract for geophysical surveys was with the city of Kivalina, but scoped and funded by the NHS. He noted that Village Safe Water grant applications were due in October and that a second grant would be necessary to place a test well at a prospective relocation site.

(3) Discussions of flooding at the existing village and conditions at the proposed relocation sites on the Kivalina and Wulik Rivers continued until 11:30 a.m. The existing village site appears to suffer more from long-term shoreline retreat that actual high water inundation. As the shoreline has retreated, seaward buildings are eventually subject to wave runup and windblown spray during severe storms. The Kivalina River bank was characterized as extremely windy in winter, with north winds being the worst.

(4) A second meeting of the committee was scheduled for 10:00 a.m. Thursday, August 7.

d. The public meeting began at its scheduled time of 1:00 p.m., led by Luke Sampson of the Northwest Arctic Borough. The first Kivalina project newsletter was provided to all in attendance. Several other representatives of the borough and other agencies from Kotzebue were present, along with about 40 people from Kivalina. Those present from our project team included Mark Anderson, Greg Carpenter, Howard Holton, James Sauceda, Bob Pawlowski, and myself. Mark Anderson had to leave Kivalina for another assignment during the later part of the meeting.

(1) Luke Sampson recognized all community and regional leaders present and called on a Kivalina elder for an invocation. Following these formalities, he announced the Anchorage meeting on the Kivalina project was rescheduled for October 20, 1997, at 9:00 a.m. at the NANA office on East Benson Avenue. He indicated State Senator Al Adams of Kotzebue would lead the October 20 meeting and invite key state leaders to attend.

(2) Compliments were received on the newsletter and discussions led to my promise of additional newsletters. The next newsletter will precede the October meeting in Anchorage and report on the results of the field measurements.

(3) I was introduced and in turn introduced each person present from our project team, allowing them each to make brief comments on their particular interest and responsibility. I went on to review the survey and mapping objectives of the week's work, concluding that three sites would be mapped for objective comparison of flood risk and for development of improvement plans

(4) NANA and Maniilaq (Native) Corporation representatives confirmed that all lands of the proposed relocation areas not held in Native allotments are held by NANA and are available for transfer to the city under terms of the Alaska Native Claims Settlement Act. A total of 1,280 acres can be transferred this way. Lease before conveyance is possible. Acquisition of Native allotments is the same as acquiring private land, except that it also requires BIA assistance and approval of the process.

(5) A representative of the borough commented that relocation cost was an important criterion, which could not be ignored in favor of social concerns or other criteria. He characterized the Kivalina relocation study as a prototype for other village improvement studies which may follow.

(6) A number of Kivalina residents spoke of present difficulties, past storms and high winds, and the need for community solidarity. Long-term erosion in the form of coastal shoreline retreat was described. No accounts were given of inundation of the village, where it now sits. Older structures located seaward of present buildings were apparently hit by wave action several times in living memory.

(7) Some attendees expressed concern about the future of existing village infrastructure during and after village relocation. Howard Holton (USKH), in response to this last concern, spoke of the implementation plan which will be

produced as a part of this project to order development along an affordable and constructible schedule. He also pointed out that the Kivalina community, and in particular its Relocation Committee, would participate in developing the implementation plan. No attendees spoke in favor of the Kivalina River site. Some did not favor the Wulik River site and apparently prefer to stay at the present site.

(8) A second public meeting dedicated to stories by village elders was scheduled for Thursday, August 7, at 1:00 p.m. in the community center.

e. James Sauceda, Jim Martel, Greg Carpenter, Howard Holton, and I walked or were carried by 4-wheelers out beyond the runway to inspect the beach and island in areas of active erosion, and an area that reportedly is overtopped in severe storms. Fresh wave-induced erosion was evident on the seaward side, near the north end of the airstrip. A lower area beyond the airstrip showed some indications of overtopping, but no prominent collections of flotsam or vegetation destruction consistent with massive overtopping. The garbage dump and the honeybucket pit are located on the lagoon side of the runway.

f. Bob Pawlowski accompanied Tim Reed in a search for the "Mound" monument at the north end of the lagoon. The monument was found destroyed. The description mentioned a nearby grave, which was found to be eroded with a human skull exposed. Lack of survey control at this corner of the mapping area was a concern to the surveyors, who knew of no suitable substitute in the area of the project. A monument on the distant mountains appeared to be the next best choice for completing a control survey of the DGPS master station on the school roof.

4. Wednesday, August 6

a. Tom Newman installed hydrographic equipment on a boat chartered from Ted Booth. A tentative arrangement had been made Monday with Bob Hawley, but he could not be reached by phone all day Tuesday nor Wednesday morning. Ted Booth, in the meantime, had offered his 20-ft outboard-powered heavy aluminum boat for service at $45 per hour, including gas. Bob Pawlowski accompanied Tom Newman on hydrographic surveys all around the village, with intermittent stops for collection of seabed samples.

b. Andy Tuthill arrived from CRREL in Hanover at midday. Bob Dugan, Bob Anderson, and Roland Cromwell of Golder Associates arrived Wednesday evening. Additional Golder equipment was scheduled for delivery the next day (Thursday.)

c. The survey team accomplished topographic surveys of the village area and began photo panel placement on the Wulik River. Ron Cothren and I discussed ways to economize and shift emphasis from the Kivalina to the more favored Wulik River. The concept of a road from the existing village or just the other side of the inlet, to the downstream Igrugaivik site and on to the upstream Kuugruaq site was discussed with others of the team. All of us liked this idea.

d. Howard Holton, Jim Martel, Joe Swan, Jr., and Jerry Norton were carried in Caleb Wesley's boat to the Kivalina River, so these two Relocation Committee members could recount conditions they had witnessed at the site in other seasons. They reiterated the severity of strong winter north winds all along the Kivalina River.

5. Thursday, August 7

a. I accompanied Bob Dugan, Roland Cromwell, and Bob Anderson at 9:00 a.m. to visit Betty Swan, city administrator, and discuss changes in the Golder scope of work related to the Corps plans for mapping and other measurements. The Golder contract was officially with the city of Kivalina, although Mark Anderson of NHS provided the funds and technical arrangements. Mark was not available by phone, so Betty approved changes, which brought Golder's plan in line with ours. Specifically, only Section 21 on the Kivalina River north bank would be investigated as a relocation site, though Golder's water supply search with geophysical methods might extend beyond the area mapped for village construction. The area on the Wulik River was agreed to include both Kuugruaq (upstream) and Igrugaivik (downstream), with a view toward a road leading to the inlet (Singauk Entrance) and nearby lakes, drained lake beds, and other surface features.

b. Howard Holton, Greg Carpenter, and I met with the Relocation Committee at 10:00 a.m. Discussions centered on the proposal to limit mapping to Section 21 on the Kivalina River and to extend mapping along the Wulik River to include a prospective road alignment to the spit opposite the present village. The committee asked many questions and had a lengthy discussion in the Inupiat language. Ultimately, they approved the proposal and expressed favor for the concept of a road to initiate development on the Wulik River.

c. Bob Dugan, Bob Anderson, and James Sauceda went by boat to the Wulik River to scan the terrain and plan measurements and sampling. Ron Cothren, Tim Reed, Sam Denny, Andy Tuthill, and Jim Martel went to the Kivalina River site to place aerial photo targets and begin hydrological observations and measurements. Two round trips were made to the Kivalina River by boat. The midafternoon return to the village was to bring Jim Martel in to catch a plane out of town and to pick up Roland Cromwell, who had stayed in the village to meet an additional air shipment of equipment for Golder.

d. Hydrographic surveys and seabed samples were completed. Both Tom Newman and Bob Pawlowski left for Anchorage that evening.

e. Howard Holton, Greg Carpenter, and I attended the meeting of Kivalina elders at 1:00. About 40 residents of all ages attended. Discussions began informally as food was served. Several conference tables were gathered in a square and seats provided for the 17 elders present. These included: Joe Swan, Enoch Adams Jr., Andrew Koenig, Colleen Swan Koenig, Jim Booth, Marilyn Swan Booth, Oscar Swan, Lucy Swan Adams, Betty Norton Swan, Austin Swan, Caleb Adams, David Swan, Rebecca Norton, Lawrence Sage, Mildred Sage, Tommie Adams, and Loise

Hawley. We were invited to sit at the table with the elders, while others sat and stood around nearby. A group of high school students recorded the entire event with two video cameras. Howard, Greg, and I made only occasional comments or questions and left most of the talking to the elders. These old friends and relatives soon became quite relaxed and spent three hours retelling stories of their younger years and stories they had heard from their parents. These tales were hugely entertaining to the Kivalina people in the room. Stories relating to extreme events generally verified and expanded on accounts we had heard earlier about extreme winter winds, shoreline retreat, and difficult times before modern health care was available at Kivalina. Some of the elders remembered the days of reindeer herding, which ended more than 20 years ago. The reindeer were brought from Russia in 1938, according to Oscar Swan. Wild caribou herds apparently absorbed the reindeer, when expenses exceeded income and the reindeer were abandoned. The relocation site name "Kuugruaq" was translated to mean "Old River," supposedly where the main Wulik River channel used to lie. "Igrugaivik" means "loading dock," a place where fish caught from the bank were loaded onto boats.

f. The helicopter from Fairbanks arrived just before 8:00 p.m. with Ed Chacho (CRREL-Fairbanks) aboard. The pilot, Joe Stribrny, left the helicopter unlocked at the airstrip. We looked around areas near the school to consider parking there for the sake of security. He decided to leave it at the airstrip, rather than invite even easier access by village children near the school. We designated a short-term landing site on the beach by the school to be used for picking up our gear and passengers. The helicopter was apparently never disturbed during the nights it was parked at the airstrip, even though village young people were riding around at all hours on their 4-wheelers.

6. Friday, August 8

a. Team members present at breakfast, besides myself, included: Ron Cothren, James Sauceda, Ed Chacho, Andy Tuthill, Tim Reed, Sam Denny, Bob Dugan, Bob Anderson, Roland Cromwell, Greg Carpenter, Howard Holton, and Joe Stribrny. We discussed our goals for the day, which centered on finishing all work at the Kivalina River. The day began with sunny weather, but a fog came from the sea in midmorning, which we feared would hinder helicopter flights. The fog remained just above minimum all day, and no flights around the project were delayed. The fog caused all fixed-wing flights in and out of Kivalina and Kotzebue to be canceled, however. Guy McConnell (Alaska District) was trapped in Kotzebue, and Greg Carpenter and Howard Holton were trapped in Kivalina as a result.

b. The helicopter arrived at the school at 9:00 a.m. to carry the first group to the Kivalina River. Caleb Wesley's jet boat had left at 8:30 to cache bulkier, heavier items at the project site. Helicopter shuttles continued all day. Everyone but me stayed the entire day in the field. Panel placement, river cross sections, and soil sampling were completed on the Kivalina River by 6:00 p.m. Ron Cothren, Tim Reed, and Sam Denny shifted to the Wulik River sites at around 3:00 p.m. to begin panel placements there. They continued work until past 8:00 p.m., also completing the control survey from a couple distant monuments.

7. Saturday, August 9

a. The entire team shifted work to the Wulik River, using the helicopter and Ted Booth's boat for transportation. Bright sunshine prevailed. Panel placements, geophysical measurements, river cross sections and other hydrological investigations, soil sampling, and exploration of the prospective road alignment continued all day with steady service of the helicopter and boat.

b. That morning I had an invitation to visit Mildred Sage, chair of the village Elders Council, at her home. She shared with me more stories of her young days in Kivalina and showed me some photos of these times. Mildred impressed me as a well-educated woman with many years' leadership experience on the Elders Council and in other capacities. I felt privileged to have her attention for the brief time at her home, before I was called away to meet an incoming aircraft.

c. The first plane arrived late morning with Guy McConnell aboard. Greg Carpenter and Howard Holton left for Anchorage on this plane. Guy and I shifted his gear to the school and packed for a visit to the Kivalina River for his reconnaissance of the environment there. We saved water samples for the next day to reduce the holding time. After a low-level helicopter flight over the Wulik River and along the Kivalina River by the site, we arrived near a photo panel at Section 21 at 1:05 p.m. Temperature, conductivity, and salinity were measured with a YSI meter. We spent the next two hours walking the terrain, making photographs, and taking notes. The helicopter came for us about 3:15 p.m. and took us to the Wulik River bank opposite the village water intake apparatus at the upstream Kuugruaq relocation site. We measured water properties again, made photographs, and took notes for about 2 hours at Kuugruaq. Our biological sampling on the Wulik River succeeded in placing fresh Arctic char on the table for the study team later that evening. We hitched a ride with Ted Booth downstream to Igrugaivik about 5:30 p.m. and repeated our observation routine. We met the Golder team at this site and witnessed some of their geophysical measurements. The hydrological team continued river cross sections and current measurements in the same area. The surveyors were placing panel points in the distance. James Sauceda continued to explore the proposed road alignment.

8. Sunday, August 10

a. The helicopter took Guy and me to the Kivalina River at 8:15 a.m. to collect water samples for shipment to an Anchorage lab for testing. The aircraft waited for us during the sampling procedure and then flew us back to the school. Guy dropped off to travel by boat for sampling on the Wulik River. Tim Reed got aboard the helicopter with a RTK-DGPS mobile system. We traveled by helicopter to intermittent points on the marsh to the west (on the opposite side of the lagoon) to measure elevations in the vicinity of old boats grounded there during past storms. Tim successfully measured several profiles that appeared to me to indicate the high water elevations of past storms. The helicopter returned us to the school at about 10:00 a.m., and I released the aircraft from further service. The pilot had to stay for some paperwork and phone calls at the school, then fly to the airstrip for fuel and maintenance prior to the long flight back to Anchorage. The pilot agreed to take Guy McConnell and Bob Anderson as far as Kotzebue, his first planned stop. The helicopter departed about 11:00 a.m.

b. Panel placements, river measurements, and soil sampling were completed. Geophysical measurements continued, but remaining measurements were left in the hands of Roland Cromwell and a hired helper (Caleb Wesley). Bob Dugan left for Anchorage on a 3:30 p.m. flight. Remaining in Kivalina that evening were Ron Cothren, Ed Chacho, Andy Tuthill, James Sauceda, Roland Cromwell, Tim Reed, and Sam Denny. The late afternoon and evening hours were spent packing equipment. James Sauceda made arrangements for airfreight of the heaviest of our equipment that evening, since it became apparent it could not accompany us as excess baggage. We were concerned for its security if we were forced to leave any of it behind on the Kivalina airstrip. The Caravan air cargo plane left for Kotzebue about 8:00 p.m.

9. Monday, August 11

a. I closed the account at the Kivalina store and had an exit interview with Betty Swan. She asked me to write a letter to the State Department of Administration to verify the need for travel support to get the Kivalina Relocation Committee to the October 20 meeting in Anchorage. I agreed to do this. We reviewed the week's activities and preliminary results. We both expressed satisfaction with the end of an exceptionally smooth field operation.

b. Remaining team members, except Roland Cromwell, left Kivalina on the same plane about 9:30 a.m. We arrived in Kotzebue just in time to catch a jet to Anchorage. Ed Chacho, who had to wait longer for a Fairbanks flight, agreed to see our airfreight on to Anchorage. The airfreight all arrived safely the next day.

10. Conclusion.

The Kivalina field expedition was a near-total success. The only measurements left undone were some spot soundings in Kivalina Lagoon. Enough measurements and observation are on record to complete the project with regard to the lagoon's navigability. All other planned observations and measurements were fully accomplished. I attribute this success to training and experience of a fully professional team of specialists, who had good equipment and well defined objectives. The hospitality of Tom Hanifan, Kivalina School principal, made our living conditions and working conditions comfortable. Betty Swan and the other leaders of the community were gracious and cooperative in their support of our work.

Orson P. Smith
Project Manager, Kivalina Relocation Study

APPENDIX L

PLAN IMPLEMENTATION

PLAN IMPLEMENTATION

Kivalina has made the decision to relocate to a new site. Following efforts will be concentrated on implementation of this chosen alternative. Implementation will consist of obtaining additional geophysical information required to finalize a site improvement master plan, preparation of the master plan, securing land transfer agreements and funding to cover the cost of the plan implementation, preparation of the designs, construction of the improvements, and moving selected families and facilities.

The most challenging of these tasks is securing the needed funding. Community expansion or relocation costs on the scale of those described in this report will require funding from a variety of agencies over a period of years. As a consequence, careful coordination and planning between agencies will be necessary to assure funds will be available when needed for a specific capital improvement package.

The table in this appendix outlines a schedule for relocation to the Wulik River (Igrugaivik) site. The agencies responsible for guiding and funding the specific implementation tasks and estimated costs are also listed. Tasks in the table have been phased over a period of time to recognize limitations on available annual funding from the various agencies. The schedule is optimistic in this regard, but nevertheless is achievable, given full support of State and Federal government. Delays are likely in some cases. An aggressive approach to funding requests will minimize these delays.

One consequence of the extended time period required for implementation of either of the two relocation alternatives is the physical separation of residents between the existing and the new sites. Some residents will have moved to the new site while others await construction or relocation of their homes. During this interim period, it will be important to maintain the sense of community with good transportation and communications systems between the sites. Further, utilities and some community facilities will have to be maintained at both sites to varying degrees. The logistics will add to the overall cost of services. Special needs of elders and schoolchildren will also have to be considered. Planning to mitigate the community separation will be part of the implementation element of the master planning process.

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TABLE L-1.--*Implementation schedule for relocation to Igrugaivik (Wulik River) site*

	Task	**Responsible agencies**	**Cost**	**By end of :**
1	Test well and soil samples along road alignment	City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Environmental Conservation (VSW), Native Health Service, Corps of Engineers	$175,000	Year 1
2	Geophysical, topographic, and hydrographic surveys: identify borrow sites and stockpile area	City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Environmental Conservation (VSW), Native Health Service, Corps of Engineers	$75,000	Year 1
3	Complete relocation Master Plan	City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Environmental Conservation (VSW), Native Health Service, Corps of Engineers	$150,000	Year 1
4	Final design coastal access road	Bureau of Indian Affairs, City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Transportation and Public Facilities, Corps of Engineers	$150,000	Year 1
5	Initiate airport master plan, wind measurements, controlled aerial photography and mapping	Alaska Department of Transportation and Public Facilities, Northwest Arctic Borough, NANA	$100,000	Year 1
6	Preliminary design of phase I housing development at Igrugaivik	Northwest Inupiat Housing Authority, City of Kivalina, Northwest Arctic Borough	$300,000	Year 1
7	Coordination, program funding, and related matters	City of Kivalina, Northwest Arctic Borough	$25,000	Year 1
8	Initiate land transfer agreements, easements, and other real estate arrangements	City of Kivalina; Northwest Arctic Borough; Maniilaq, NANA, Bureau of Indian Affairs, Bureau of Land Management	$25,000	Year 1
		Year 1 subtotal	**$1,000,000**	
9	Complete land transfers, easements, and other real estate arrangements	City of Kivalina; Northwest Arctic Borough; Maniilaq, NANA, Bureau of Indian Affairs, Bureau of Land Management	$100,000	Year 2
10	Excavate borrow and place in stockpile	City of Kivalina, Northwest Arctic Borough, Alaska Department of Transportation and Public Facilities, Corps of Engineers	$1,500,000	Year 2
11	Construct access road	Bureau of Indian Affairs, City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Transportation and Public Facilities, Corps of Engineers	$2,500,000	Year 2
12	Final design and initial construction of landfill for community development	Bureau of Indian Affairs, Northwest Inupiat Housing Authority, City of Kivalina, Northwest Arctic Borough, Corps of Engineers	$2,000,000	Year 2
13	Final design and initial construction of water supply and distribution, wastewater collection and treatment, new sanitary landfill, power distribution, and telephone system extension	City of Kivalina, Northwest Arctic Borough, NANA, Alaska Department of Environmental Conservation (VSW), Native Health Service, Corps of Engineers	$1,000,000	Year 2

TABLE L-1.--*Implementation schedule for relocation to Igrugaivik (Wulik River) site*

	Task	Responsible agencies	Cost	By end of :
14	Final design of phase I housing development at Igrugaivik	Northwest Inupiat Housing Authority, City of Kivalina, Northwest Arctic Borough	$400,000	Year 2
15	Final design new airport	Alaska Department of Transportation & Public Facilities	$600,000	Year 2
16	Design of relocation of movable existing buildings	Northwest Inupiat Housing Authority, City of Kivalina, Northwest Arctic Borough	$100,000	Year 2
17	Design of replacement community buildings	City of Kivalina, Northwest Arctic Borough and/or other identified funding agencies	$800,000	Year 2
		Year 2 subtotal	**$9,000,000**	
18	Construct phase I housing development at Igrugaivik	Northwest Inupiat Housing Authority, City of Kivalina; Northwest Arctic Borough	$11,000,000	Year 3
19	Preliminary design of phase II housing development	Northwest Inupiat Housing Authority, City of Kivalina; Northwest Arctic Borough	$300,000	Year 3
20	Relocate movable existing buildings	Northwest Inupiat Housing Authority, City of Kivalina; Northwest Arctic Borough	$800,000	Year 3
21	Construct water supply and distribution, wastewater collection and treatment, new sanitary landfill, power distribution, and telephone system extension	City of Kivalina, Northwest Arctic Borough, NANA, Alaska Village Electric Co-op, Alaska Department of Environmental Conservation (VSW), Native Health Service, Corps of Engineers	$4,000,000	Year 3
22	Initiate construction of new airport	Alaska Department of Transportation and Public Facilities	$4,300,000	Year 3
		Year 3 subtotal	**$20,400,000**	
23	Complete construction of new airport	Alaska Department of Transportation and Public Facilities	$2,000,000	Year 4
24	Initiate design of new school	Northwest Arctic School District, City of Kivalina, Northwest Arctic Borough	$500,000	Year 4
25	Final design of phase II housing development	Northwest Inupiat Housing Authority, City of Kivalina, Northwest Arctic Borough	$400,000	Year 4
		Year 4 subtotal	**$2,900,000**	
26	Final design and initial construction of new school	Northwest Arctic School District, City of Kivalina, Northwest Arctic Borough	$7,000,000	Year 5
27	Construct phase II housing development	Northwest Inupiat Housing authority, city of Kivalina, Northwest Arctic Borough	$7,000,000	Year 5
		Year 5 subtotal	**$14,000,000**	

TABLE L-1.--*Implementation schedule for relocation to Igrugaivik (Wulik River) site*

	Task	**Responsible agencies**	**Cost**	**By end of :**
28	Complete construction of new school	Northwest Arctic School District, City of Kivalina, Northwest Arctic Borough	$7,000,000	Year 6
		Year 6 subtotal	**$7,000,000**	
		TOTAL DEVELOPMENT COST	**$54,300,000**	

APPENDIX M

CORRESPONDENCE

NORTHWEST INUPIAT HOUSING AUTHORITY

P.O. Box 331 • Kotzebue, Alaska 99752 • (907) 442-3450 • FAX (907) 442-3486

December 22, 1997

Mr. Orson Smith, Project Manager
U.S. Army Corps of Engineers
P.O. Box 898
Anchorage, AK 99506-0898

Subj: Comments on Preliminary Draft Report
Kivalina Community Improvements Study

Dear Mr. Smith:

In review of the draft feasibility study and on behalf of the Northwest Inupiat Housing Authority, I offer the following comments specifically pertaining to the housing issue of the document:

1. NIHA currently has title and management responsibilities to only twenty six (26) single family units within the townsite.
2. Your cost estimates for new construction are considerably low in regards to actual construction costs NIHA has occurred in recently completed and ongoing projects. For example, we are currently completing a forty two (42) unit project within three (3) different communities in our region, at an approximate cost of $9.75 million. The units are comprised of 21 each three (3) bedrooms & 21 each four (4) bedrooms with a living area of 1,128 sq. ft. & 1,240 sq. ft., respectively.
3. Your report doesn't specifically state the actual number of new units which will be required for either of the two (2) new sites.
4. NIHA recently received a program reservation from HUD on behalf of Kivalina for the construction of up to fifteen (15) new single family units. NIHA is awaiting the communities' relocation decision prior to discussing the issue of what, when, and where to build these new homes.
5. With the new housing act recently enacted, i.e. NAHASDA, all HUD funds are allocated to eligible recipients on a block grant basis, which means that it will most likely take a special appropriation from the Secretary of HUD to provide additional funds to construct the proposed new units. Under the formulating process of this block grant, the Kivalina IRA Council, or it's designee, is eligible for approximately $380,500, for this coming year, 1998, and it is NIHA's opinion that this amount will not significantly increase in the following years.

For various reasons, primarily limited funding sources, NIHA must take a reactive stance to the final decision made by the community of Kivalina. With budget cuts and the task of meeting the housing needs of the entire NANA region, the likelihood of utilizing all, if not most, of NIHA's funds to one (1) community is slim at best.

NIHA intends to offer any assistance that is within our means, however, we can not at this time or in the near future, financially accommodate the possibility of a move by the community.

I hope these comments heightens your understanding of NIHA, and it's role in this matter.

If you have any questions, and or require further clarification, please do not hesitate to contact me at 442-3450.

Sincerely,

Bill C. Bailey
Executive Director

cc: Kivalina IRA Council
City of Kivalina
Northwest Arctic Borough

FAXED 12/22/97

Kivalina IRA Council
Native Village of Kivalina
P.O. Box 50051
Kivalina, Alaska 99750
Telephone: (907)645-2153
Telefax: (907)645-2193

December 24, 1997

To: Orson Smith, Project Manager
U.S. Army Corps of Engineers
P.O.Box 898
Anchorage, Alaska 99506-0898

Subj: Comments on Preliminary Draft Report
Community Improvements Feasibility Study

Dear Mr. Smith;

After reviewing the report as described above, the Kivalina IRA Council submits the following comments:

From Administration: In listening to the community concerns during public meetings on the relocation/expansion study, I am becoming increasingly agitated with the comments made by agencies involved on costs and feasiblities of certain options. Such comments like, 'this option may cost too much', the agency involved most likely won't like this because of costs', they won't want to build here', Fish & Game won't like this or maybe will be too protective of this area' etc, etc. Well,

1 The agencies involved have for the most part a one time cost. I really don't care how much you end up spending and that is in retaliation to all the tax dollars we've paid to the government to date without really getting anything back. It's about time we got something back. Aside from that, the people of Kivalina will be the ones spending money to live at the site selected. We will be living with the long term expense and problems that may arise. I do not appreciate being told that we need to make our decision in a hurry. We're the ones who will be living with the consequences if our decision should be so hastily made that it becomes an uneducated decision. When I make my decision on the site, it will be a decision I am absolutely sure is the right one and a cost effective one for myself. Most people because of our economic situation can't afford very much at this point in time at our present site. Having the added expenses of water & sewer services and other expenses will be even harder for them. It should be stressed that the move will be to a site that the people can afford to live with. A permanent decision such as

this needs to be the best that it could ever be so don't tell me about government agency concerns about expenses. We've paid our taxes and you've all benefited for decades.

2: We have been living with overcrowded conditions that have caused problems within family structures both physically and mentally. Our living condition has to a certain degree caused a lot of substance abuse problems. This has resulted in a lack of interest in the young people to improve upon themselves. This move to improve the living condition is an opportune time for us to deal with this problem. Careful consideration should be given to contracts to allow for the people's ability to participate fully in the actual work involved without being barred for any cause for reasonable employment.

3: Please consider also other housing construction arrangements in the budgeting of the improvements. HUD housing eligibility requirements are determined by an individuals income status. NIHA will not be able to house a lot of people because they either have no income or will have too much income. For anyone to plan to provide HUD housing to all the people is ambiguous. The people need to be aware of that.

4: If it would help, in lieu of including a decision on a site for inclusion on the draft report, I would suggest including the results of the election that was held initially to get the ball rolling when the people of Kivalina were asked if the City should begin exploring options to improve the living conditions of the people by looking at expansion or relocation options.

From the Council:

1: Land Disposal Ordinances should be in place prior to assignment of lots or prior to the move.

2: Weather changes are causing high winds. Kivalina at it's present site can't survive much longer. (Elder Councilman comment).

3: Global warming will cause the sea to rise. Kivalina at it's present site will not survive.

4: Make training available to prepare young people for jobs by careful consideration on contract bids that allow for OJT's, etc.

Thank you for your consideration of these concerns.

Sincerely,

Colleen E. Koenig, Tribal Administrator

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

NORTHERN REGION PLANNING AND ADMINISTRATIVE SERVICES

TONY KNOWLES, GOVERNOR

2301 PEGER ROAD
FAIRBANKS, ALASKA 99709-5399
PHONE: (907) 451-5150
TDD: (907) 451-2363
FAX: (907) 451-2133

December 31, 1997

RE: Kivalina

Orson Smith, P.E., Ph.D.
U.S. Army CRREL
P.O. Box 898
Anchorage, AK 99506-0898

Dear Dr. Smith:

The following are DOT&PF comments on your December 1997, Draft Community Improvements Feasibility Study for Kivalina, Alaska. That document contains information that should aid the Kivalina community in their decision regarding improvement and/or relocation. It should also help appropriate agencies evaluate their involvement in development of whichever alternative is selected. We understand the funding and schedule related constraints, which were imposed on this study. Our comments are not intended as criticism of the study, but to point out where additional information would be valuable to the selection process. Generally, our comments reflect DOT&PF's role as an agency with substantial responsibility for transportation infrastructure, and for long-term maintenance and operation of the airport.

While these comments will reflect on positive and negative aspects of the three alternatives prescribed, it is not the intent of DOT&PF to steer the community toward any specific choice. Regardless of which alternative they may select, it is our intent to serve the community's transportation needs. We hope that the information we offer will be useful to the community for their decision.

Specific comments:

We expect the permitting process for development of any of the alternatives will be very involved. It will address issues which could not be considered within the level of detail presented in this report, and may lead to stipulations and prohibitions that impose limitations on development of the selected alternative. Major activities, which will require permits, will include material extraction, river/ocean access, construction in wetlands, water supply, and wastewater discharge. The community should be provided with all of the information possible regarding the "permitability" of each alternative.

The study notes the existence of, and the sensitivity of, the designated Wulik River Dolly Varden Overwintering Area. It also notes "restrictions related to mining and gravel extraction in the active floodplain, wastewater discharge, and to flow maintenance." Discussion of these issues needs to be carried throughout the document and a preliminary conclusion regarding compatibility should be offered in discussion of the Wulik River alternative.

As pointed out in recent meetings, a target population of 600 may be appropriate for planning within a finite timeframe, but it should not be allowed to impose a limit on potential community growth. Planning should address the possibility of future growth beyond that level.

The extent to which any alternative could require development and maintenance of erosion or flood protection is critical to the choice of alternatives. Analysis of alternatives should, at a minimum, address capital costs, maintenance costs, agency responsibility and a prognosis for success. It would be ironic, and unfortunate, for a new community to be faced with problems similar to what forced relocation in the first place. Erosion in ice rich ground would be especially critical given the low success rate for protection measures.

ADOT&PF is not able to commit to development or maintenance of substantial erosion or flood control efforts.

A preliminary indication of whether or not withdrawal of 24,000 gallons of water a day from the thaw bulbs of either the Kivalina or Wulik rivers would be permitable should be included in the document. Water withdrawal from fish overwintering habitat is a sensitive issue in arctic rivers.

Discussion of the alternative to improve the existing community site should note the FAA requirement for 5,000' of separation between the runway and the landfill. That separation requirement is not currently being satisfied, and may be difficult to achieve at the current location. We assume that adequate separation would be incorporated into either of the community relocation alternatives.

Note that upgrading the existing airport will not alleviate the existing crosswind condition. Community relocation offers the only practical opportunity for a runway that is appropriately aligned with the prevailing winds.

With regard to phased development of any alternative, it will be important, for budget purposes, to not double up on facilities. This is especially true for the airport. The operational budget is funded for minimal maintenance of a single community airport. We expect construction of a new airport to be contingent on closure of the existing airport.

We recommend using the following airport cost estimate information:

- A new airport (3000' runway) in an ice rich permafrost location would cost approximately $7,000,000. This estimate includes runway, safety area, apron, snow removal equipment, building and access road construction. It also includes insulation to protect the permafrost foundation.

- The same airport on an upland site which is not ice rich would cost approximately $5,000,000.

- A 600' displacement of the existing runway would cost approximately $1,500,000. This estimate includes a 600' runway extension, apron and snow removal equipment building relocation, runway resurfacing and a new runway lighting system. It does not include erosion control.

Cost estimate breakdowns should specifically address development of utility systems and development of a local street system. It is not clear where, or if, those improvements are currently included.

We suggest adding the following factors to your "comparison of alternatives" matrix:

1) **AIRPORT SITE**

- Kivalina Town—Poor. No practical ability to develop a wind-oriented runway.
- Wulik River—Moderate. Appears to require construction and maintenance of an airport on ice-rich ground, probably to west or southwest of community site.
- Kivalina River—Good. Has variety of location, elevation and foundation condition options.

2) **FUNDING** (i.e., factors that might affect the ability to obtain funding for improvements)

3) **DRAINAGE** (i.e., topographic and soil conditions that might complicate or facilitate drainage management)

4) **LONG TERM MAINTENANCE**

- Kivalina Town—Poor. Effort required to maintain beach erosion control and flood control is unknown and could be substantial. There is currently no commitment for maintenance. A utility system within the space and conditions of the existing community may also present long-term maintenance disadvantages.
- Wulik River—Moderate. There is a high potential for foundation permafrost degradation. Technology is available to minimize threat. River erosion is possible, but is not evident at this time. Setback requirements could alleviate hazard.
- Kivalina River—Good. No apparent requirement for flood or erosion protection. Upland site reduces the potential for permafrost degradation.

5) **FOUNDATION CONDITIONS** (based on cursory information)

- Kivalina Town—Good.
- Wulik River—Poor.
- Kivalina River—Good.

6) **MATERIAL AVAILABILITY**

- Kivalina Town—Poor. Would require dredging, or a long haul.
- Wulik River—Moderate/unknown. Would rely heavily on river sources.
- Kivalina River—Good. Offers upland and alluvial options.

7) **CLIMATLOGICAL FACTORS**

- Residents indicate that weather/wind conditions at the Kivalina River site are more severe than at the other two sites. Study should also be done to see if the reliability of air access would be affected by an upland location such as north of the Kivalina River alternative. Also, study should be done to see if coastal fog significantly reduces accessibility to the existing runway.

Ideally, a community relocation decision would be based on more detailed information than could be gathered by this study. Unfortunately, funding is not available for such a detailed comparison of alternatives. Hopefully, this "overview" study will allow the community to make an informed choice. They are the ones who will have to live with the product. None of the alternatives is perfect and complications will surface with the development of any of them. Certainly some adjustments and compromises will be required to achieve any of the alternatives. Hopefully this study will provide adequate information to the community so that they can choose a direction, which will satisfy their needs.

If you need elaboration on any of these comments, or need additional input on any transportation-related aspect of Kivalina development, contact Norm Piispanen at (907) 451-1285.

Sincerely,

Michael D. Gavin, P.E.
Manager
Capital Projects Planning

cc: Chuck Green, Mayor, Northwest Arctic Borough
Betty Swan, Kivalina City Administrator
David Swan, Kivalina IRA

I\p\NP\Kivalina\CRREL

NORTHWEST ARCTIC BOROUGH

P.O. BOX 1110
KOTZEBUE, AK 99752
(907) 442-2500 / FAX 442-2930

Post-it® Fax Note 7671	Date 2/13	# of pages ▸ 4
To Orson Smith	From Chuck	
Co./Dept. Corp Engineers	Co. NWAB	
Phone #	Phone # 442-2500	
Fax # 753-2526	Fax # 442-2930	

Friday, February 13, 1998

An Open Letter to the People of Kivalina

We at the Northwest Arctic Borough are aware of some discussions concerning a move of the Village of Kivalina by some residents to a point closer to or at the Port Site for the Red Dog Mine.

On the surface such a move would seem logical for economic reasons. There might be a tendency for village residents to obtain more employment with the operators of the port site and the mine. In fact, this is false. The hiring offices are not situated either at the port site or the mine.

But, setting that single issue aside for the moment, let us examine the possibilities for a move either TO the port site or CLOSER TO the port site.

The port site is fairly high in comparison to the land to the north of it all the way to Kivalina. Underlying it is terrace bedrock. The LAND, for building purposes, is some of the best available, comparable or superior to the site at Imnaqquq/Sivuchiaq.

On the other hand, the road and the traffic, and the fact that the port site is an industrial "Hard-Hat" area means the village could not be located where children might access the port site or its equipment. The road itself is closed to public traffic by the National Park Service and likely to remain so. The dangers of children's access to industrial traffic and areas and the possible noise and dust problems make being really near the port site unattractive, to say the least.

The access to fishing is limited, requiring a boat or snowmachine trip at the cost of quite a lot of gasoline to access the Wulik or Kivalina rivers.

Barge access is much better, provided that there is room on the backhauls by the ore carriers to supply the village.

Now for the NEAR sites.

From Port Site to Kivalina, there is little to offer that would produce a viable site. Beach sites are flood plain. Inland sites have limited barge access and no good year-round water site, and the cost of a road to access the port site is very high, perhaps several million dollars per mile, because the whole area is wet tundra. Such sites were considered early in the studies and abandoned for that reason.

AT the port site, there are barriers. The land for all other sites considered had a friendly owner, NANA Regional Corporation, working for a better solution for the community. The land at the port site is owned instead by the Federal Government and protected. The mine has a special dispensation for a transportation corridor. IF the National Monument could be persuaded to allow a village, all the Federal environmental laws would have to be observed and no waivers would be allowed. What that means is that it would be illegal to throw away the half-gallon of paint left over from the inside of your house. It would have to be put in an overpack and barged out to a disposal center and the disposal paid for. Batteries would have to be stored and sent out for recycling. Spray cans would require special treatment and paper and plastics would have to be stored and sent out for recycling at Kivalina's expense. The dump would have to have a liner, would have to be covered by a certain depth of mineral material daily, and would have to be closed properly when full. The environmental regulations would mean that Water/Sewer/Garbage service would cost in the neighborhood of $350-$700/month.

There is no identified, reliable water source at the port site that would supply the number of people resident to Kivalina, just as there is none yet for Igrugaiviq. This could mean resorting to desalinization, which typically costs up to $1.00 per gallon. This could further raise water/sewer to about $500-$850/month per household, much more for large households. At least at Igrugaiviq, there could be a summer line to fill a tank from the Wulik.

A previous study for the purpose of setting up a fuel distribution system looked at a port site airport. As that alone it was of questionable economic viability, but as an alternate to Red Dog, which is frequently weathered in, and as a shared airport to the community, it gains a great deal of impetus. It would mean a larger airport.

So there are the pros and cons. The "stoppers" on the consideration were the land ownership, extremely unlikely to grant space for Kivalina, and the regulations that would apply IF ownership were granted. Keep in mind that if a township were granted, all the property there would be unprotected.... None would be NANA land, and anyone with enough money could start squeezing out the village residents by buying the land at auction, or guaranteeing debts local people could not pay, and so on.

Finally, it is unwise to bring this issue to fore as if it had not been previously considered for it could weaken Kivalina's position on selecting a site and moving. At the moment, the political situation favors Kivalina's finding the money to move to a new site and build a model village, but that window is fast closing. To discuss this issue, which isn't apparently achievable without many years of negotiation could mean that Kivalina, whose people want to move, might get a site and be unable to move because no monies would be available to fund it.

Sincerely,

Chuck Greene
Mayor

ISSUE	PRO	CON
Economy--Jobs Access	Closer to potential work sites	Hiring is still done remotely with respect to the village
Flood Plain	Out of Flood Plain	
Water Source		None identified. Could cost $1/gallon or more. No near source for good ice.
Land for building	The best available--comparable to Imnaqquq/ Sivuchiaq	
Land Ownership		A serious barrier--Port Site is within a national monument. Could take 5-10 years to get an ANSWER, no guarantee it will be yes.
Environment		Dust could be a serious problem. Environmental regularions would be strictly enforced causing many many new costs, driving Water/Sewer/Garbage service prices to $500/month or more
Barge Access	GREAT	May not be able to carry all village needs
Access to Fish		People would have to go back to Kivalina sites to get fish.

KIVALINA CITY COUNCIL

P. O. BOX 50079
KIVALINA, ALASKA 99750
(907) 645-2137 FAX (907) 645-2175

RESOLUTION NO. 98-01

A RESOLUTION OF THE JOINT MEETING OF THE CITY AND IRA COUNCIL'S OF KIVALINA RATIFYING THE KIVALINA RELOCATION ELECTION PROCESS.

WHEREAS: The Native Village of Kivalina is a Federally recognized tribe and the Kivalina IRA Council is the governing body of the Native Village of Kivalina; and

WHEREAS: The Kivalina City Council is a municipal government for this community; and

WHEREAS: The joint council and relocation committee held a public meeting on January 23, 1998 to place the matter of Site Selection for Kivalina Relocation up for special election; and

THEREFORE BE IT RESOLVED: the City of Kivalina and the Kivalina IRA Council ratifies the election process.

PASSED and APPROVED BY the Joint Council this 26th Day of January 1998, by a vote of 11 yays 0 nays.

SIGNED: Oran Sage Sr
Mayor

SIGNED: [signature]
President

SIGNED: [signature]
City Clerk

SIGNED: [signature]
Secretary/Treasurer

KIVALINA RELOCATION ELECTION COMMITTEE
P.O. BOX 50079
KIVALINA, ALASKA 99750

NOTICE OF ELECTION

Notice is hereby given that on Thursday, February 26, 1998 a special election of the City of Kivalina, Alaska, will be held for the purpose of selecting a site for Community Improvements:

(A) IGRUGAIVIK (Wulik River)
(B) IMNAAKUQ (Kivalina River)
(C) CURRENT SITE (KIVALINA)

Voter Qualifications: "Voter" means a United States citizen who is 18 years of age, a qualified to vote in local elections, who is a permanent resident of the municipality for 30 days immediately preceding the election.

IN THE EVENT THAT THERE IS A TIE AND/OR THE SELECTION DOES NOT RECEIVE 50 PERCENT PLUS 1 OF THE TOTAL VOTES, A RUN-OFF ELECTION WILL BE HELD 8 DAYS FOLLOWING THE DATE OF THE FIRST ELECTION, WHICH IS MARCH 6, 1998. ANY QUESTIONS REGARDING THE 1998 SPECIAL ELECTIONS PLEASE CALL THE ELECTION COMMITTEE.

The Polling Place: New Community Building

The Polls will be open from 8:00 A.M. until 8:00 P.M. on election day.

Dated this January 26, 1998

[signature] 1-26-98

ATTEST: Secretary DATE

KIVALINA RELOCATION
ELECTION BALLOT

Fold ballot to this line　　　　　　　　　　　　　No. ____

Special Election Ballot　　　　　　　　　　　　**Kivalina, Alaska**

February 26, 1998

Mark only by use of "X" marks. Place marks in squares at the left of the sites or issues that you wish to vote for.

Mark must be inside or touching the square so that it shows the intent of the voter.

"VOTE FOR ONE SITE ONLY! BALLOTS WITH MORE THAN ONE SITE SELECTED WILL NOT BE COUNTED".

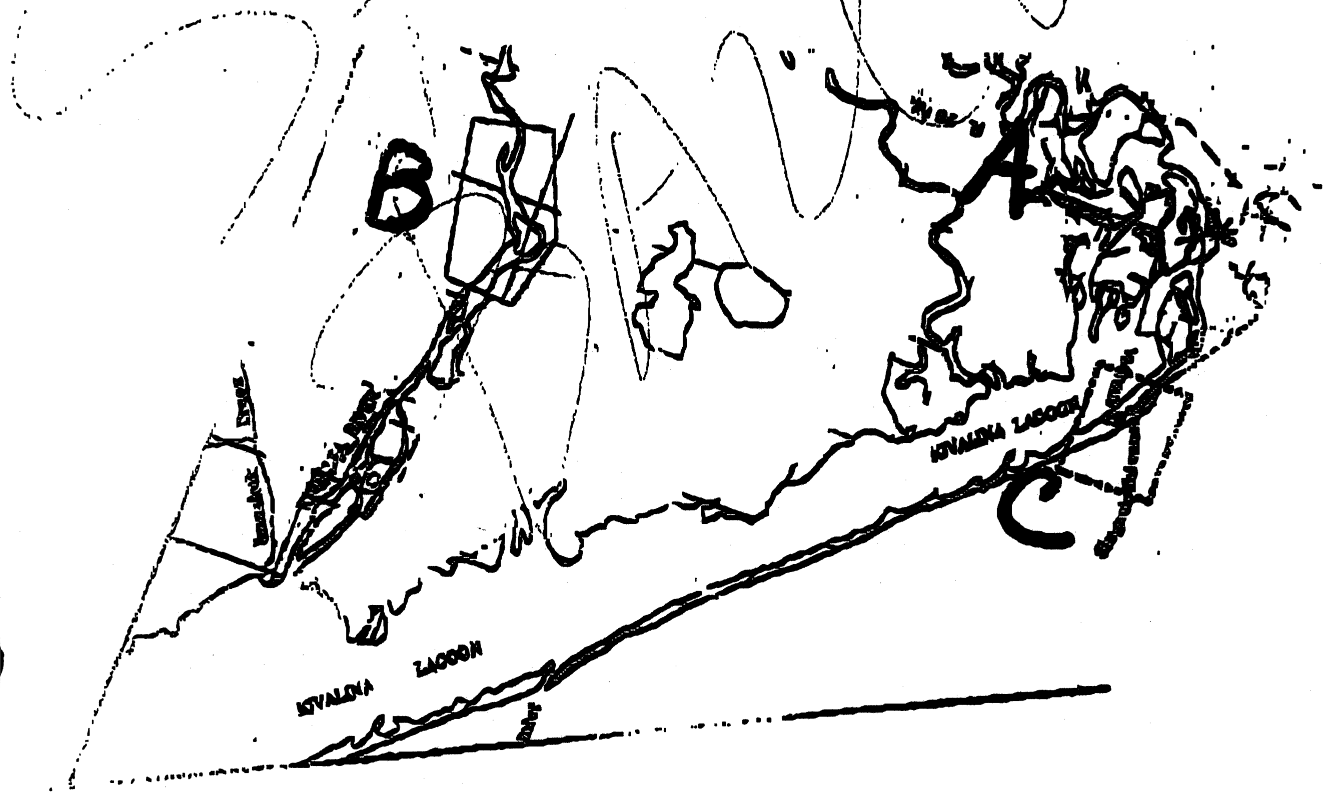
If you spoil your ballot, give it back to one of the election judges and get another ballot. Your spoiled ballot will be destroyed while you are with the judge.

☐ IGRUGAIVIK (Wulik River) - Site A

☐ IMNAAKUQ (Kivalina River) - Site B

☐ CURRENT SITE (KIVALINA) - Site C

MAP



KIVALINA CITY COUNCIL
P.O. BOX 50079
KIVALINA, ALASKA 99750

MEMORANDUM

TO: KIVALINA IRA/CITY COUNCIL Members

FROM: Betty Swan, Administrator

DATE: March 4, 1998

SUBJ: Special Meeting - CERTIFY SPECIAL ELECTION

Please be advised that there will be a Special Meeting between the City Council, Kivalina IRA Council, Relocation Committee, on **March 6, 1998, at 9:30 a.m.** at the City Office Conference Room. Purpose of this meeting is to certify the February 26, 1998 **SPECIAL ELECTION**.

If you have any problems or if you have any questions, please contact me at the office. Thank you.

KIVALINA CITY COUNCIL

P. O. BOX 50079
KIVALINA, ALASKA 99750
(907) 645-2137 FAX (907) 645-2175

RESOLUTION NO. 98-02

A RESOLUTION OF THE JOINT MEETING OF THE KIVALINA IRA AND CITY COUNCIL AND RELOCATION COMMITTEE CERTIFYING THE SPECIAL ELECTION OF FEBRUARY 26, 1998.

WHEREAS: The Kivalina Relocation Committee is the Planning Committee for this community; and

WHEREAS: The Kivalina City Council, IRA Council and the Relocation Committee have met and placed the matter of KIVALINA RELOCATION up for special election which was held; and

THEREFORE BE IT RESOLVED: the Joint Councils hereby certify the special election held February 26, 1998 and final results are:

Igrugaivik (Wulik River) Site A	85
Imnaaquq (Kivalina River) Site B	25
Current Site (Kivalina) Site C	19

PASSED and APPROVED BY the ________ this 6th th Day of March 1998, by a vote of 17 yays 0 nays.

SIGNED: [signature] President Attest: [signature] Secretary

SIGNED: [signature] Mayor Attest: [signature] Clerk

SIGNED: [signature] Relocation Committee Chair Attest: [signature] Secretary