KOTLIK, ALASKA
COASTAL EROSION STUDY

Prepared For:

Department of the Army
Alaska District, Corps of Engineers
P.O. Box 898
Anchorage, Alaska 99506-0898

Prepared By:

R&M Consultants, Inc.
5024 Cordova Street
Anchorage, Alaska 99503

November, 1986

KOTLIK, ALASKA

COASTAL EROSION STUDY

Prepared For:

DEPARTMENT OF THE ARMY
P.O. Box 898
Anchorage, Alaska 99506-0898

Prepared By:

R&M CONSULTANTS, INC.
5024 Cordova Street
Anchorage, Alaska 99503

November 1986

KOTLIK, ALASKA
COASTAL EROSION STUDY

TABLE OF CONTENTS

KOTLIK, ALASKA
COASTAL EROSION STUDY

1.0 INTRODUCTION

1.1 Study Authority

This report is submitted in partial response to a resolution of the committee on Public Works of the U.S. House of Representatives, adopted 2 December 1970, which reads:

> Resolved by the committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports of the Chief of Engineers on Rivers and Harbors in Alaska, published as House Document Numbered 414, 83rd Congress, 2nd session; Cook Inlet and Tributaries, Alaska, published as House Document 34, 85th Congress, 1st Session; Copper River and Gulf Coast, Alaska published as House Document Numbered 182, 83rd Congress, 1st session; Tanana River Basin, Alaska, published as House Document Numbered 137, 84th Congress, 1st session; Southwestern Alaska, published as House Document Numbered 390, 84th Congress, 2nd session; Northwestern Alaska, published as House Document Numbered 99, 86th Congress, 1st session; Yukon and Kuskokwim River Basins, Alaska, published as House Document Numbered 218, 88th Congress, 2nd session; and other pertinent reports with a view to determining whether any modifications of the recommendations contained therein are advisable at the present time.

1.2 Scope of Study

This study includes an analysis of the elements necessary to assess the extent of existing, potential and projected coastal erosion problems at Kotlik, Alaska. The study elements have included: (1) a literature search, (2) a site visit, and (3) an in-office analysis of pertinent data.

The scope of work includes:

A. A community profile which includes general economic and governmental information as well as climatological, geological, oceanographic, land ownership, material sites and cultural resources.

B. Described the existing erosion problem. Identify threatened facilities and/or structures and a projected date of loss without protective action will be documented.

C. Identify and describe previous erosion studies and projects.

D. Discuss potential alternatives, including no action, relocation and structural solutions. Perform an economic analysis will be performed to compare alternatives.

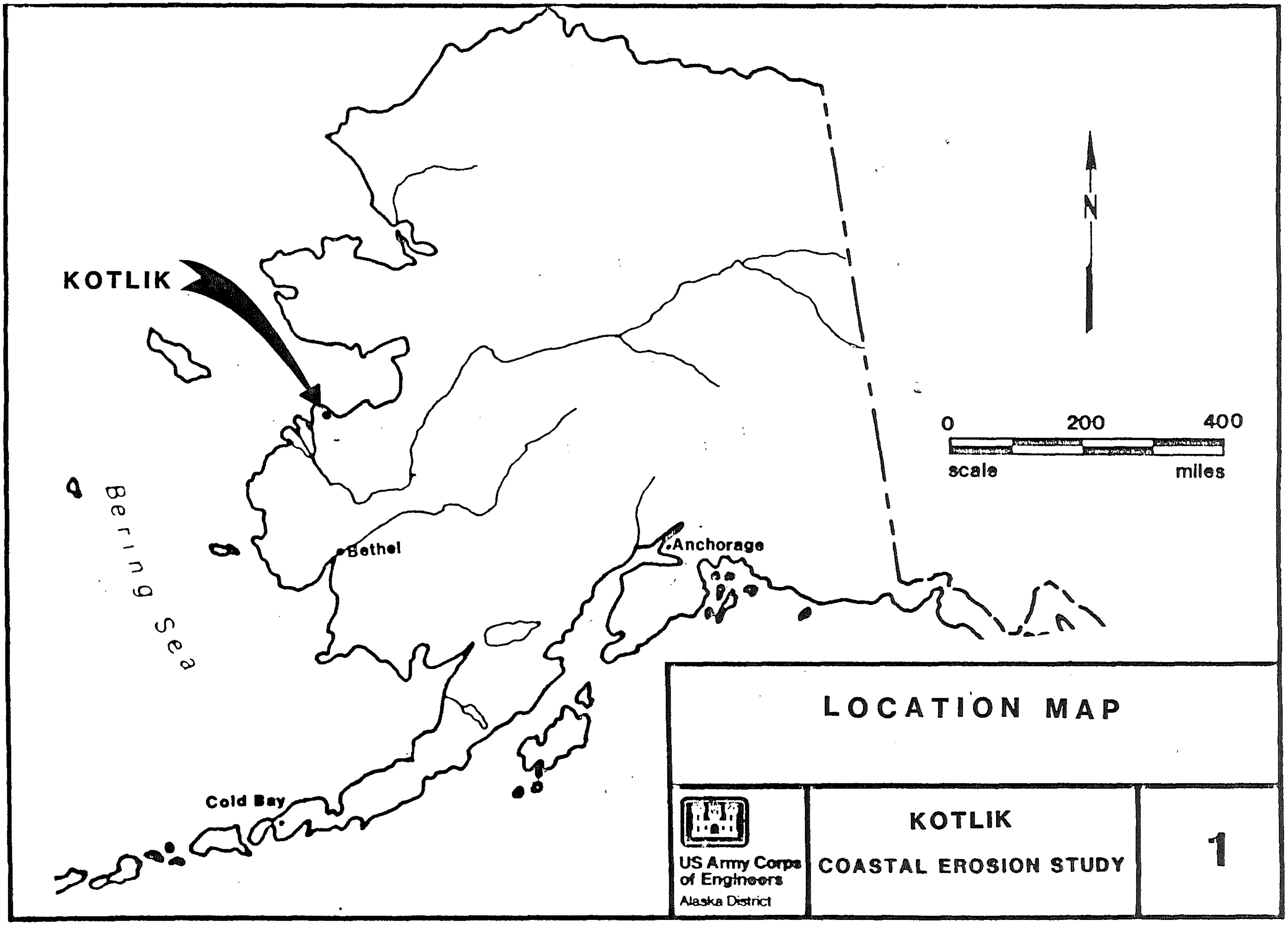
1.3 Study Objectives

The objective of this work is to develop physically and economically sound solutions to coastal erosion problems at Kotlik. The proposed solution, or recommended plan, is to be based on the definition of existing conditions an assessment of probable future damages due to coastal erosion processes and physical and economic analyses.

2.0 COMMUNITY DESCRIPTION

2.1 Location

Kotlik is located along the northern margin of the Yukon River Delta in western Alaska. The community is situated approximately five miles inland from the southern coast of Norton Sound where the Kotlik and Little Kotlik Rivers empty into Apoon Pass, a distributary of the Yukon River (see Figure 1). Kotlik is 35 miles northeast of Emmonak, 105 miles southwest of Unalakleet, 167 miles northwest of



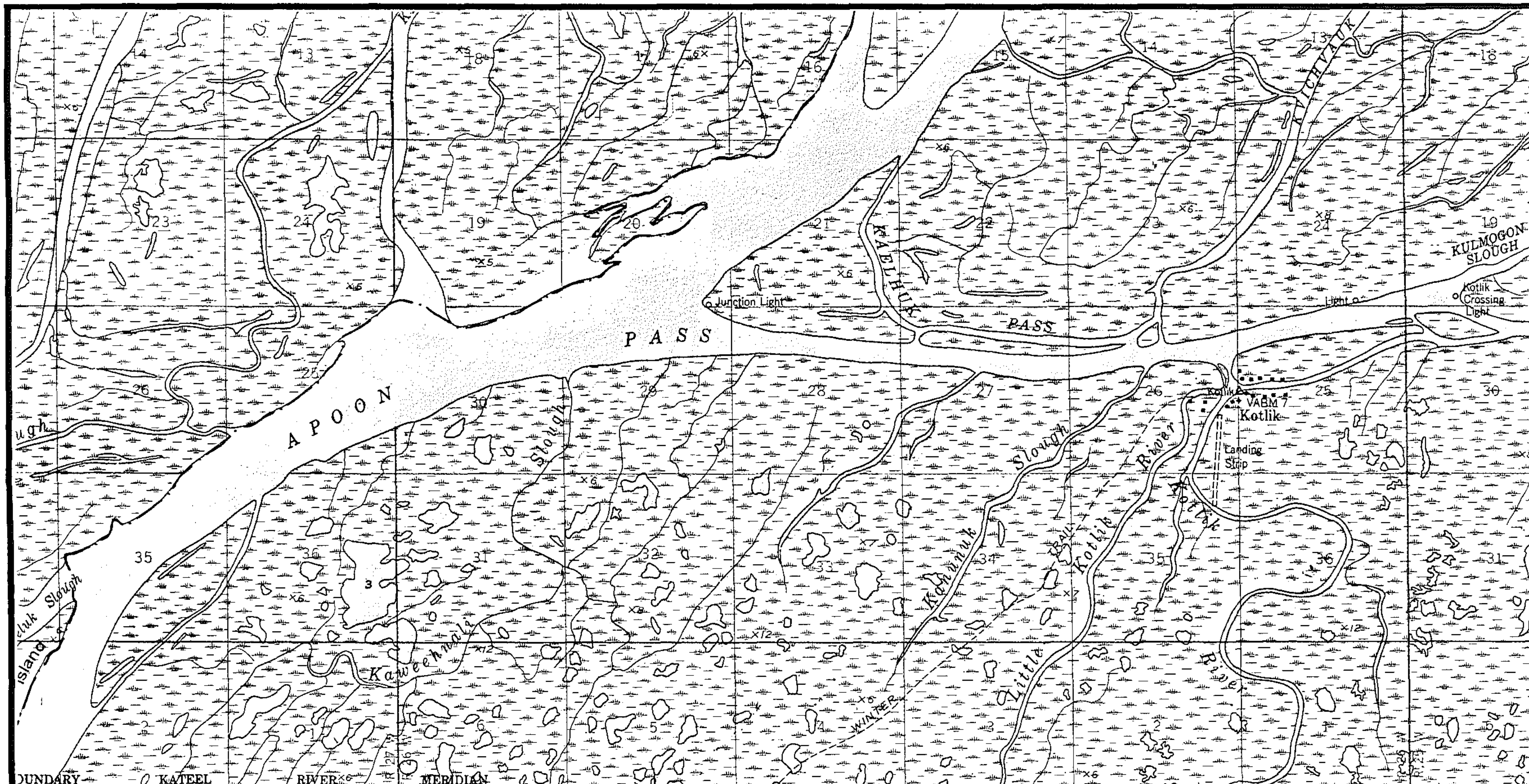
LOCATION MAP

KOTLIK

COASTAL EROSION STUDY

1

95796



VICINITY MAP

US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

2

Bethel and 460 miles northwest of Anchorage. See the Location Map and Vicinity Map in Figures 1 and 2.

2.2 Population

A 1985 census by the City of Kotlik recorded a population of 414. With the 1970 population of 305, the annual population growth rate was 2.1 percent.

2.3 Government

Kotlik was incorporated in 1970. The second class city has a seven member council that meets twice a month. Regular city council elections are held in October. The city owns its electric utility and a washeteria. City officials include a mayor, vice mayor, clerk, two health aides and a police chief. A two percent sales tax is levied.

Native residents of Kotlik are shareholders in the Kotlik Yupik Corporation. This organization was incorporated in accordance with the terms of the Alaska Native Claims Settlement Act (ANCSA).

2.4 Economy and Employment

The economy of Kotlik is similar to many of the other cities and villages on the lower Yukon River: June through August is fishing season. Several species of salmon are caught and sold to buyers. Other employers include two general stores, an elementary school, a high school, the city, a clinic, and a post office. Total government employment was about 23 in 1980. Non-government employment information was not available.

2.5 Climate

The climate of Kotlik is subarctic, which is characterized by cool summer temperatures and cold winters. Temperatures range between

-50 degrees F and 87 degrees F (Unalakleet data). Kotlik averages 60 inches of snowfall and 16 inches of precipitation annually.

2.6 Regional Geology

The community lies on the banks of Kotlik slough and the topography consists of gently rolling to level delta, low terraces, broad shallow depressions, and swampy floodplains are typical of the surrounding landscape. There is a drainage problem in the city because the elevation of the surrounding area is not sufficient to facilitate adequate run-off. The active layer in the area ranges between 1½ to 3 feet. The soils are formed from stratified silts and sandy lacustrine deposits or alluvial sediment. The soil is ice rich and frost susceptible.

Soils data are available from several investigations conducted as part of either state or federal construction projects at Kotlik. Howard Grey and Associates, Inc. (1980) completed 8 borings to a maximum depth of 10 feet at a number of locations along the entire waterfront. All borings encountered approximately 12 inches of organic peat underlain by silts containing organics and some clay. Grain size analysis indicated that 95 percent or more of materials sampled passed the #200 sieve. Silts were observed to be medium soft to medium stiff, wet and highly frost susceptible. Permafrost was not observed in any of these shallow borings.

McLaughlin (1982) reports the results of two borings, 11 and 24 feet deep, obtained in an area south of the school. Permafrost was not found in either hole, but the water table at both locations was observed close to the ground surface. In both holes, organic brown silts were observed from the surface to the bottom of the borings.

2.7 Coastal and Hydraulic Processes

The Apoon Pass of the Yukon River and the Kotlik and Little Kotlik Rivers in the vicinity of Kotlik are all tidally influenced due to the relatively low topographic relief of the area. Tides at Kotlik have a diurnal range on the order of 4 feet, although tides are greatly affected by winds which are sometimes strong enough to entirely obliterate these astronomical tides (National Oceanic and Atmospheric Administration, 1980). According to local residents, daily predictions for times of high and low water at Kotlik may be estimated by subtracting 2 hours and 20 minutes from tide tables for St. Michael. Corrections for the St. Michael tides are reportedly not required to predict tidal elevations at Kotlik.

The estimated tidal data for Kotlik (based on St. Michael) is shown below.

MHHW	1.6 feet
MSL	0.8 feet
MLLW	0.0 feet
ELW	-2.5 feet (est.)

Tides during the field trip period of 20 and 21 September, 1986 as obtained from tide tables were as follows:

20 September 1986	21 September 1986
03:49 + 1.5 feet	05:08 + 1.2 feet
09:28 + 2.6 feet	10:27 + 2.2 feet
15:39 + 1.1 feet	15:38 + 1.3 feet
20:21 + 3.0 feet	20:46 + 3.04 feet

Currents at Kotlik include both the effects of river flows and tidal effects. During the ebb tide, currents past Kotlik are typically 2 to 3 knots to the north or east. With a flood tide, currents are typically 1.5 to 2 knots to the west or south. Information is not available regarding currents occurring during flood events.

Storm surges in combination with high tides reportedly cause flooding at Kotlik. Flooding from these combinations of events may result in flooding to an elevation of approximately 6 to 6.5 feet above mean sea level. Storm surges which affect Kotlik normally occur with a southwest wind and are sufficient to inundate all but the northwest area of the community. The last reported storm surge occurred in the late 1970's.

Based on conversations with local residents, waves present in the Kotlik River in front of the community may be a result of either winds or boat traffic. North winds reportedly produce waves 1 to 1.5 feet in height while southwest winds in combination with a flood tide produce wave heights of 1 to 2 feet.

The hydraulics of the Kotlik area are dominated by the Yukon River. The annual flow regime of the Yukon fluctuates dramatically with relatively low flows in the winter, and an order of magnitude higher flows in the summer. River flooding in the Yukon Delta normally occurs during either the spring snowmelt and river breakup or during summer rainstorms. During springtime, snowmelt and precipitation create rapid increases in streamflow. Snowmelt is more pronounced in the upper reaches of the watershed where springtime temperatures are generally higher than along the Lower Yukon and in the Delta region. Upstream snowmelt causes the river to rise until sufficient forces exist to break up and flush ice from the river channels. In the lower portions of the Yukon, ice remains strong later into the year because of the colder temperatures, and ice jams occur where the stronger ice will not yield. Gradually, the breakup front works its way downstream into the delta in a series of surges as ice jams weaken and give way to the breakup flows. Near the coastline the breakup front is slowed down due to the flat river gradient. Ice jams in delta channels and at the ocean front can cause extensive backwaters and flooding.

During breakup, which usually occurs in late May, most of the delta area is subject to flooding. The Kotlik area is, however, somewhat fortunate as ice jams and associated flooding have not been reported for the area in the past 20 years. In early 1960's there was, however, some apparent ice jamming on the Apoon Pass downstream of Okwega Pass (approximately 3 nautical miles upstream from Kotlik). It has also been reported that ice jamming occurs intermittently along the reach of Apoon Pass between Nagachik and Hamilton (approximately 15 nautical miles from Kotlik).

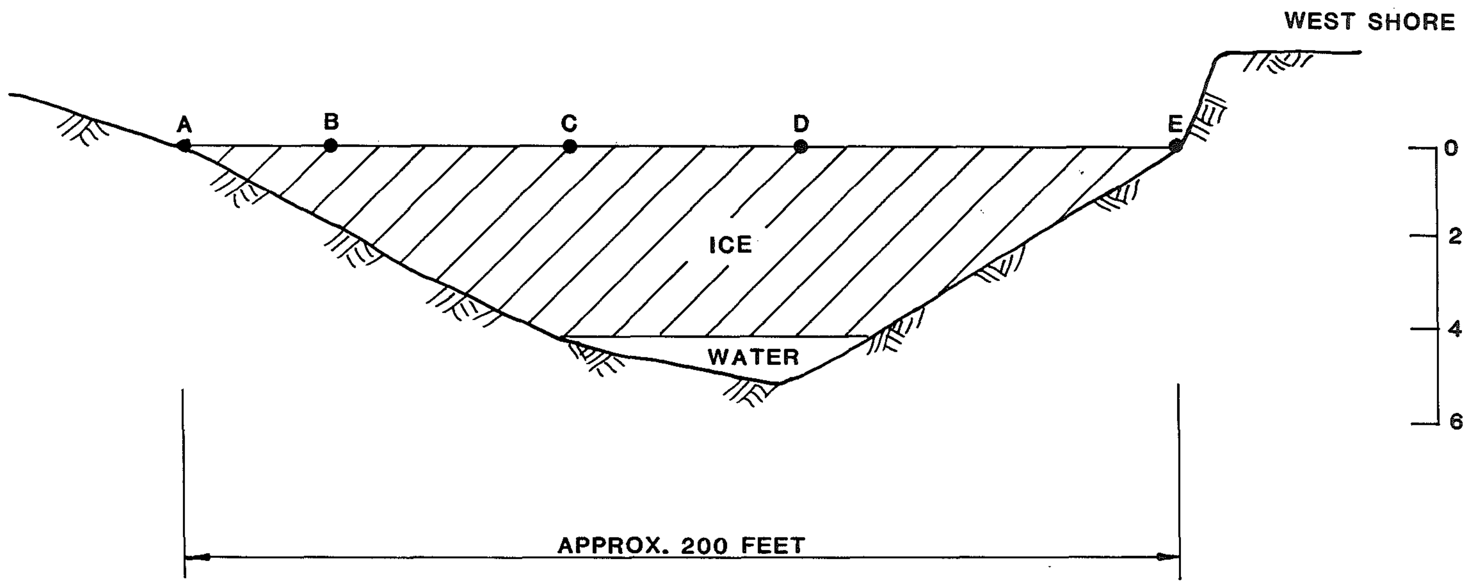
Following ice breakup, snowmelt and precipitation in higher elevations of the Yukon basin will normally continue to increase river flow through June. Flows then decrease due to the normal warm and dry Interior weather during July. During August, rainfall will again increase flow, but no significant flooding of the delta area generally results. Flow decreases through September and and ice cover forms normally during late October to mid-November.

2.8 Shoreline Characteristics

Bathymetric and topographic survey data are not available to adequately describe the configuration of the Kotlik River in the vicinity of the community. Most of the shoreline is bordered by near vertical banks 3 to 6 feet in height. The organic and organic silt banks also have as much as 3 to 4 foot wide sections caving from the banks.

NORTEC, in 1983, augered several holes through the ice to obtain water depths at a cross-section on the Kotlik River approximately 50 feet upstream of the mouth of the Little Kotlik River. This data is presented in Figure 3.

95796



STATION	DEPTH
A	0 ft.
B	1.9 ft.
C	4.2 ft.
D	5.0 ft
E	0 ft.

FROM: NORTEC 1983

KOTLIK RIVER CHANNEL CONFIGURATION

(50 ft upstream of Little Kotlik River)

US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

3

Two bank profiles were also obtained for this study and are shown in Figure 4. Profiles were obtained at locations noted on Figures 5A and 5B.

2.9 General Information

As there are no roads in the community, principal land use revolves around the waterfront, which supports most of the local commerce and allows access to commercial and subsistence fishing and hunting areas. Other land uses include the local airstrip, which provides freight, passenger and mail service on a daily basis. Additional public buildings including the schools, teachers' quarters, city offices, washeteria, and clinic account for additional public land usage which is integral to the residential area of the community.

3. PROBLEM IDENTIFICATION

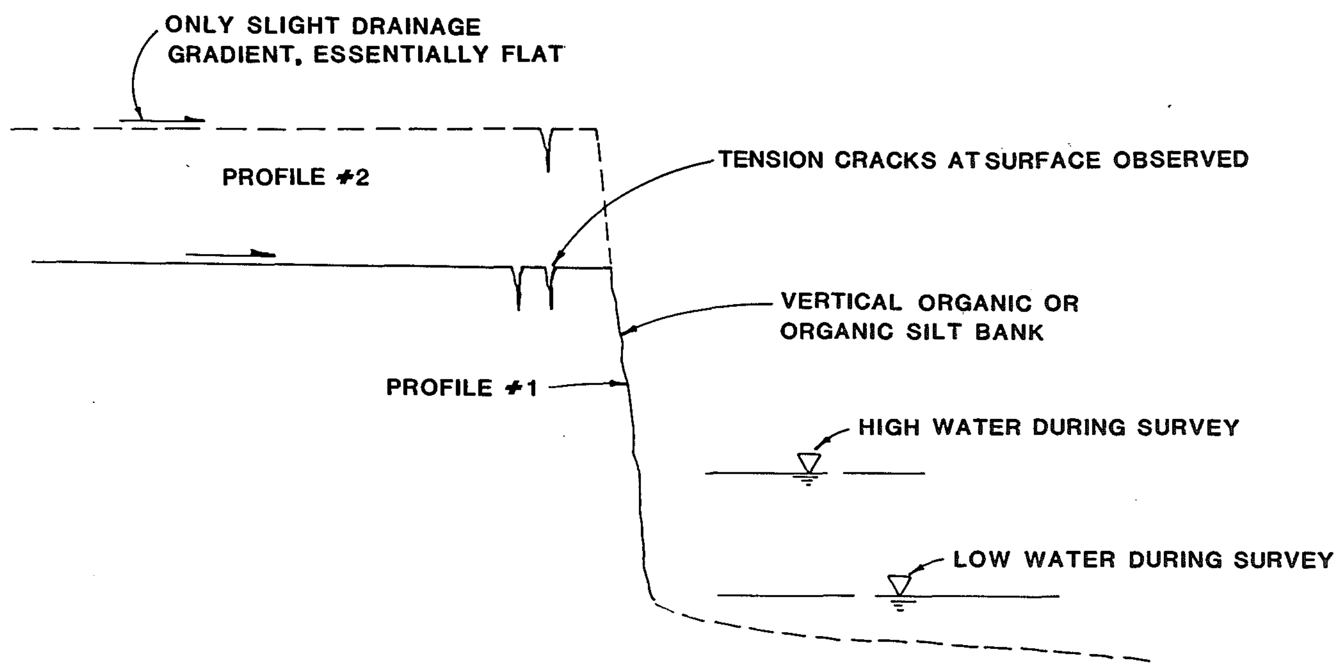
3.1 Problem Description

Based upon field observations and interviews with local residents conducted during the field trip on 20 and 21 September, 1986, Kotlik has severe bank erosional problems along the full extent of the shoreline fronting the community. Residents noted that an estimated 3 feet of shoreline per year is lost to erosion.

Erosion at Kotlik occurs along most of the community's waterfront area. Actual annualized erosion rates vary from less than 0.5 to 8.8 feet per year (NORTEC, 1983). Approximately 3,000 feet of river bank is eroding at an average rate of over 3.5 feet per year and for the most part is centered in the vicinity of the confluence of the Kotlik River, Little Kotlik River and Apoon Pass Slough.

Existing buildings which may be threatened by erosion within the next 50 years are both publicly and privately owned. Publicly owned

95796



NOTE: FLOOR OF SCHOOL BUILDING 43' FROM EDGE OF BANK WAS 11.3' ABOVE LOW WATER SHOWN. FLOOR OF SCHOOL ABOVE MAXIMUM FLOOD LEVEL.

SCALE:
HORIZONTAL 1"=2'
VERTICAL 1"=2'

EXISTING NATURAL SHORELINE PROFILE

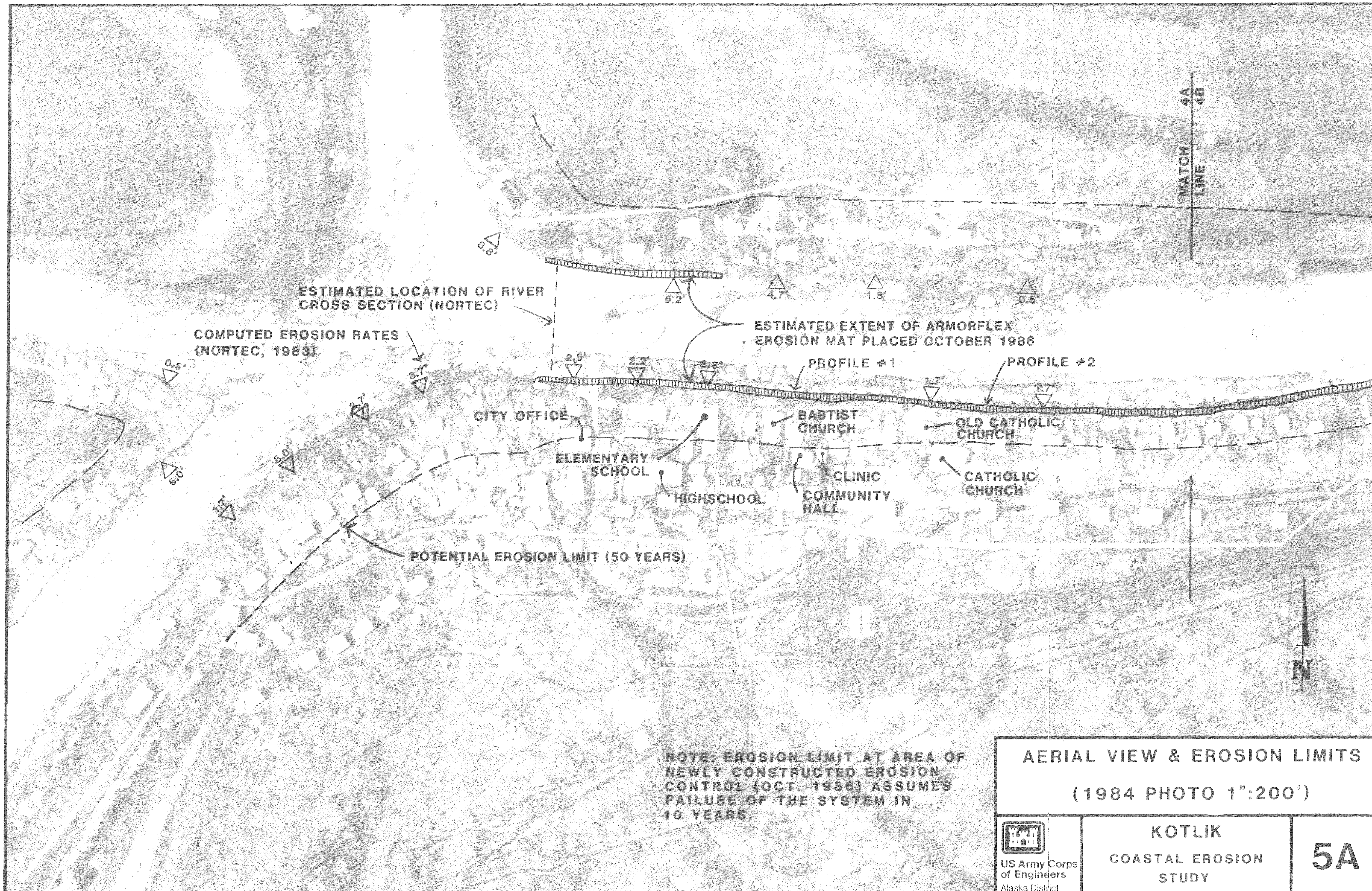
US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

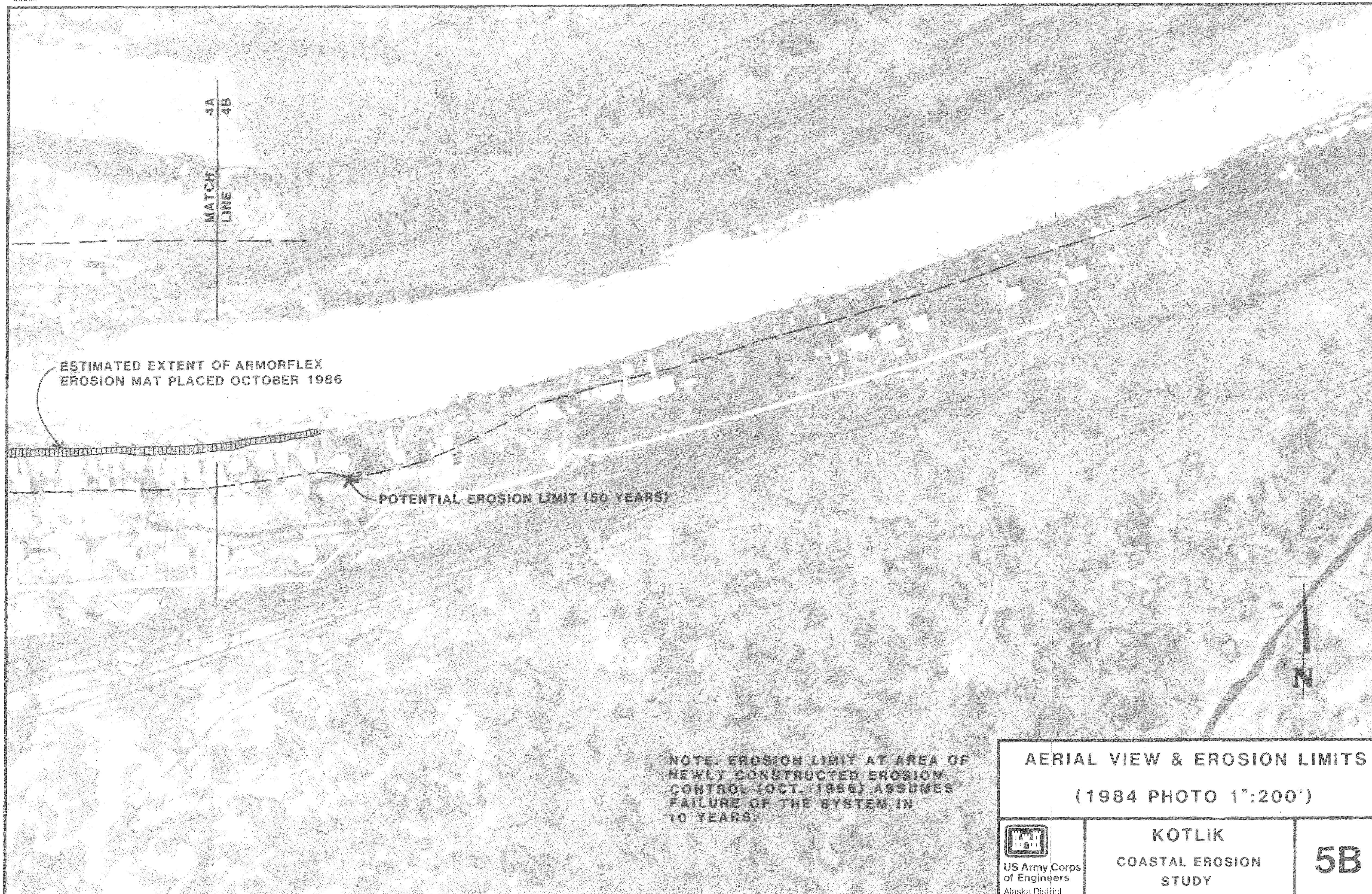
4

95866



MATCH LINE
4A
4B
ESTIMATED LOCATION OF RIVER CROSS SECTION (NORTEC)
COMPUTED EROSION RATES (NORTEC, 1983)
ESTIMATED EXTENT OF ARMORFLEX EROSION MAT PLACED OCTOBER 1986
PROFILE #1
PROFILE #2
8.8'
5.2'
4.7'
1.8'
0.5'
0.5'
2.5'
2.2'
3.8'
1.7'
1.7'
3.7'
2.7'
8.0'
5.0'
1.7'
CITY OFFICE
ELEMENTARY SCHOOL
HIGHSCHOOL
BABTIST CHURCH
OLD CATHOLIC CHURCH
CLINIC
COMMUNITY HALL
CATHOLIC CHURCH
POTENTIAL EROSION LIMIT (50 YEARS)
N
NOTE: EROSION LIMIT AT AREA OF NEWLY CONSTRUCTED EROSION CONTROL (OCT. 1986) ASSUMES FAILURE OF THE SYSTEM IN 10 YEARS.
AERIAL VIEW & EROSION LIMITS
(1984 PHOTO 1":200')
US Army Corps of Engineers
Alaska District
KOTLIK
COASTAL EROSION STUDY
5A

95866



AERIAL VIEW & EROSION LIMITS

(1984 PHOTO 1":200')

US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

5B

threatened buildings include part of the school complex, the Baptist Church, Catholic Church, old Catholic Church, health clinic, community hall, and the city office building. Forty-five privately owned residences and a commercial building (Hunt's Store) also may be threatened by erosion within the next 50 years.

Previous erosion control reports have concluded that erosion at Kotlik is a result of two major factors:

1) Wake erosion from small boat traffic, and
2) Wave erosion during periods of high winds.

It has been determined that the boat wakes are presently about three times as important in causing erosion as are wind waves. Flooding associated with breakup in the Kotlik area does not appear to contribute to erosion of river banks. This is probably due to the fact that river banks are still frozen during breakup, and therefore, resistant to erosion by either river ice or water.

River currents during both flood and ebb tide periods appear to have relatively little effect on erosion of river banks. This is substantiated by the fact that erosion is occurring on both sides of the Little Kotlik and Kotlik Rivers and the inside and outside of meanders at approximately equal magnitudes.

3.2 Previous Studies or Erosion Projects

A detailed erosion study, "Kotlik Erosion Control Study", was performed by NORTEC under contract to the Alaska Department of Transportation and Public Facilities (ADOT/PF) in 1983. Since the larger budget for that study allowed a considerable level of effort in determination of erosion rates and alternatives, much of that information was used in this study.

Kotlik was also included in the Alaska DOT/PF 1983/84 Task Force on Erosion Control project. The inventory team visited Kotlik on 12 September, 1983. This program agreed with the findings of the earlier NORTEC report. The task force report recommended protection alternatives including concrete erosion control mat or a pile/fascine revetment system. The latter system entails driving shallow piling at 8 feet(±) on center along the bank, behind which are placed willow branches. Sand bags were then to be placed on top of the branches for anchorage. The concrete erosion control mat recommended was similar to the articulated concrete mat system discussed elsewhere in this report.

3.3 Present Construction

Apparently as a result of these two studies, Kotlik received a direct grant from the State of Alaska for the purpose of airport improvements and erosion control. Kotlik reportedly received $2 to $3 million. The portion of the grant spent for airport improvements was not sufficient to complete the airport work. Other money was spent constructing a benched timber retaining wall bulkhead along the bank for erosion control. Only a short portion was installed, but it was destroyed by ice action and was washed away during breakup. The contractor performing the airport work and timber erosion control was terminated. With the unspent grant monies, Kotlik then hired another contractor, Cowdery Excavating and Construction Company (Coexco) to construct a concrete mat erosion control system. Coexco was to have been constructing the system during our field visit; however, the barge of materials was delayed so Coexco had stopped work and returned to Anchorage. There were no engineered drawings of the proposed installation. The Vice Mayor, Jim Akaran, said that they had bought 20,000 square feet of Armorflex and were going to install it in such a manner as to maximize the length of shoreline protected.

Since no work was completed and no engineered plans of future work are available. It is difficult to estimate the adequacy of the system. Communications with Coexco indicate that the project is complete. The installation was reportedly completed similar to that shown in Figure 6. The contractor installed Armorflex Class 55 (the heaviest units available in Anchorage) over a geotextile fabric laid upon a 1.5:1(±) slope. The slope was formed by pulling down the existing organic silt embankment by hand tools or a low pressure dozer. The Armorflex blocks were placed by hand and threaded together with wire rope. Anchorage at the top of the slope was provided by Armorflex block deadmen at 15'(±) on center. A 1" diameter rebar was also driven near the top at 4'(±) on center for additional anchorage. The estimated extent of the current installation is shown in Figures 5A and 5B. The contractor installed approximately 2100 lineal feet of erosion control.

It is unknown how the newly installed erosion control system will perform over the long term; that is, how settlement of the highly organic silt soil beneath the mat will affect the installation. It will likely provide several years of useful protection. A more typical "engineered" section for construction of "Armorflex" erosion control would be similar to that shown in Figure 7. The use of gravel fill beneath the "Armorflex" is expensive, but would limit future settlement deformation of the concrete mat and thus provide a prolonged period of performance.

3.4 Definition of Project Area

As identified in Figures 5A and 5B, all public structures have been protected by the "Armorflex" erosion control installed by Coexco in October 1986. The actual service life of the system as installed by Coexco is difficult to predict, but it is certain to eventually fail because of improper grade preparation. For the purpose of analysis, it was assumed that the contractor-installed shore protection would begin to fail in about year five and at year ten, erosion would continue at its present rate. Erosion of presently unprotected areas will likely continue at the current rate of loss. Based on these assumptions, the estimated 50-year erosion limit will be as defined in Figures 5A and 5B.

Erosion rates were determined by comparison of the river bank position as observed on 1975 aerial photography with existing conditions. Actual erosion was determined as the difference between the bank locations at a number of discrete positions for which common reference points (buildings) were available in both the 1975 aerial photos and the reconnaissance field trip. It should be emphasized that erosion rates are reported as an average annual value. Actual annual erosion rates may have varied considerably from year to year and may vary in the future.

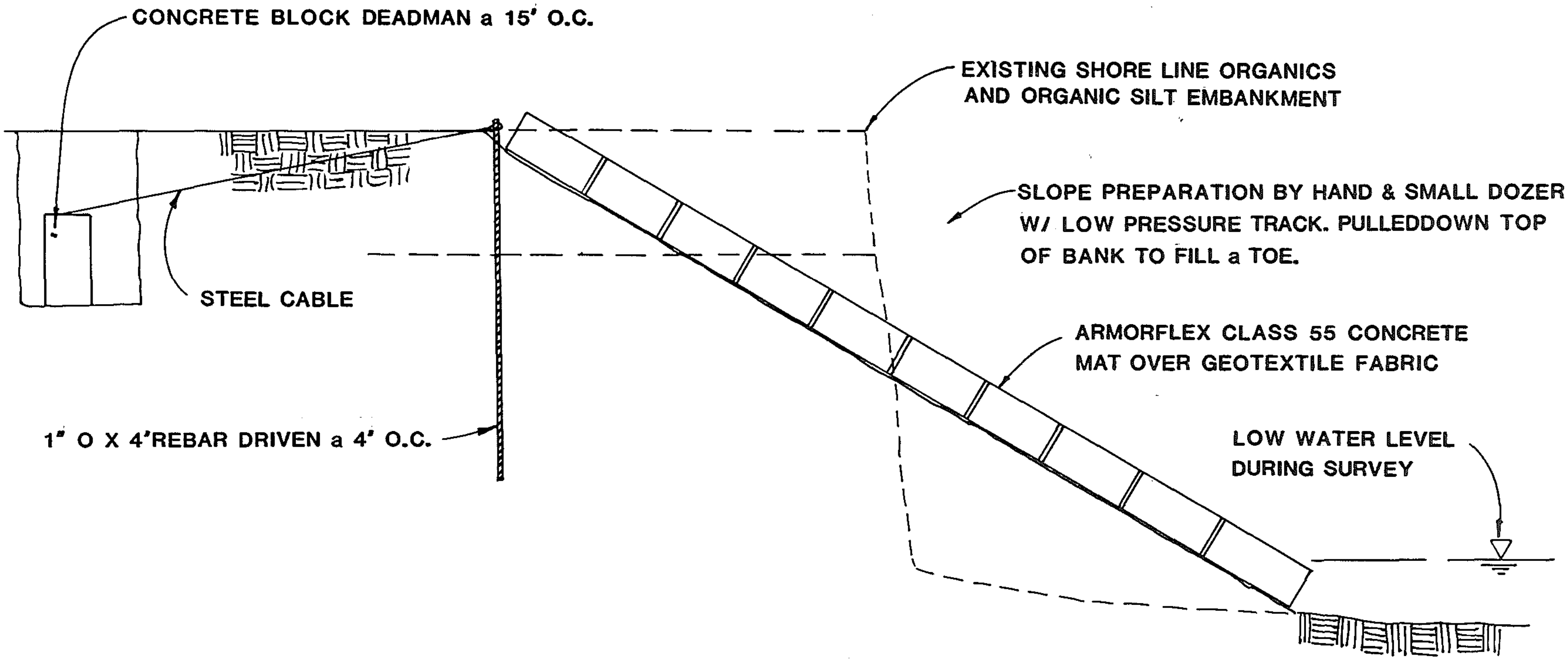
4. ALTERNATIVE SOLUTIONS

4.1 No Action Alternative

The no-action alternative is not a preventative measure. It simply implies that no government project will be implemented to cease shoreline recession or mitigate erosional damages. A no-action program is usually recommended when the benefits derived from a project cannot offset the project's costs. However, present erosion rates will cause damages to existing structures and the loss of land to the extent that the local residents feel that additional erosion control is justified.

If no action is taken to prevent further erosion, it may progress to the limit shown in Figures 5A and 5B. This will destroy considerable portions of the present community including both private and public

95796



DETAILS OF CONSTRUCTION OBTAINED DURING CONVERSATION WITH COWDERY EXCAVATING & CONSTRUCTION CO. (THE INSTALLATION CONTRACTOR).

SCALE:
HORIZONTAL 1"=2'
VERTICAL 1"=2'

NEW EROSION CONTROL SYSTEM CONTRACTOR DESIGNED

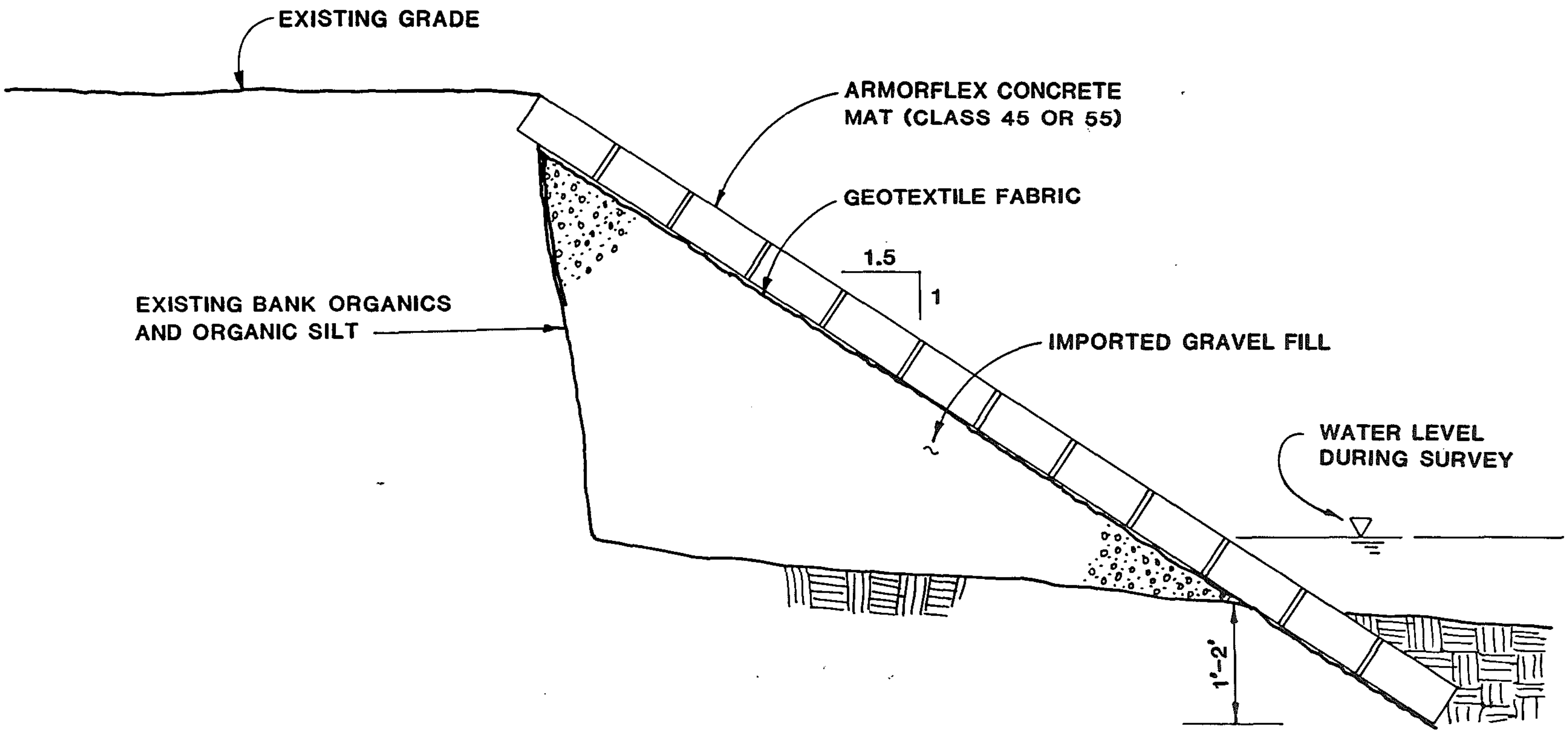
US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

6

95796



RECOMMENDED SHORE PROTECTION

US Army Corps of Engineers
Alaska District

KOTLIK

COASTAL EROSION STUDY

7

facilities. Included within this erosional zone are some 45± residences, half of the school complex, city offices, post office, Baptist Church, Old Catholic Church, and a store. Table 1 summarizes the estimated value of losses anticipated.

Table 1

Structure	Year Loss	Value*
School Complex & Fuel Tanks	12	$2,800,000
Baptist Church	13	510,000
Old Catholic Church	17	428,000
City Office	33	130,000
Residental Dwellings (45 units @ $90,000/each)		4,050,000
		===========
Total Losses		$7,918,000

* Costs for the above noted facilities were obtained from the Kotlik Erosion Control Study (NORTEC, 1983). Assumed commercial or public building costs of $250 per square foot and residential dwellings at $83,000/unit. These 1982 cost figures were herein adjusted by 1.093 to account for inflation and other cost escalating affects. Costs do not include land values.

4.2 Relocation Alternative

Land is available for relocation of public and private structures. The community could conceivably rebuild or expand to vacant city owned land to the south. For analysis of the relocation alternative, all public, residential, and commercial structures falling within the project area shown on Figures 5A and 5B were assumed to require relocation.

4.3 Structural Alternatives

Several structural alternatives are possible. NORTEC (1983) investigated a riprap revetment, sandbag revetment, and ~~an~~ "Armorflex" articulated concrete mat revetment in its study. The Alaska Task Force on Erosion Control report recommended a pile and fascine revetment which incorporated driving shallow "soldier" piles (@ 6' o.c.) behind which were laid willow branches. Sandbags are then piled on top of the willow branches to anchor them in place.

The City of Kotlik unsuccessfully tried to construct a system similar in concept to the pile and fascine revetment. Shallow soldier piles were driven and then 3x12 treated timber lagging was placed to retain and protect the embankment. The void behind the wall was filled with silt material. This system was easily destroyed by icing of the river. Ice froze to the wall and the resulting buoyancy pulled out the piles as the tides rose. In the spring, everything installed floated downstream. A similar system is therefore not recommended.

Although the articulated concrete mat revetment is the most costly considered, it should be superior in other aspects so as to outweight the cost disadvantage to other alternatives.

The chief mode of transportation is boats, which are moored along the river banks. A riprap revetment would cause considerable damage to moored boats. In consideration of the sandbag revetment, durability of the sandbags is questionable. It is probable that the exposure to ultraviolet radiation, damage from boat moorage, props, etc. and abrasion by ice during breakup would exact a heavy toll of damage. Maintenance of such a system could be an expensive task. Because there are no such systems installed to obtain annual maintenance costs and the apparent high susceptibility to damage, the sandbag revetment was not considered suitable.

Other systems were briefly considered, but the difficulty of river access imposed by bulkheads or retaining wall concepts was substantial enough to prompt rejection.

An articulated concrete mat revetment is therefore likely to be the most suitable method of protection when considering physical protection provided and the allowance for river access. Even with the concrete revetment, it is still uncertain as to how much boat damage will occur and how easy river access will really be. Access to boats over a 3:1 concrete slope may not be as easy and safe as might be initially assumed. Nevertheless, it does appear to be the most suitable of all alternatives considered. A typical cross section is shown in Figure 7.

5. ECONOMIC ANALYSIS

5.1 Projected Date of Losses and Benefit Analysis

For the purpose of this analysis, the 50-year erosion limit (project area) is as shown on Figures 5A and 5B. In the no-action alternative, reconstruction of affected buildings is assumed for compilation of costs. Although residences are not considered public structures within the guidelines of this study, costs associated with these are shown so that the total affect to the community can be realized. For the purpose of this study, a midpoint analysis was used for evaluation of losses attributable to the residences, i.e., the residences were assumed losses in year 25. Table 2 represents analysis of annualized costs/benefits.

Table 2

Structure	Cost	Replacement Year	P/F	Present Value
Public:				
School Complex & Fuel Tanks	$2,800,000	12	.36046	$1,009,299
Baptist Church	510,000	13	.33108	168,850
Old Catholic Church	428,000	17	.23562	100,845
City Office	130,000	33	.06045	7,859
				===========
Present Value Public Structures				$1,286,853
Private:	4,050,000			483,327
Residences (45)	4,095,000	25	.11934	488,697
				==========
Present Value All Structures				1,775,550
				1,770,180

Annualized Benefits = PV x CRF = $1,775,550 x 0.090032 = $159,856
159,373

* The annual benefits shown in Table 2 were calculated using a capital recovery factor (CRF) based on an 8-7/8% effective interest rate over a 50-year period (CRF = 0.090032). Effective interest denotes the net of the anticipated rate of return over inflation. The cost/benefits to be realized in the future are first discounted to the present value (PV) by multiplying the future cost/benefit by the present worth factor (P/F). The present value is then annualized by multiplying by the CRF to obtain annualized cost/benefits.

5.2 Alternative Cost Analysis

5.2.1 **Relocation Alternative.** The cost for this alternative includes the following elements: (1) rebuild the elementary school; (2) relocate the Baptist Church, old Catholic Church, and city office building; and (3) relocate residences. The cost of the relocation alternative is shown in Table 3A. Relocation costs were based on information from Brown's House Moving who moved the community of Point Lay and has performed numerous other building relocations throughout Alaska. A midpoint analysis was assumed for the scheduled loss of residences. In the relocation alternative, foundations for relocated buildings were assumed to be piling into permafrost soils, since there is no

TABLE 3A

CONSTRUCTION COST ESTIMATE

LOCATION Kotlik Alaska

RELOCATION ALTERNATIVE COSTS

JOB NAME

JOB NUMBER

PRELIMINARY [X] FINAL [ ]

BY DATE 11/86

CHECK DATE

LINE	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	RELOCATE:				
	Baptist Church*	1700	SF	35.00	60,000
	Catholic Church*	2300	SF		80,000
	Old Catholic Church*	1250	SF		44,000
	Health Clinic*	650	SF		23,000
	Community Hall*	1500	SF		52,000
	City Office *	2400	SF		84,000
	Residences	45	ea.	25,000	1,125,000
	Reconstruct:				
	Elementary School Complex & Fuel Tanks				2,800,000
	Mobilization/Demob				200,000
	SUBTOTAL				4,468,000
	Contingency (25%)				1,117,000
	SUBTOTAL				5,585,000
	Engineering Supervision and				
	Administration** (07%)				196,000
	TOTAL PROJECT COSTS				5,781,000
	Average Annual Cost (x 0.090032)				520,475
	* Cost based on square foot cost of				
	average house relocation				
	**Only includes Elementary School				
	and Tank Farm				

sand or gravel in the vicinity for construction of building pads. Residences were estimated to require 10 piles at $2,000/pile.

Table 3A assumes immediate relocation in year 1; therefore, the annualized costs are higher than those indicated in Table 2 which involved replacement of structures in the future when destroyed by erosion. The fact that total replacement appears less costly than relocation may be misleading because of the discounting factors involved with future expenses.

Review of the relocation alternative with a view toward a scheduled relocation of structures as they are endangered may be more appropriate. Table 3B shows costs associated with the scheduled relocation of structures. Costs of relocating individual structures were increased in Table 3B to account for mobilization costs associated with each relocation. Relocation was assumed to be required 2 to 5 years prior to being damaged. The results of this analysis indicate that a scheduled relocation of buildings is cost effective when considering total replacement.

Table 3B

SCHEDULED RELOCATION ALTERNATIVE COSTS

Description	Cost	Reloc./Repl. Year	P/F	Present Cost
Relocate:				
Baptist Church	80,000	20	.182573	$ 14,606
Old Catholic Church	84,000	25	.119343	10,025
City Office	110,000	40	.033333	3,667
Residents (45)	1,325,000	25	.11934	158,125
Reconstruct:				
Elem. School Complex and Fuel Tanks	2,800,000	20	.182573	511,204
				===========
Total Present Cost of Relocation				$697,627
Average Annual Cost (x 0.090032)				$ 62,809

5.2.2 **Structural Alternative.** The cost for constructing the articulated concrete mat (Armorflex) erosion control is shown in Table 4. Cost analysis herein assumes that shoreline protection extending 3700 lineal feet would be installed to protect most of the public and private structures within the 50-year erosion limit at Kotlik. Although there is presently a newly constructed erosion control system, for reasons previously discussed its failure is eminent. In this cost analysis no consideration was given to the existing concrete units with regards to construction cost reduction. It was assumed that the cost of salvaging the existing concrete would be about the same as purchasing new materials. Development costs include the cost of importing gravel since it is not locally available. The annualized cost of

TABLE 4

CONSTRUCTION COST ESTIMATE

LOCATION Kotlik, Alaska

JOB NAME

JOB NUMBER

ARTICULATED CONCRETE MAT REVETMENT

PRELIMINARY [X] FINAL [ ]

BY DHA DATE 11/86

CHECK DATE

LINE	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	COST PER LINEAL FOOT OF SHORE				
	Gravel Embankment	0.42	CY	75.00	31.50
	Geotextile Fabric	1.5	SY	4.00	6.00
	Armorflex (Class 45 or 55)	10.5	SF	20.00	210.00
	COST PER LINEAL FOOT				247.50
	COST FOR 3700 L.F. PROTECTION				
	Typical Section Cost	3700	LF	247.50	915,750
	Mob/Demob		ALL		250,000
	SUBTOTAL				1,165,750
	Contingency (25%)				291.450
	SUBTOTAL				1,457,200
	Engineering Supervision and				
	Administration * (07%)				102,000
	TOTAL PROJECT COST				1,559,200
	Average Annual Cost (x 0.090032)				140,378

construction is $140,378. It should be emphasized that the 3700 lineal feet will not provide protection for all residences of Kotlik. Additional work is necessary to determine if residences on the west and north sides of the river should be protected, or if they should be relocated.

5.3 Economic Summary

Analysis of the benefit/cost ratio for alternatives will consider the no action alternative costs (annualized) as the numerator or "benefit" factor in the ratio. The benefit/cost ratios for alternatives considered herein are shown in Table 5.

TABLE 5
BENEFIT/COST RATIO SUMMARY

Alternative	Cost (Benefit)	B/C Ratio
No Action	(159,856)	N/A
Relocation	520,475	.31
Scheduled Relocation	62,809	1.54 2.55
Structural	140,378	1.14

6. RECOMMENDATIONS

6.1 General

The newly constructed erosion control protects about 2100 lineal feet of shoreline. Although public structures are now protected, residents desire additional protection to protect the rest of the community. Additionally, it is highly likely that the existing erosion protection will fail within 10 years. The newly installed protection should probably be considered a "temporary" repair to prevent the immediate loss of certain facilities. So that while the community may have forestalled the loss of land and buildings for the near future, erosion will likely continue when the "temporary" bank protection fails. On the basis of analyses herein, additional work at Kotlik would be warranted.

Additional work could include 1) detailed evaluation of existing bank protection to review performance and more accurately predict service life; 2) a more detailed cost estimate taking into account possible use of existing concrete materials; and 3) design of bank protection for unprotected portions of the community. Additional work is required to determine the actual extent of erosion protection, (i.e., is it desirable to protect residences on the west and north sides of the river or relocate these residences?) While the emergency status which existed prior to the construction of the new bank protection has been alleviated by the October construction, further investigations appear warranted.

7. REFERENCES

Alaska, State of. Department of Community and Regional Affairs and Alaska Municipal League. 1986. "Alaska Municipal Officials Directory 1986". 156 p.

Alaska, State of. Department of Community and Regional Affairs. 1980. "Kotlik Community Profile". 16 p.

U.S. National Oceanic and Atmospheric Administration. 1985. "Coastal Pilot". 363 p.

U.S. Army Corps of Engineers. "Coastal Environment, Bathymetry and Physical Oceanography along the Beaufort, Chukchi and Bering Seas." 357 p.

Alaska Department of Transportation and Public Facilities. 1984. Task force on erosion control, final report. (January 3).

Hines, C. 1986. Real estate appraiser, Hines Price & Associates, Fairbanks. Personal Communication. October 17.

Selkregg, Lidia L. 1976. Alaska regional profiles, northwest region. Pub. by University of Alaska, Arctic Environmental Information and Data Center, Anchorage. 265 p.

U.S. National Ocean Service. 1986. Rockville, Maryland. Personal Communication. October 6.

Wise, J.L., A.L. Comiskey, and R. Becker, Jr. 1981. Storm surge climatology and forecasting in Alaska. Arctic Environmental Information and Data Center. Anchorage. August. 58 p.

Briant, Harold. 1986. Owner of Browns House Moving, Inc., Anchorage, Alaska. Personal Communication. November 5.

Northern Technical Services. 1983. "Kotlik Erosion Control Study". For Alaska Dept. of Transportation and Public Facilities. Anchorage. 48 p.

Akaran, Jim (Vice Mayor); Tonuchuk, Victor (Mayor). 1986. Residents of Kotlik. Personal Communications. September 20 and 21.

McHenry, Bill; John Cowdery. 1986. Cowdery Excavation & Construction Company, Inc. Personal Communications. November 13, 1986.

Hammond, Bob. 1986. Alaska Dept. of Transportation and Public Facilities, Construction Division (Anchorage). Personal Communication. November 17, 1986.