PRODUCT EVALUATION FOR ARMORFLEX AND ARMORFORM EROSION CONTROL SYSTEMS

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EXECUTIVE SUMMARY

ARMORFLEX is an erosion control system consisting of precast concrete blocks, interconnected by galvanized steel cables to form a flexible protective mattress. This system is designed to be used for both bank and shore protection.

ARMORFLEX has been installed at seven (7) locations in Alaska. To this date, the ARMORFLEX product has performed successfully (i.e. the protective mattress has remained intact and there has not been any significant bank or shore erosion at any of the Alaska installations). However, some of the installations have suffered minor damage reflected by depressions and displacement of the mattresses. These problems may be attributed to possible design and construction inadequacies including improper installation of the geotextile, insufficient anchorage on steep side slopes, using an improper geotextile as a filter system, and not extending the toe of the erosion protection system far enough.

In low energy environments, ARMORFLEX appears to be an acceptable erosion control system if proven to be economical over riprap or other conventional erosion control systems. The system has not yet demonstrated its long term performance in the Alaskan environment.

ARMORFORM is an erosion control system consisting of cast-in-place blocks which are interconnected by galvanized steel cables to form a flexible protective mattress. The forms for the blocks are synthetic fabric, woven into a matrix of rectangular compartments.

The Noatak installation was the first time and to this date the only time that the ARMORFORM erosion control system had been used as bank protection in North America. There were several significant performance problems with the Noatak installation. Some of these problems can be corrected by implementing the suggested modifications to the design and construction procedures contained in this report. The ARMORFORM erosion control system should still be considered experimental and should only be used when riprap and other proven erosion control systems are not feasible.

INTRODUCTION

Two relatively new artificial erosion control systems were used in lieu of riprap on two projects recently constructed by the Alaska DOT&PF. In 1981 a system of pre-assembled mats of precast articulating concrete blocks tied together by steel cables called ARMORFLEX was installed as shore protection adjacent to the Hooper Bay airport. Since that time, several ARMORFLEX systems have been installed by the oil companies on the North Slope and by several villages in western Alaska (figures 1 & 2). In 1982, a system of articulating cast-in-place concrete blocks attached together with steel cables called ARMORFORM was installed as river bank protection at the village of Noatak. Both products are manufactured by Armortec, Inc.

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ARMORFORM and ARMORFLEX INSTALLATIONS

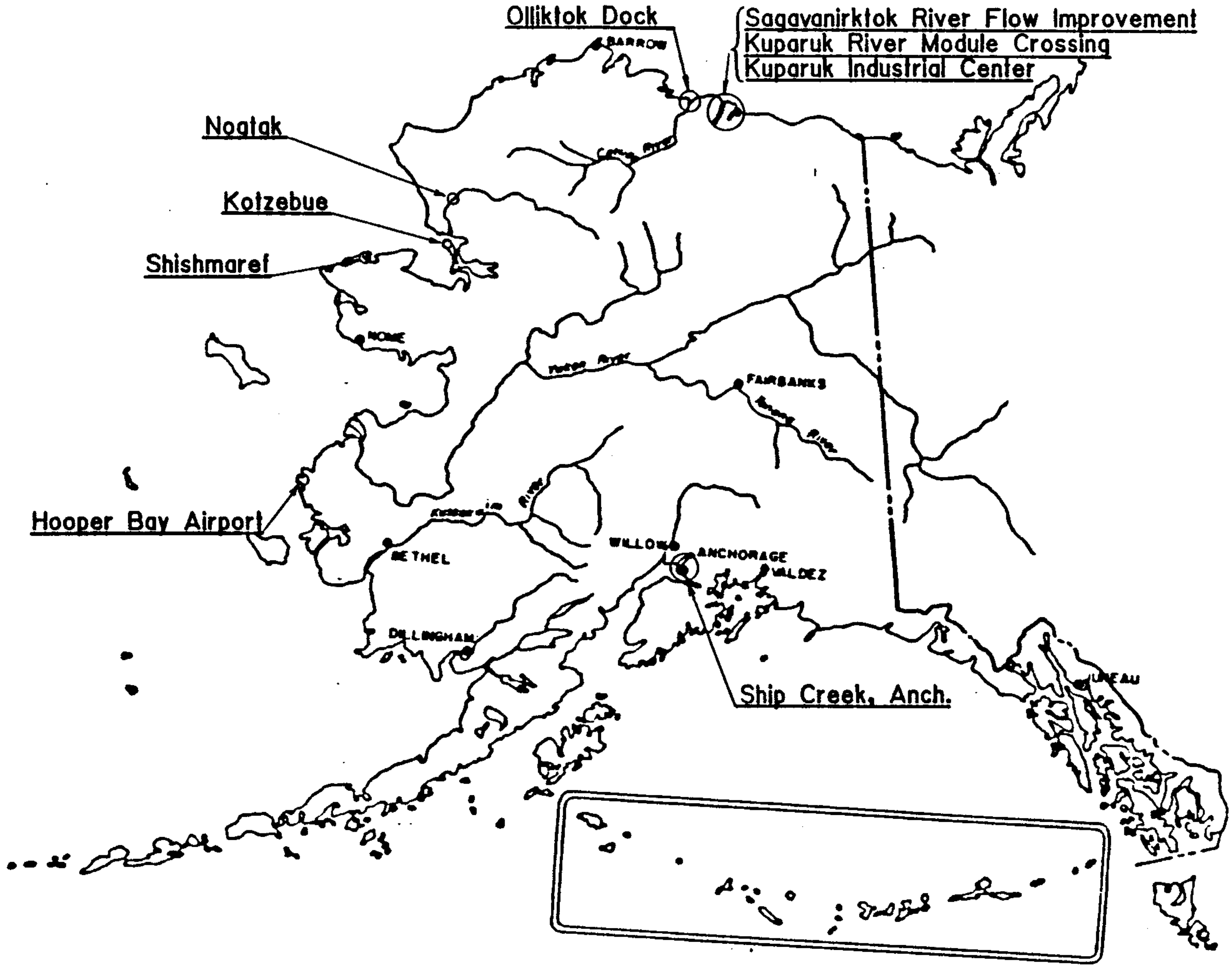


Figure 1

ARMORFLEX INSTALLATIONS IN ALASKA

LOCATION	TYPE**	CELL** DESIGN	DATE	APPLI-CATION	QUANTITY	DESIGN WAVE	DESIGN VELOCITY	UNIT COST
HOOPER BAY AIRPORT	CLASS 50	OPEN CELL	1982	SHORE	21,905 SF	4-6 FT		$23.51/SF
SAGAVARNIRKTOK RIVER FLOW IMPROVEMENT	CLASS 45	CLOSED CELL	1980	BANK	68,000 SF		9-10 FPS	---
KUPARUK RIVER MODULE CROSSING	CLASS 55	CLOSED CELL	1981	BANK	95,000 SF		8-10 FPS	---
SHIP CREEK, ANCHORAGE	CLASS 50	OPEN CELL	1982	BANK	3,700 SF		6-8 FPS	$ 7.50/SF
OLIKTOK POINT DOCKHEAD	CLASS 55	CLOSED CELL	1982	SHORE	27,000 SF	3-4 FT		---
KUPARUK INDUSTRIAL CENTER	CLASS 55	CLOSED CELL	1983	CHANNEL LINING	12,000 SF			---
SHISHMAREF	CLASS 55	CLOSED CELL	1984-85	SHORE	58,000 SF	4 FT		$24.14/SF
KOTZEBUE *	CLASS 55	CLOSED CELL	1985	SHORE	15,000 SF	4 FT		$13.33/SF

NOTE - INSTALLED UNIT COST INCLUDES EQUIPMENT MOB & DEMOB, GEOTEXTILE, AND ARMORFLEX.
*DOES NOT INCLUDE EQUIPMENT MOB & DEMOB.
**SEE FIGURE 4.

Figure 2

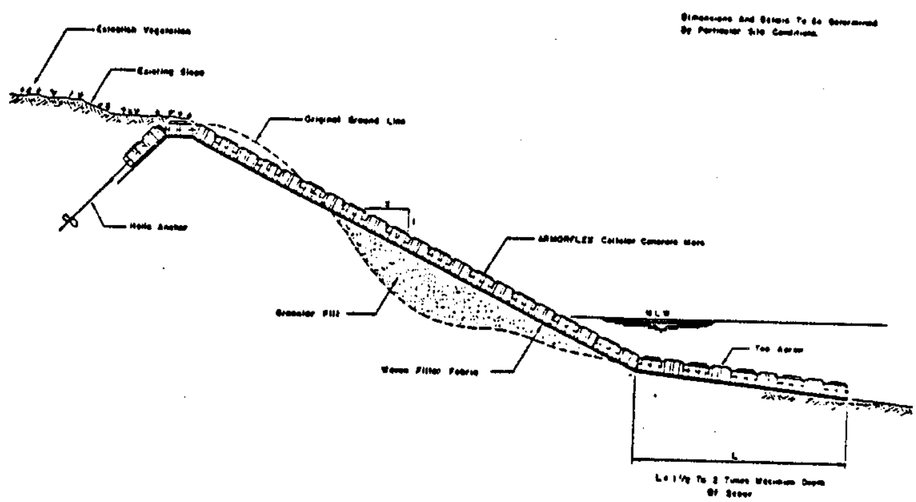
This product evaluation report examines the design techniques, construction procedures, and performance of the two erosion control systems. In addition, this study will examine the economic and practical feasibility of using these two systems as an alternative to riprap for shore and streambank erosion protection.

ARMORFLEX

A. DESCRIPTION

ARMORFLEX consists of precast concrete blocks (grids) interconnected by steel cables to form a mattress. The mattress is placed on the slope of the streambank or beach to provide a flexible and structurally integrated erosion protection system (figure 3).

ARMORFLEX EROSION CONTROL SYSTEM



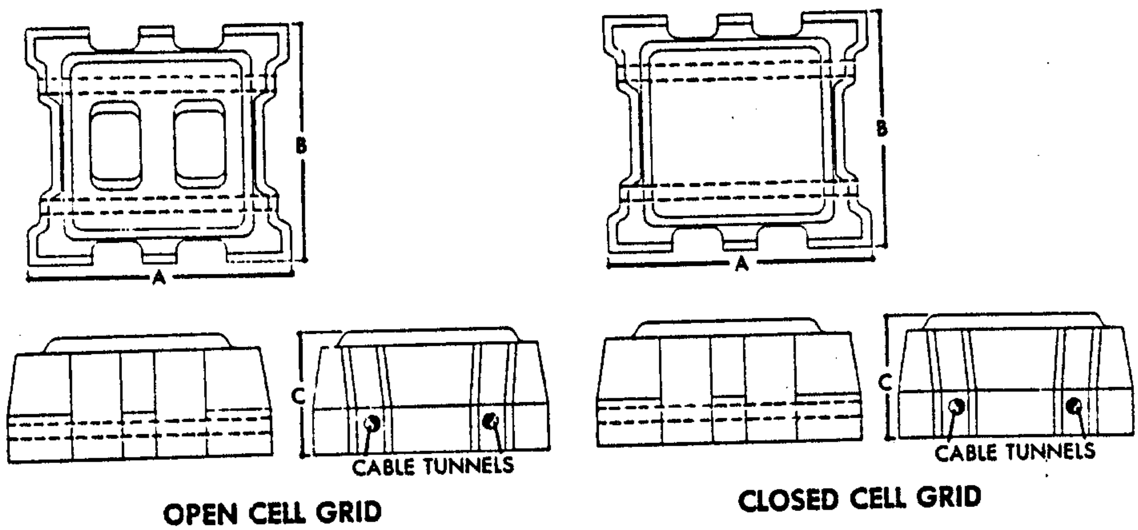
ARMORFLEX REVETMENT WITH TOE APRON

To the best of our knowledge, the information contained herein is accurate. However, Armortec, Incorporated cannot accept liability of any kind for the accuracy or completeness thereof. Final determination of the suitability of any information or material for the use contemplated and of its manner of use is the sole responsibility of the user.

Figure 3

ARMORFLEX is available with six different class blocks. The Class 45, 55, and 85 systems consist of solid concrete blocks (figure 4). The Class 30, 50, and 70 systems consist of concrete blocks with two vertical open cells.

The blocks are designed to interlock with the six adjacent blocks. The side walls of the blocks are tapered to permit the blocks to articulate and adjust to the subgrade surface without being displaced or rolled out of position. A series of four 1/4" to 5/8" diameter galvanized cables are threaded through each block to form the articulating mat (figure 5). The blocks are strung together in a staggered pattern such that each block is interconnected to six adjacent blocks.



ARMORFLEX GRID SPECIFICATIONS											
		TECHNICAL DATA			DIMENSIONS & WEIGHTS						
					NOMINAL DIMENSIONS IN.						
CLASS		SPECIFIC WEIGHT LBS./CU.FT.	COMPRESSIVE STRENGTH LBS./SQ.IN.	% MAXIMUM ABSORPTION	A	B	C	GROSS AREA/ GRID SQ.FT.	WEIGHT/ GRID LBS.	WEIGHT/ AREA LBS./SQ.FT.	OPEN AREA %
OPEN CELL	30	130-150	4000-5000	5	13.0	11.6	4.75	0.98	31-36	32-37	25
	50	130-150	4000-5000	5	13.0	11.6	6.0	0.98	45-52	46-53	20
	70	130-150	4000-5000	5	17.4	15.5	9.0	1.77	120-138	68-78	20
CLOSED CELL	45	130-150	4000-5000	5	13.0	11.6	4.75	0.98	39-45	40-46	10
	55	130-150	4000-5000	5	13.0	11.6	6.0	0.98	53-61	54-62	10
	85	130-150	4000-5000	5	17.4	15.5	9.0	1.77	145-167	82-95	10

Figure 4

The blocks in the solid (closed cell) system range in size from 13" x 11.6" to 17.4" x 15.5" with a block thickness of 4.75", 6.0", or 9.0". The individual blocks vary in weight from 39 lbs. to 167 lbs. depending on the class of block and the specific weight of the concrete. A system of closed cell blocks provides a mat weight of between 40 psf and 95 psf. The Manning Roughness Coefficient for the solid blocks is .026-.028.

The open cell blocks have the same dimensions as the closed cell blocks. The dimensions of the two open cells for the class 30 and class 50 block are approximately 2.5" x 4", and the dimensions for the open cell for the class 70 block is approximately 3" x 5.5". The individual open cell blocks vary in weight from 31 lbs. to 138 lbs. A system of open cell blocks provides a mat weight of between 32 psf and 78 psf. The open cells can be filled with dirt and seeded to promote the growth of vegetation. The Manning Roughness Coefficient for the blocks without vegetation is .031-.034 and is .041-.044 with vegetation. The higher percent of surface area of the open cells permits more rapid relief of hydrostatic pressure than do the solid blocks.

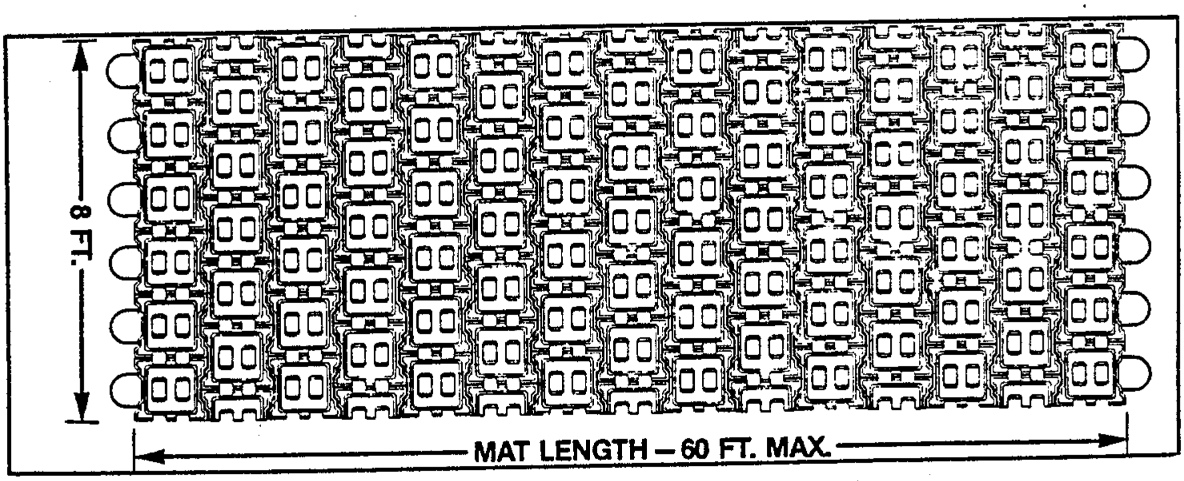


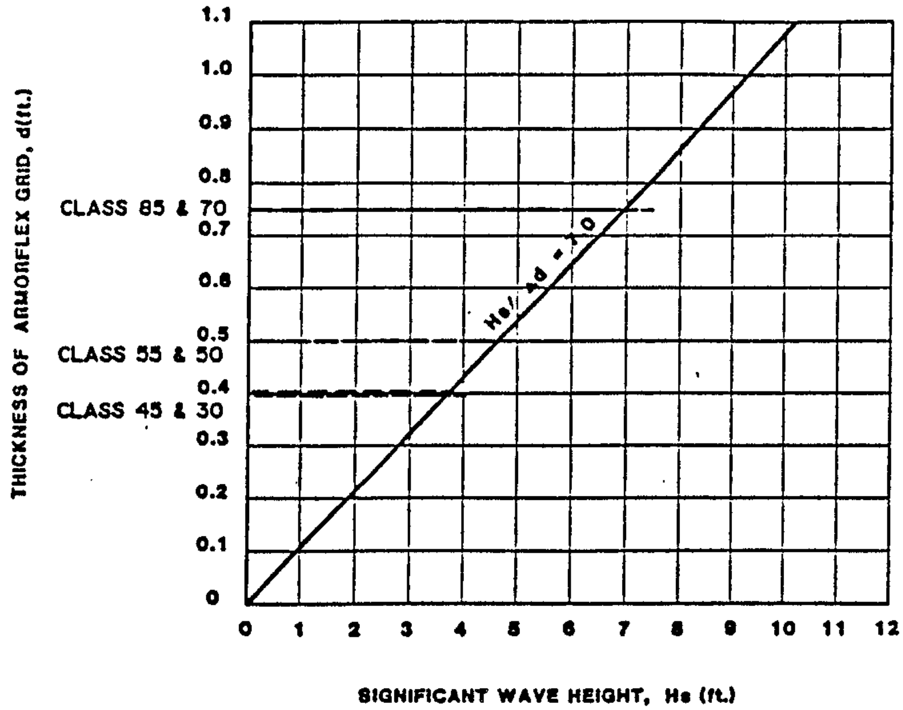
Figure 5

To install the ARMORFLEX, the subgrade slope is prepared by removing all obstacles and grading the streambank or beach. The slope of the subgrade is dependent on the angle of repose of the subgrade soils. A geotextile with high permeability or granular filter system is placed over the prepared subgrade. The filter system should be designed to permit water to pass through the ARMORFLEX without washing out the subgrade soils. The articulating mat can be placed directly over the filter system with a lightweight crane. In areas where equipment is not available, the blocks can be placed and strung together by hand with unskilled labor. For areas with steep side slopes, helix type ground anchors can be attached to the top of the mattress and installed at the top of the slope.

According to the manufacturer, the ARMORFLEX can be used as bank protection where the mean stream velocities do not exceed 12 ft/sec. On certain projects in the U.S., ARMORFLEX has been used to protect dam spillways where the mean water velocity has exceeded 12 ft/sec without serious damage.

Based on wave tank tests the ARMORFLEX, when placed on a 2:1 to 3:1 slope (figure 6), can be used in areas where the significant wave height does not exceed 7 ft. (signigicant wave is 75% of the maximum wave height). In addition the wave tank tests demonstrated that the cables did not prevent erosion depressions from developing, but they did prevent massive slope failure caused by progressive block dislodgement. There appears to be no significant difference in wave runup between the open cell block and the open cell block filled with gravel.

SHORE PROTECTION DESIGN CHART



ARMORFLEX STABILITY ON A 1:3 TO 1:2 SLOPE, AS A FUNCTION OF SIGNIFICANT WAVE HEIGHT

*open cells filled with sand

Figure 6

The gravel filled open cell block is considered as stable as the solid cell block of the equivalent size. The primary advantages of the open cell blocks over the closed cell blocks are 1) more economical, 2) lighter, 3) permit vegetative growth, and 4) permit quicker dissipation of hydrostatic pressure. The primary advantage of the closed cell blocks are 1) the smooth surface does not inhibit pedestrian traffic and 2) there is less potential for ice to pluck the blocks away from the slope.

B. INSTALLATIONS

1. Hooper Bay Airport (Shore Protection)

The village of Hooper Bay is located on the west coast of Alaska approximately 80 miles southwest of the mouth of the Yukon River. In 1972, a 4000 foot long runway was constructed on the beach adjacent to the Bering Sea. Sand filled barrels were used as a shore protection. In 1979 a storm wiped out a portion of the runway and destroyed the barrel shore protection system.

In 1981, the runway was repaired and an ARMORFLEX erosion protection system consisting of Class 50 (open cell) block was installed to protect two of the most vulnerable areas of the runway (photos #2 thru #8). Approximately 21,905 sq.ft. of ARMORFLEX was installed to protect 772 lineal feet of shoreline. The design wave height was 4-6 ft. Since riprap would have to be hauled to the site by barge, it was not considered economically feasible. The contractor's bid price for the ARMORFLEX was $12.00 per sq.ft., however, the supplier quoted a price of $5.20 per sq.ft. to the design engineer. The total cost of the entire erosion protection system including mobilization, demobilization, geotextile, and ARMORFLEX was $514,995 or $23.51 per sq.ft. The second lowest bidder was $449,185 or $20.51 per sq.ft., however, their bid on the other non-erosion protection work was substantially higher than the low bidder. The engineer's estimate was $480,041 or $21.92 per sq.ft.

The ARMORFLEX blocks were fabricated and strung together in 8' x 33' mats in Anchorage and barged to Hooper Bay. The subgrade consisting of fine beach sand was graded to a 3:1 slope. A Nicolon 70/20 geotextile was used as a filter blanket and was placed over the prepared subgrade. A 30 ton crane and a 966 loader were used to place the 33' long mats. A field-fabricated boom was attached to the loader bucket which would pick up the uphill end and the crane would pick up the downhill end of the mat and place it directly on top of the geotextile (see photo #3). In some cases additional blocks had to be placed and cables strung through the mats by hand (see photo #4) to achieve their design length of 37'. Four foot long ground anchors attached to the top of the mattresses were installed at 24' intervals. The 21,905 sq.ft. of Armorflex and geotextile were installed in 5 days by a nine man crew.

Shortly after installation, a storm struck Hooper Bay and damaged a portion of the ARMORFLEX. Small depressions approximately 15-20 sq.ft. and 1 ft deep were formed at the corner of the installation. The ARMORFLEX mat remained intact. The fact that the open cells had not been filled with material may account for the depressions.

This installation was inspected in October 1984. Approximately 10% of the installation had been damaged, primarily in the form of 1 to 3 ft depressions. It appears that the subgrade material washed out from behind the mat. The mat remained intact, and conformed into the depressions. Only one block was broken, and the cables kept the mattress together. All the cable connections remained intact and there was no sign of corrosion or distress in the cables.

2. Sagavanirktok River Flow Improvement (Bank Protection)

In 1980, approximately 68,000 sq.ft. of ARMORFLEX Class 55 and Class 45 erosion control system was used to protect 1600 lineal feet of river bank at the Sagavanirktok (Sag) River Crossing in the Prudhoe Bay oil field. In recent years the main channel of the Sag River had migrated and caused serious scouring at the bridge support piles. ARMORFLEX was used to protect two gravel training dikes which were constructed to divert the main flow of the river into the old channel. The dike slopes were 2.5:1 and the design velocity was 9-10 ft/sec. Helix ground anchors were used to anchor the mats to the top of the slopes.

Due to the urgency of the problem, the training dikes were constructed during the winter. The ARMORFLEX blocks were fabricated and strung together in Fairbanks and trucked to the site. The mats were laid on the frozen gravel dikes.

This installation survived breakup and the spring floods without any damage. However, pockets of severe settlement occurred during the summer. This was apparently caused by the melting of the frozen gravel embankment. The cables kept the mats intact and the settlement areas were repaired by removing the mats, regrading the slope, and replacing the mats.

3. Kuparuk River Module Crossing

The Kuparuk River Crossing is located on the road between Prudhoe Bay and Kuparuk oil field. In 1981, approximately 95,000 sq.ft. of ARMORFLEX Class 55 erosion control system was used to protect the slopes of the approach ramps of the Kuparuk River Module Crossing. The embankment slopes were 2:1 and 1.5:1 and the design water velocity of 8-10 ft/sec. Helix ground anchors were used to anchor the mats to the top of the slope. Geolon 1250 geotextile was used as the filter system.

The ARMORFLEX blocks were fabricated and strung together in Anchorage and trucked to the site. A 90 ton truck-mounted crane was used to place the mats.

The installation survived a record flow in 1982 without any appreciable damage.

4. Ship Creek, Anchorage (Bank Protection)

Approximately 3,700 sq.ft. of ARMORFLEX Class 50 mats were installed at the Ship Creek Overlook in Anchorage. The mats were placed on a 2.5:1 slope of the sandy gravel streambank (photo #1). The design stream velocity was 6-8 fps. Nicolon 70/20 geotextile was used as the filter material. The unit price including the geotextile was $7.50 per sq.ft. The price was approximately 25% higher than riprap, however the designer opted for the ARMORFLEX for aesthetic reasons.

The installation was installed in April 1982 and appears to be performing adequately.

5. Oliktok Point Dockhead

Approximately 27,000 sq.ft. of ARMORFLEX Class 55 was installed as shore protection in 1982. The mats were placed on a 3:1 to 4:1 slope of coarse gravel. Nicolon 40/30 geotextile was used as the filter material. The design wave was 3 to 4 ft.

6. Kuparuk Industrial Center

In 1983, approximately 12,000 sq.ft. of ARMORFLEX Class 55 was installed as channel lining of an intake channel for a reservoir. The mats were placed on a 4:1 and a 2:1 slopes of fine sandy gravel.

Some of the mats have slipped down the 2:1 slope where the intake channel dumps into the reservoir. According to the design engineer, this may have been caused by an insufficient number of anchors.

7. Shishmaref (Shore Protection)

Shishmaref is located approximately 100 miles west of Kotzebue on a barrier island between the Chukchi Sea and Shishmaref Inlet. The village is located on the beach which is composed of fine sands. Major storms from the Chukchi Sea have caused the beach to erode and threaten to flood the village with storm surges.

ARMORFLEX Class 55 (solid block) erosion control system is currently being installed on both sides of the existing shore protection system which consists of sand bag filled gabions. Approximately 58,000 sq.ft. of ARMORFLEX is to be installed to protect approximately 1700 lineal feet of the beach. Nicolon 7006 geotextile was used as a filter. The unit price including mobilization, demobilization, ARMORFLEX, and geotextile was

$24.14 per sq.ft. This installation was designed to withstand 4 ft high wave attack and ice flows. ARMORFLEX was selected because it provides a smooth surface for pedestrians and was more economical than riprap.

The blocks were manufactured in Anchorage and barged to Shishmaref. The mattresses were strung together at the job site by local labor. An 18 ton crane was used to place the mats on a 3:1 slope.

A storm struck Shishmaref in July of 1984, before the installation was completed. The approximately 500 lineal feet of ARMORFLEX suffered some damage in the form of surface depressions (photos #9 thru #12). These depressions were caused by the migration of the subgrade soil from beneath the ARMORFLEX. According to the manufacturer, the loss of the subgrade soil was due to the fact that the geotextile filtering system was not permeable enough to prevent the buildup of excess hydrostatic pressure which lifted the blocks and permitted the soil to migrate beneath the toe of the mattress. The damage was compounded by 1) insufficient burial of the toe of the mattress, 2) insufficient overlap of the geotextile, and 3) using too small of a block for the beach slope.

8. Kotzebue (Shore Protection)

The village of Kotzebue is located on the northwest coast of the Baldwin Peninsula. Storms from Kotzebue Sound have eroded the beach and exposed the town to flooding during storm surges. The existing shore protection* consisting of gravel filled barrels and sandbag-filled gabions in grain

*Experimental sections of various types of shore protection being evaluated by the U.S. Army Corps of Engineers.

configuration has deteriorated. Both systems have lost part of their fill material. Some of the barrels have rusted through and ice push has deformed the gabion basket toes. There are two age groups of 50 gallon barrel protection. One was constructed more than 20 years ago and is now largely rusted out. The newer drums are not rusted nearly as much.

Approximately 15,000 sq.ft. of ARMORFLEX Class 55 Erosion Protection System is scheduled to be installed in 1985. This installation is designed to protect approximately 350 lineal feet of shoreline. The estimated cost for installing the geotextile and ARMORFLEX is $13.33 per sq.ft. This lower unit cost reflects the fact that the equipment required to prepare the subgrade and place the mats is available in Kotzebue. The design wave height is 4 ft and the design beach slope is 4:1.

ARMORFORM

DESCRIPTION

ARMORFORM is a cast-in-place, flexible, tendon reinforced erosion control system. The form is a geotextile woven into square or rectangular compartments (figure 7). The compartments are separated by a narrow perimeter of geotextile that contains interconnecting strands of high strength cable which extends through each row and column of the compartments. One transverse and one longitudinal cable pass through each pillow. The form is laid on the bank or beach surface and filled with grout. When the form is filled with grout it resembles a mattress of concrete pillows. The compartments vary in size from 18" x 18" x 6" to 48" x 96" x 16" (figure 8) and can provide a surface load on the slope of 35 psf to 125 psf.

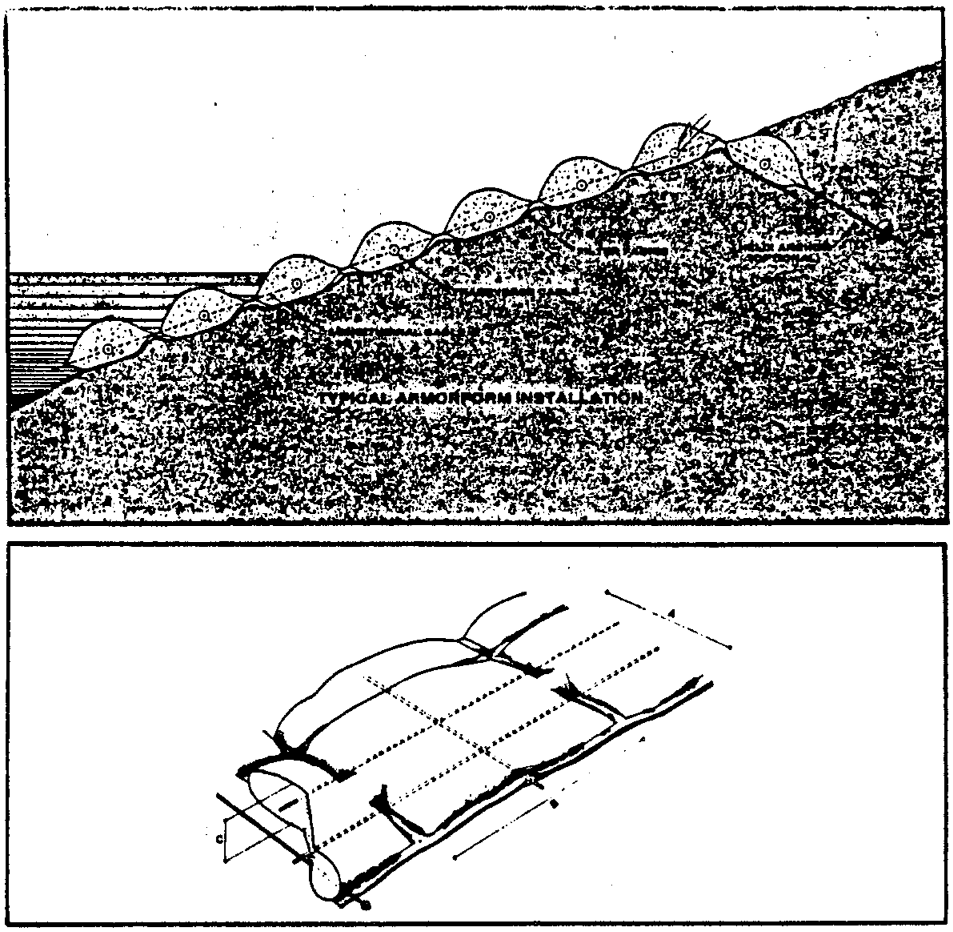


Figure 7

ARMORFORM DATA:

DIMENSIONS, VOLUMES & WEIGHTS							
CLASS	NOMINAL DIMENSIONS IN. A	B	C	GROSS AREA/ BLOCK SQ.FT.	MORTAR VOLUME/ AREA CU.FT./SQ.FT.	WEIGHT/ BLOCK LBS.	WEIGHT/ AREA LBS./SQ.FT.
1818	18	18	6	2.25	0.28	78-87	35-39
1836	18	36	6	4.5	0.32	185-210	40-47
3030	30	30	10	6.25	0.46	360-405	58-64
3060	30	60	10	12.5	0.55	865-970	69-78
4848	48	48	16	16.0	0.74	1480-1660	92-104
4896	48	96	16	32.0	0.88	3550-3980	110-125

Figure 8

The ARMORFORM is placed over a geotextile on the bank slope or beach. The Geotextile is intended to act as a filter and prevent the subgrade soils from washing away. The system is designed such that the pillows and cables will provide a satisfactory protection system even after the pillow fabric has disintegrated due to ultra-violet light. Optional ground anchors can be installed at the top of the bank protection to prevent the pillows from slipping down slope.

The subgrade slope is prepared to a maximum steepness of a 2:1 slope. A geotextile is placed over the slope to prevent the subgrade soils from washing out. The geotextile pillow forms are then rolled out on the slope by hand and filled with grout. The panels are connected along their edges by field sewing or by swaged cable connections. The only equipment required is a dozer to prepare the subgrade, concrete mixer, concrete pump, and a backhoe or boom truck.

The manufacturer has recently changed the ARMORFORM design. The pillows are now rectangular in shape and are placed in a staggered pattern. The reinforcement of the panels has been increased with three longitudinal cables and one transverse cable passing through each pillow.

A. INSTALLATION - NOATAK

The village of Noatak is located approximately 55 miles north of Kotzebue. The village is situated on a 10 to 30 foot high bluff on the outside bank of a bend in the Noatak River. The river bank soils are generally frozen silts containing massive ice overlying frozen gravel. The Noatak River is a moderately swift flowing braided river which is migrating towards the village and eroding the riverbank at an average rate of 5 ft per year with a maximum recorded yearly rate of erosion of 18 ft per year. As the river migrates towards the village it undercuts the bank by melting and washing away the ice masses and frozen silts.

Prior to the mid-1960's, there was no attempt to control the erosion. The endangered buildings would either be abandoned or relocated as the river eroded into the village. In the mid-1960's a log retaining wall was constructed to retard the erosion. By 1974 the wall was beginning to fail and had to be temporarily buttressed by sandbags. In 1979 the river channel changed course, which increased the erosion adjacent to the sewage lagoon and the school. During the winter of 1981, a 2800 ft gravel buttress was constructed along the riverbank. This $800,000 gravel buttress was "reinforced" by two levels of trees. However, the spring breakup of 1981 damaged approximately 60% of the gravel dike.

In 1981 a contract was let to provide either riprap, articulating cable tied concrete block, or an alternative system for bank protection. Riprap was not economically feasible since a 10 mile long haul road would have to be constructed to the nearest source of suitable rock. The contract was awarded on the basis of the most bank protection (1250 lineal ft) to be constructed for a fixed sum using an articulating cable tied block system. Due to the problems in delivering the precast blocks and equipment to Noatak, i.e. the 2500 ft long runway is too short for large cargo planes (C-130) and the river is too shallow for dependable barge services, the contractor proposed substituting ARMORFORM for the articulated concrete block system. The amount of bank protection using ARMORFORM was increased to 1500 lineal ft at no extra cost to the State. This was the first installation of ARMORFORM as an erosion control system for bank protection in North America. ARMORFORM had been used previously as channel lining at several installations in the U.S.

In the fall of 1981, a 15 ft high gravel buttress was constructed along the river bank during low water. The top of the 10 ft wide buttress was approximately 11 ft above the low water surface. This buttress was constructed on a 2:1 slope and provided a smooth bedding surface for the ARMORFORM.

The ARMORFORM was installed prior to the spring breakup of 1982 (photos #13 thru #22). The ARMORFORM 3030 which has a pillow dimension of 30" x 30" was used for this project. The pillows ranged in thickness from 6" to 10" depending on the amount of concrete placed in each pillow. This size pillow provides 40 to 64 psf of surface load and a 240 to 405 lb. block. The pillows contracted approximately 20% in each direction during filling. The geotextile forms were sewn into 68 ft long by 16 ft wide panels. Although the geotextile forms were light enough to be flown in, they were barged to Noatak with the equipment. The forms were fabricated in Atlanta.

The site was dewatered by diverting the Noatak River away from the riverbank. The forms were placed directly over the gravel buttress. The top pillow of each panel was placed on top of the buttress and the lower portion of the panel was placed directly on the river bottom (Appendix B).

At the corners, portions of the panels were folded to fit between the adjacent panels. An attempt was made to sew the panels together, however, the seams split when the pillows were filled with grout. Along the slope of the buttress the panels were connected to each other by swaging the transverse cables. The portion of the panels on the river bottom were not connected.

A 3" PVC pipe was used as a grout tube to grout the pillows from the bottom up. The grout was mixed at the site using a local source for the 3/4" minus aggregate. A 5.5 sack mix of concrete with 30 oz/cu.yd. plastizer was used for the grout.

Five foot long helix ground anchors were used to anchor the top of the panels to the buttress. The anchors were placed on eight ft intervals which resulted in the installation of three anchors per panel.

It took approximately 6 to 7 weeks to place and fill the panels. The time could have been reduced by 7 to 10 days if the aggregate did not have to be thawed out prior to mixing the grout. The maximum production for a 10 man crew was approximately 400-500 pillows during a 12 hr shift. The ten man crew was composed of three equipment operators and 7 unskilled laborers. the equipment required to place and fill the pillows consisted of a batch plant, mixer truck, grout pump, and backhoe.

During the first period of high water (which nearly crested the top of the ARMORFORM), approximately 1000 lineal ft of bank protection was damaged.

Approximately 200 ground anchors were pulled out and 224 lineal ft of ARMORFORM slid 4' to 5' down the slope. In addition, a portion of one panel on the river bottom lifted up and folded over on itself.

The primary contributions to the failure were 1) inadequate ground anchoring system, 2) inadequate cable connections between the panels on the slope, 3) lack of connections between the panels on the river bottom, 4) inadequate permeability through the panels to relieve the excess hydrostatic pressure, and 5) too steep a side slope.

Prior to spring breakup of 1984, the ARMORFORM installation was repaired at a cost of $80,000 by 1) pulling 14 ARMORFORM panels back into place, 2) replacing the helix ground anchoring system with a deadman anchoring system consisting of buried logs, 3) swaging the cable connections between the panels on the slope with three crimps instead of the two crimps used during the initial construction. In addition, the bank protection was extended up the slope with sandbags and a small log retaining wall.

The newly repaired bank protection system survived the 1984 breakup without any further noticeable damage. However, it appears that the ARMORFORM panels were not pulled completely back to their original position during the 1984 repair effort.

CONCLUSIONS AND RECOMMENDATIONS

ARMORFLEX

To this date the ARMORFLEX installations appear to be effective but none of the installations have stood the test of time. The protective mattresses of concrete blocks interconnected by steel cable have remained intact and there has not been any significant bank or shore erosion at any of the Alaska installations. However, due to the lack of climatalogical and hydrological data, it was not possible to determine if any of the installations were exposed to their respective design wave attack or design stream velocities. To further evaluate the long term performance characteristics of the ARMORFLEX erosion control systems would require a longer period of observations where the ARMORFLEX is exposed to large quantifiable wave attacks and stream velocities.

Some of the Alaska installations have suffered some damage which may be attributed to design and construction inadequacies such as:

1. Insufficient overlap of the geotextile filter system.

2. Using improper geotextile for filter system. The geotextile filter system should have 1) high permeability to prevent the buildup of excess hydrostatic pressure and 2) a low enough EOS to prevent the movement of subgrade soil through the filter system.

3. Inadequate embedment of depth of mattress toe for scour protection. The most probable cause for the damage at Hooper Bay was the migration of the soils from beneath the toe of the ARMORFLEX.
4. Insufficient anchorage on steep side slopes. The damage at Kuparuk Industrial Center was caused by ground anchor failure.
5. Improper size block for the beach slope angle.

It is essential that the ARMORFLEX installations be designed to include 1) proper block size for the design beach slope, 2) adequate geotextile filtering system, 3) sufficient toe embedment, 4) adequate end treatment, and 5) adequate anchoring system, if necessary. In relatively low energy environments, the ARMORFLEX erosion control system appears to be an acceptable alternative to riprap or other proven erosion control systems. Long term observation of existing installations are needed to confirm this. Before selecting this product over conventional erosion control methods, a thorough economic evaluation of all potential alternatives should be performed.

ARMORFORM

The ARMORFORM erosion control system installed at Noatak was the first time that this system had been used as a river-bank protection in North America. This installation suffered significant damage during the first spring breakup. The installation was repaired prior to the second breakup which it survived without any further significant damage.

The following modifications to the recommended design and construction procedures should be implemented:

1. A grout tube should be used to fill the pillows from the bottom up.

2. The grout should be squeezed out of the necks between the pillows. This will permit the necks to break when the panels are flexed and provide a flexible system to conform with changes in the subgrade surface.

3. The ground anchoring system should be improved. The initial Noatak installation had four longitudinal cables attached to each helix ground anchor. This method proved unsatisfactory during the first breakup and was replaced with a continuous deadman anchoring system for the second breakup.

4. The geotextile forms should be cut between the pillows to enhance the relief of hydrostatic pressure.

5. An ultraviolet resistance geotextile should be used as a filter and placed on the subgrade below the ARMORFORM.

6. The entire length of the ARMORFORM panels should be connected together. These connections should be made by swaging the cable with three crimps.

7. The geotextile forms should be placed and filled in the dry. This will permit proper placement of the panels, proper cable connections, and prevent cement from leaching through the geotextile and polluting the stream.

The ARMORFORM should be considered an experimental product and should only be used in situations where other erosion control systems such as riprap or ARMORFLEX are not feasible. In addition, it should only be considered at locations where there is a local source of suitable grout aggregate, and preferably where it can be placed in the dry.

BIBLIOGRAPHY

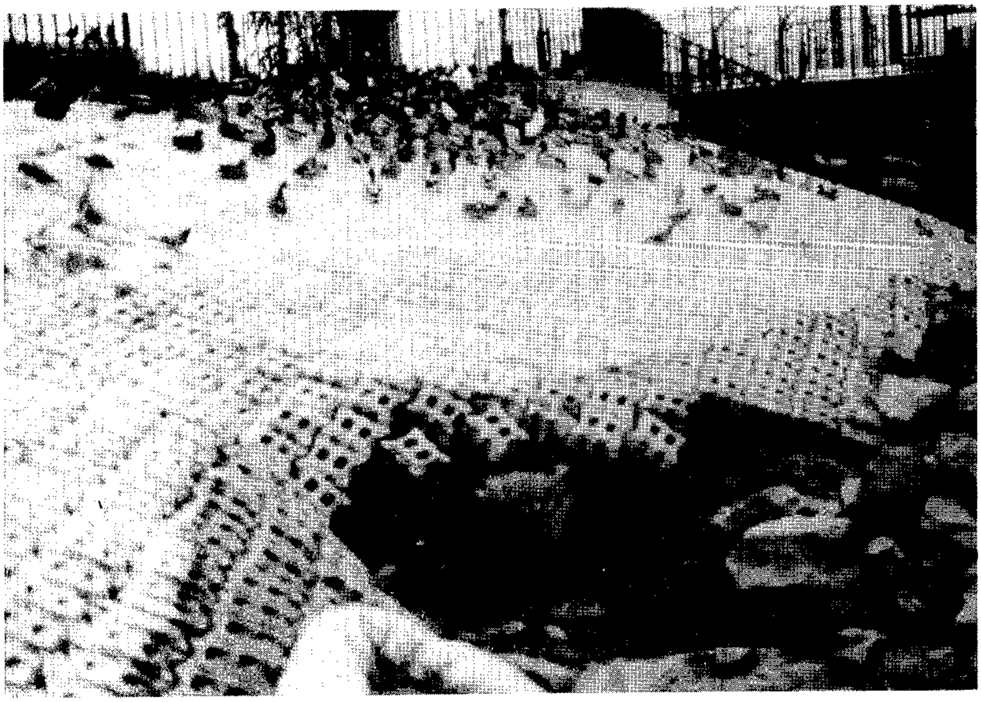
ARMORFLEX, Erosion Control System, Bank and Channel Protection, Technical Bulletin BC-1, ARMORTEC, INC., October 1981.

Stability of Armorflex block slope protection mats under wave attack, Report on model investigation, Delft Hydraulics Laboratory and Delft Soil Mechanics Laboratory, M 1910, May 1983.

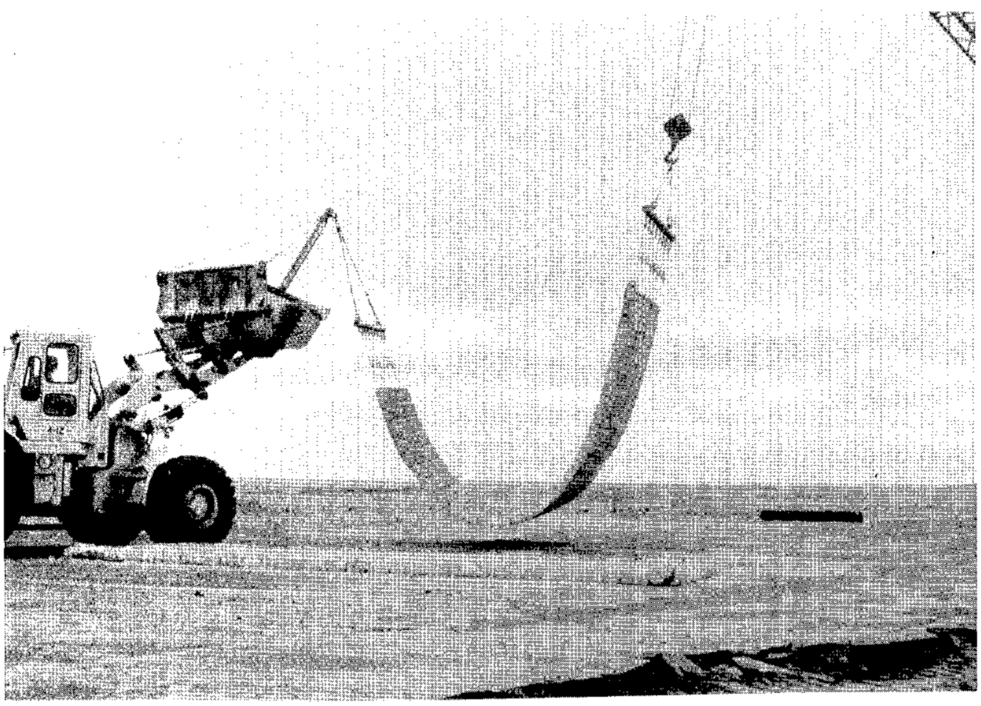
Wave Tests of Armorflex Block Slope Protection Mats, Tetra Tech, Inc., TC- 3475, September 1981.

APPENDIX A

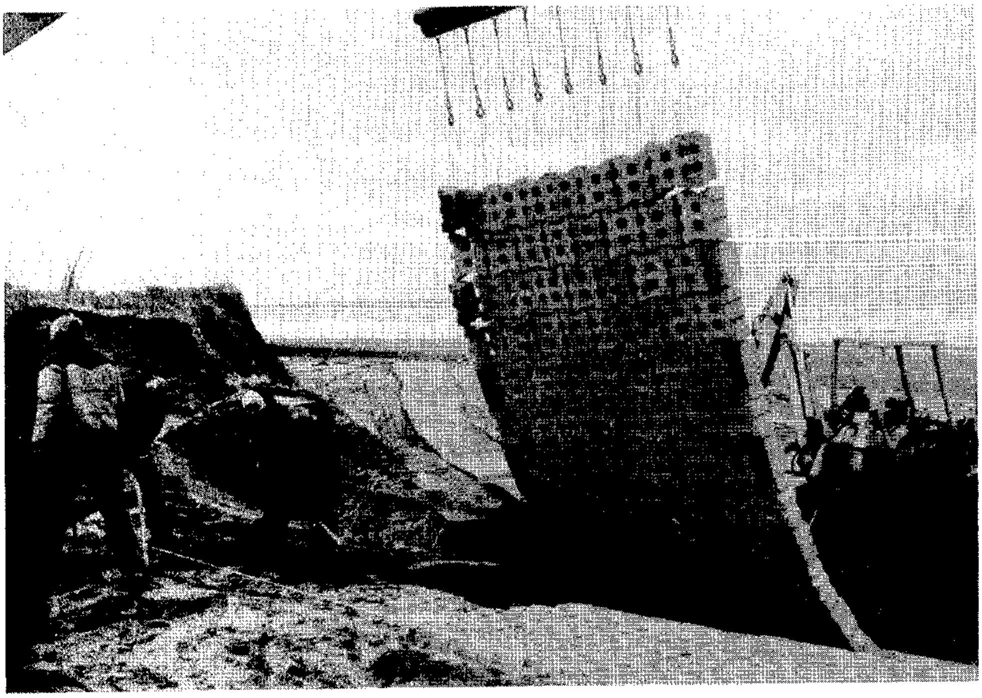
Photos



1. Ship Creek Overlook ARMORFLEX Installation

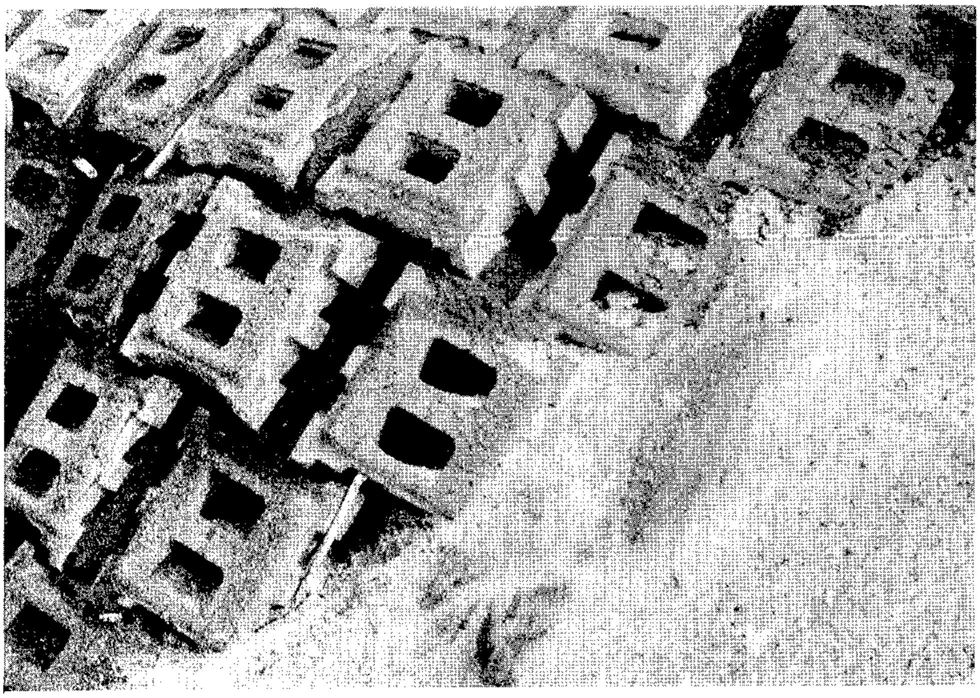


2. Hooper Bay moving ARMORFLEX Mattress with Loader and Crane

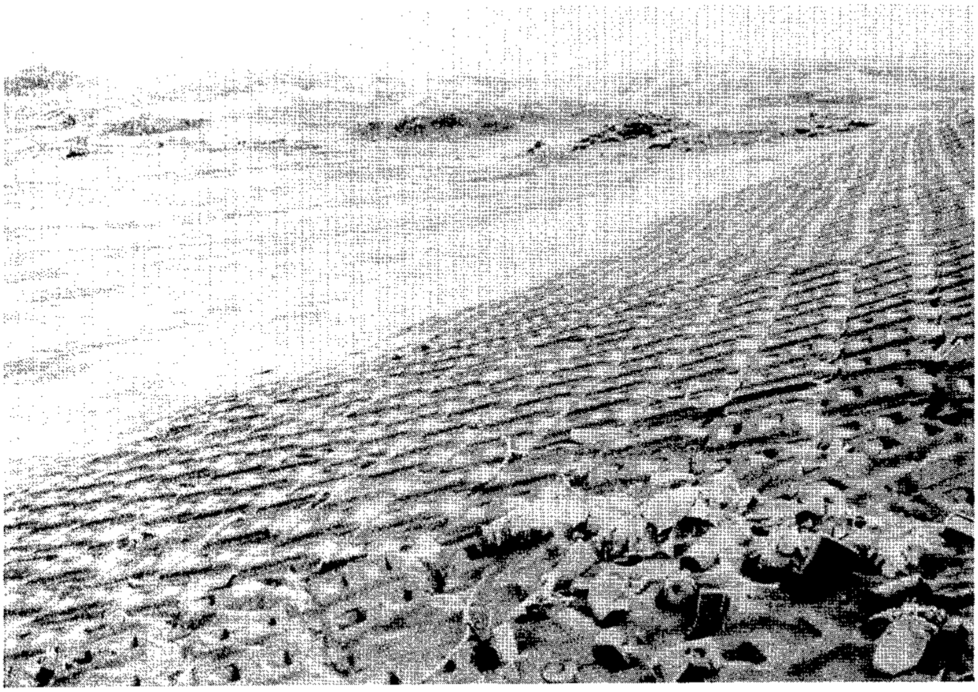


3. Hooper Bay. Placing ARMORFLEX Mattress over Geotextile

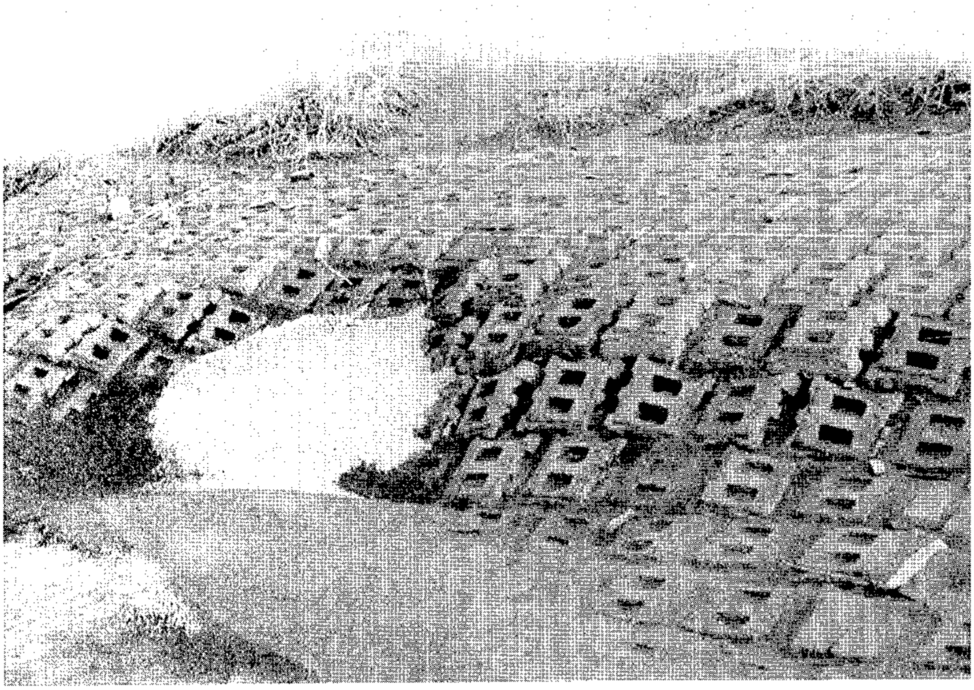
4. Hooper Bay. Stringing the ARMORFLEX Mattress by Hand



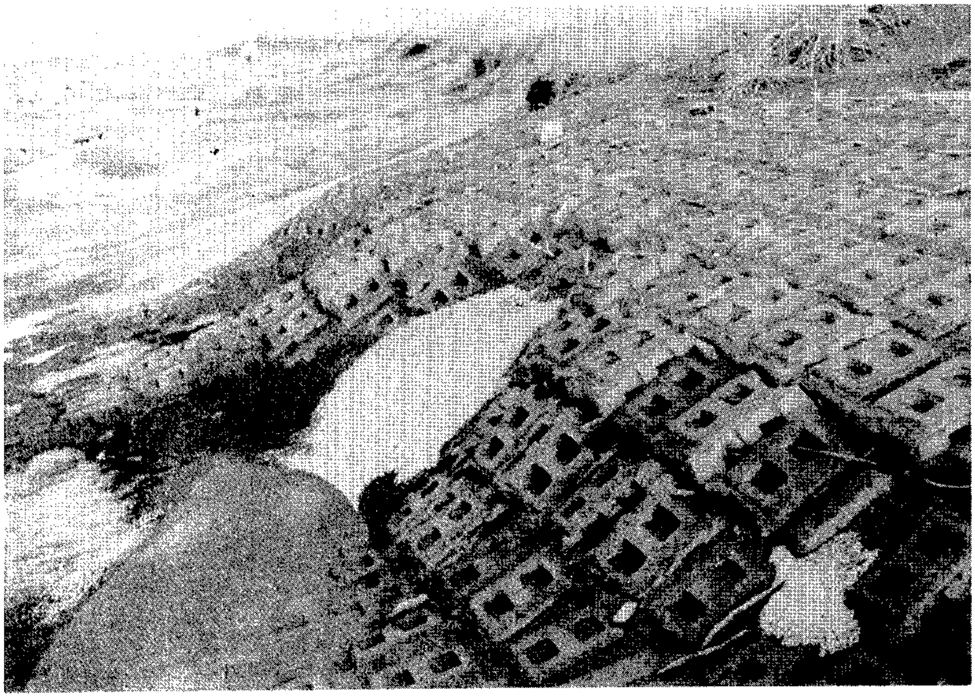
5. Hooper Bay ARMORFLEX, 1984



6. Hooper Bay ARMORFLEX, 1984

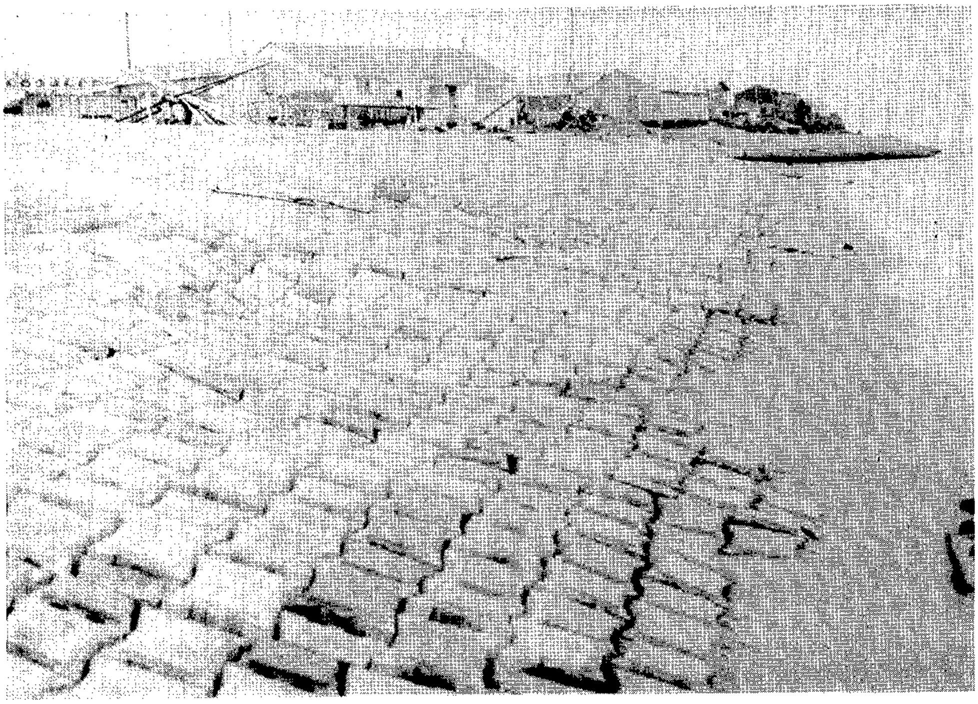


7. Hooper Bay ARMORFLEX, 1984



8. Hooper Bay ARMORFLEX, 1984

9. Shishmaref ARMORFLEX, August 1984



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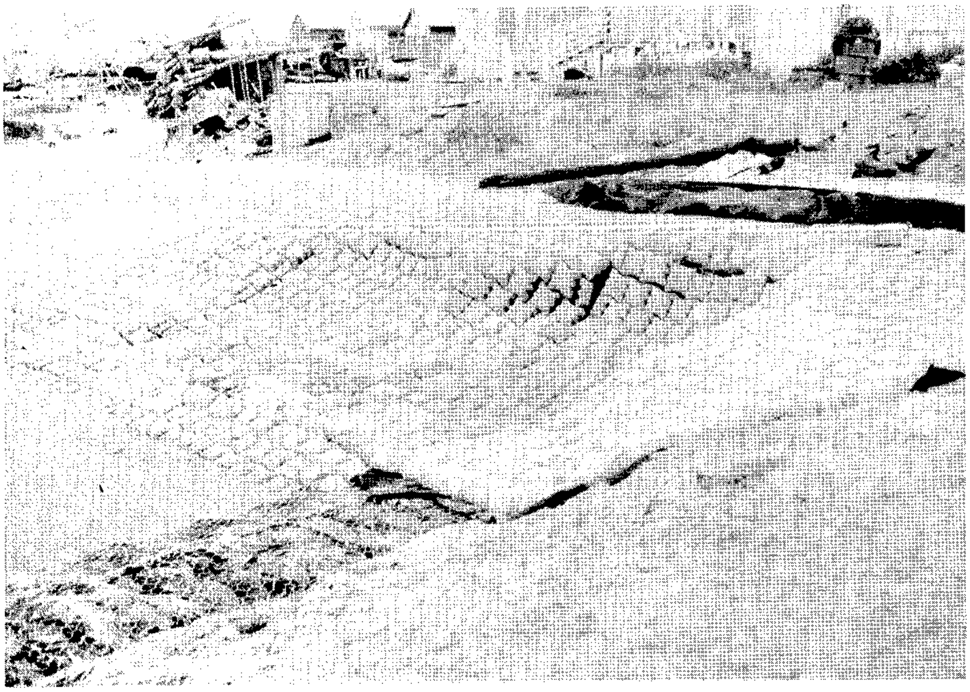
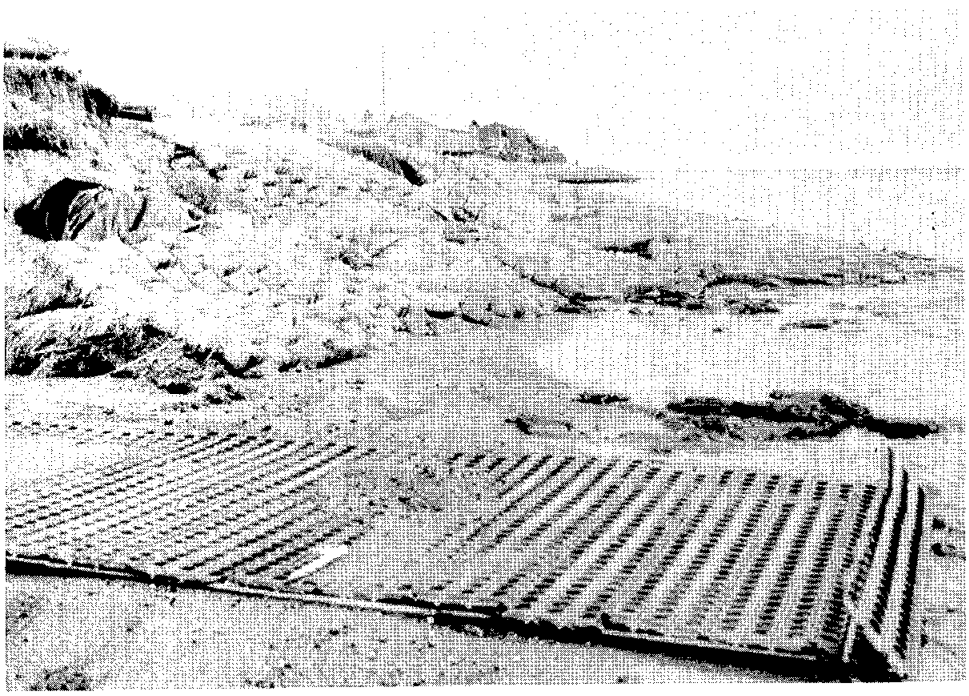


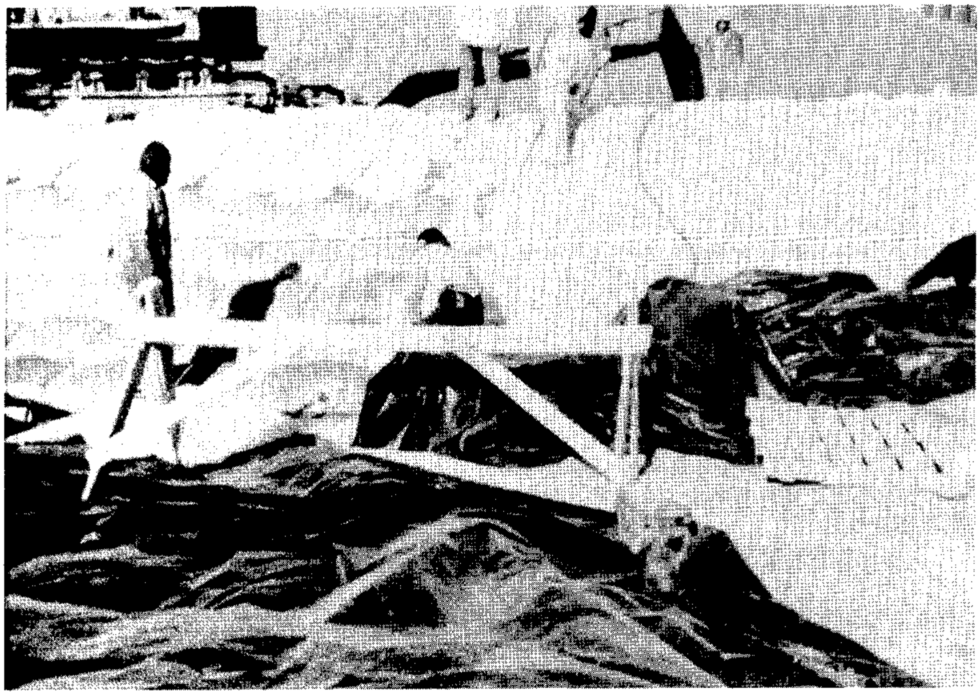
11. Shishmaref ARMORFLEX, August 1984



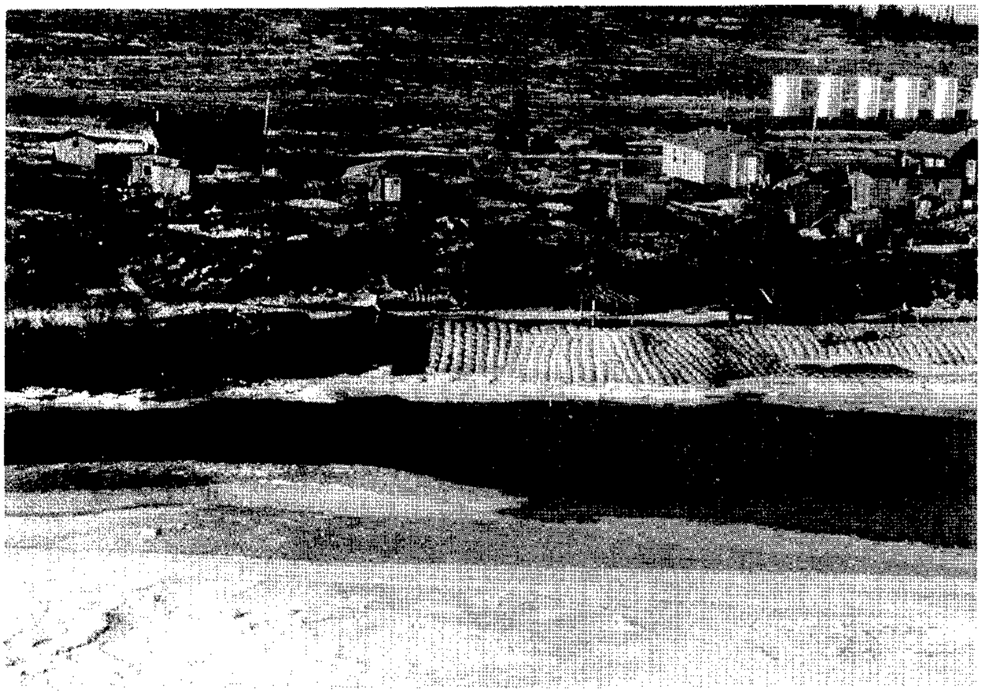
12. Shishmaref ARMORFLEX, August 1984

13. Noatak, Pumping Grout into ARMORFORM

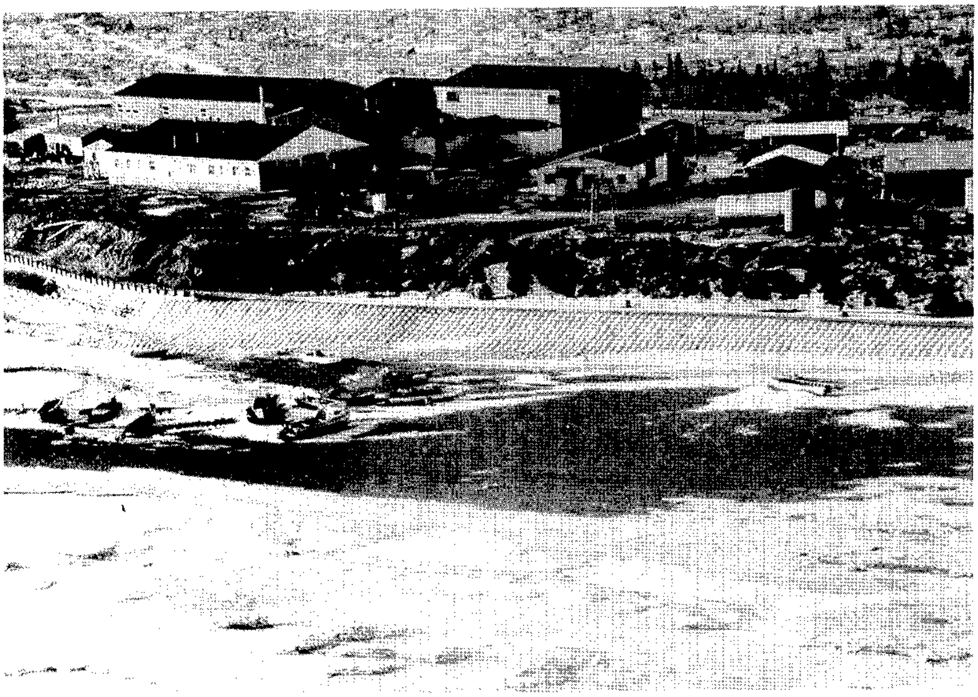
14. Noatak, Pumping Grout into ARMORFORM



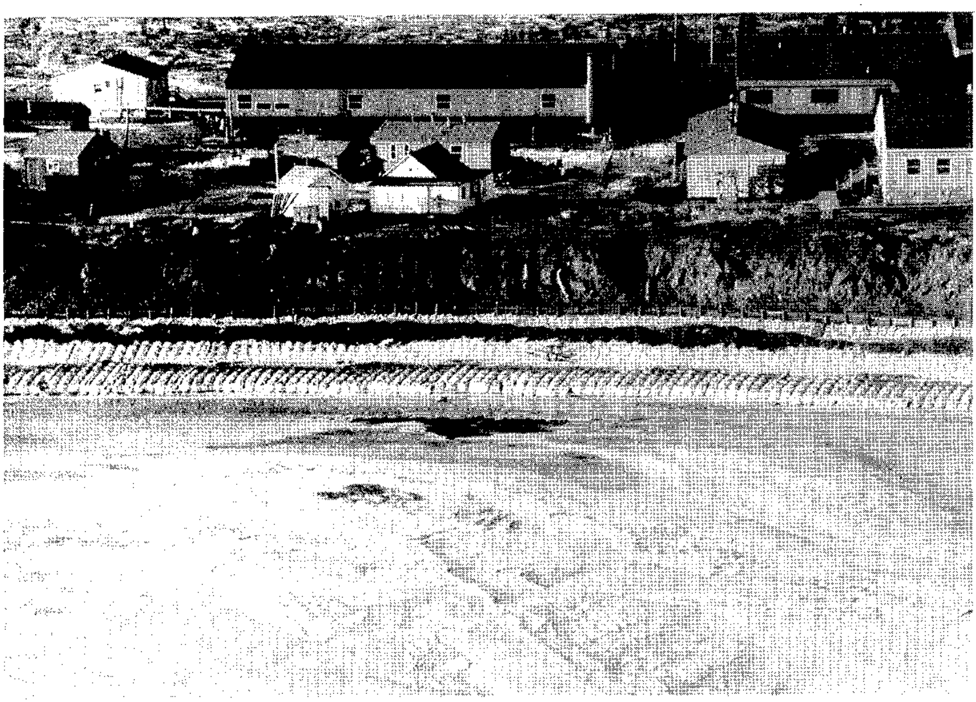
15. Noatak, ARMORFORM with Grout



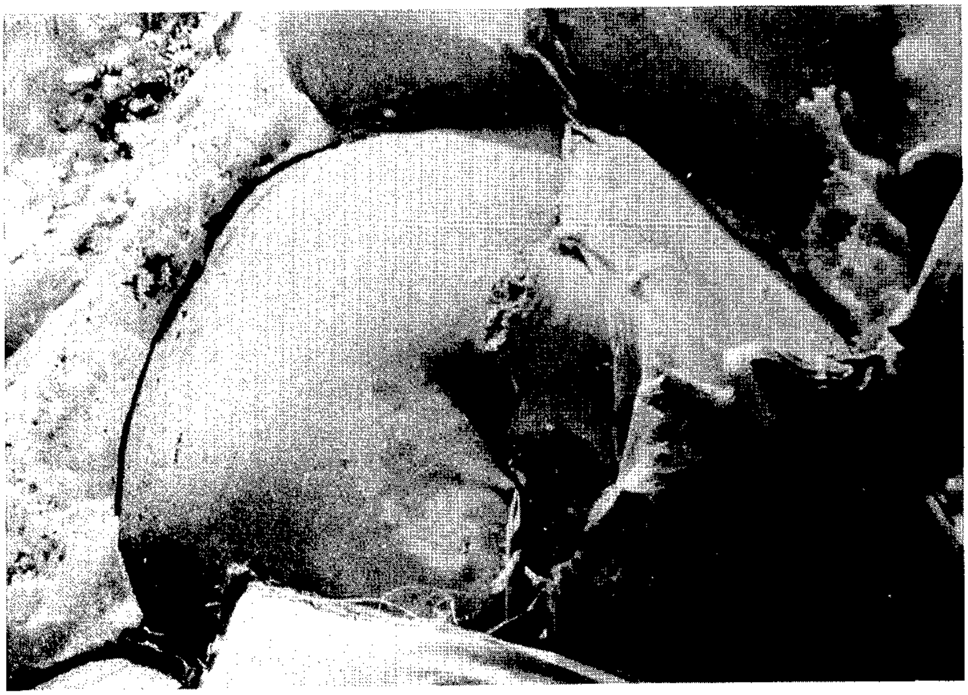
16. Noatak, ARMORFORM, 1984



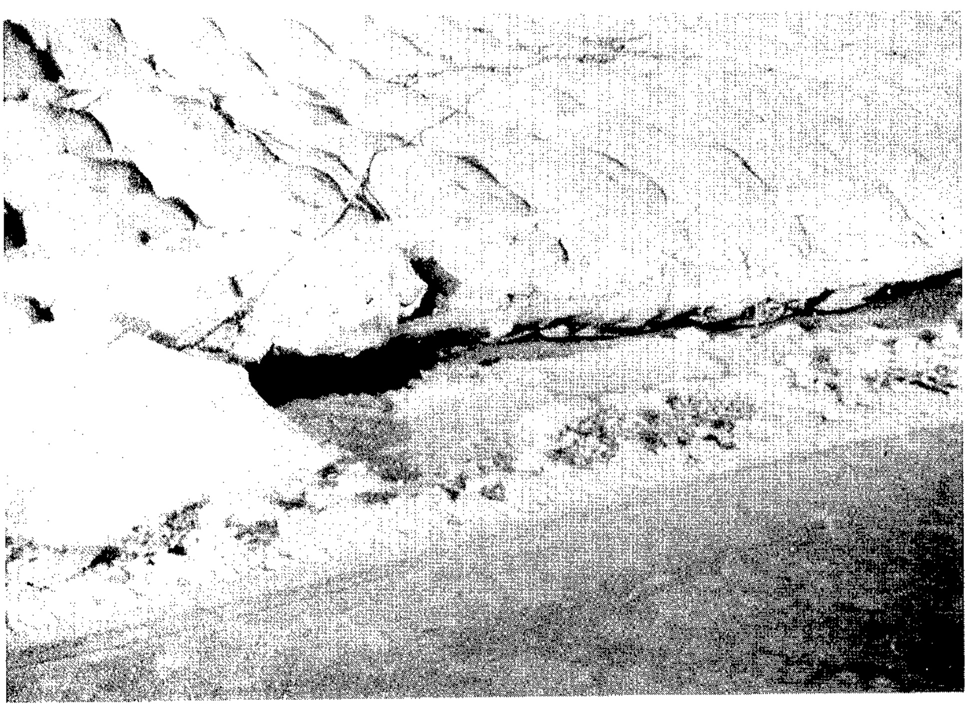
17. Noatak, ARMORFORM, 1984



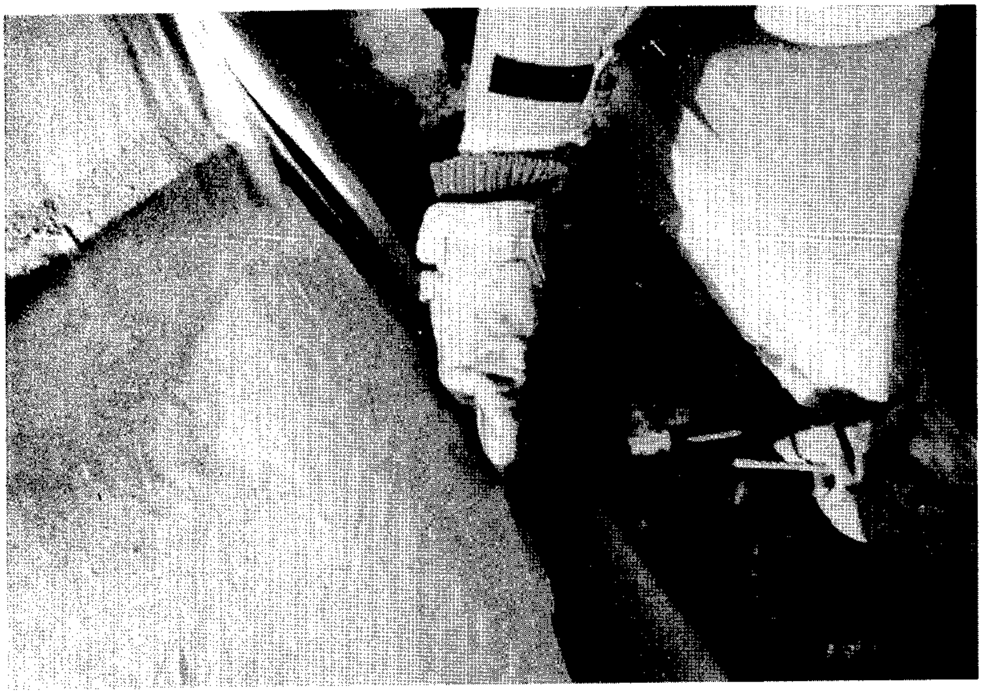
18. Noatak, ARMORFORM, 1984



19. Noatak, Broken Neck Between Two ARMORFORM Blocks



20. Noatak, the ARMORFORM has Slipped Down Slope



21. Noatak, Cable Slipped Out of the Connection

22. Noatak, ARMORFORM, 1984

APPENDIX B

Plans and Specifications for ARMORFLEX
Erosion Control System at Hooper Bay Airport

STATE OF ALASKA

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

PROJECT: Hooper Bay/Chevak	Opened at: Anchorage, Alaska	Certified True and Correct
LOCATION: Hooper Bay/Chevak, Alaska	By: William A. Allison	CLAYTON C. [illegible], DIRECTOR, DIVISION OF AVIATION, DESIGN & CONSTRUCTION
	Date: April 15, 1981	
	Compiled by: [illegible]	

COMPILATION OF BIDS

Page 1 of 2

Item No.	Bid Item	Quantity	Unit	ENGINEER'S ESTIMATE Unit Price	ENGINEER'S ESTIMATE Amount	Low: Knik Construction Co., P.O. Box 433, Lynden, Washington 98264 Unit Price	Low Amount	2nd Low: Brice Incorporated, P.O. Box 668, Fairbanks, Alaska 99701 Unit Price	2nd Low Amount	3rd Low: Spruce Construction, 8210 Hartzell Road, Anchorage, Alaska 99507 Unit Price	3rd Low Amount	Other Bidders In Decending Order
HOOPER BAY EROSION CONTROL												Name
100	Mobilization & Demob.	One Job	L.S.	---	$360,000.00	---	$247,000.00	---	$225,000.00	---	$350,000.00	Total Amount
125	Engineer's Vehicle	One	Each	---	$ 6,000.00	---	$ 5,000.00	---	$ 5,000.00	---	$ 5,000.00	Name
330(d)	Borrow Embankment	6,033	C.Y.	$7.50	$ 45,247.50	$8.00	$ 48,264.00	$20.00	$120,660.00	$11.00	$ 66,363.00	Total Amount
430	Concrete Block Armor Mat	21,905	S.F.	$5.20	$113,906.00	$12.00	$262,860.00	$10.00	$219,050.00	$15.00	$328,575.00	Name
910	Sodding	3,200	S.Y.	$20.00	$ 64,000.00	$7.00	$ 22,400.00	$20.00	$ 64,000.00	$10.00	$ 32,000.00	Total Amount
3[illegible]	Petroleum Escalation	All Req'd		$135.00	$ 135.00	$135.00	$ 135.00	$135.00	$ 135.00	$135.00	$ 135.00	Name
CHEVAK AIRPORT RUNWAY EXTENSION												Total Amount
[illegible]	Mobilization & Demob.	One Job	L.S.	---	$100,000.00	---	$100,000.00	---	$175,000.00	---	$200,000.00	Name
125	Engineer's Vehicle	One	Each	---	$ 2,000.00	---	$ 3,000.00	---	$ 2,500.00	---	5,000.00	Total Amount
150a	Equipment Rental	225	Hours	$210.00	$47,250.00	$200.00	$ 45,000.00	$200.00	$ 45,000.00	$150.00	$ 33,750.00	Name
150b	Equipment Rental	225	Hours	$210.00	$ 47,250.00	$200.00	$ 45,000.00	$200.00	$ 45,000.00	$150.00	$ 33,750.00	Total Amount
150c	Equipment Rental	200	Hours	$160.00	$ 32,000.00	$200.00	$ 40,000.00	$200.00	$ 40,000.00	$120.00	$ 24,000.00	Name
150d	Equipment Rental	200	Hours	$210.00	$ 42,000.00	$200.00	$ 40,000.00	$200.00	$ 40,000.00	$235.00	$ 47,000.00	Total Amount
150e	Equipment Rental	200	Hours	$210.00	$ 42,000.00	$200.00	$ 40,000.00	$200.00	$ 40,000.00	$235.00	$ 47,000.00	Name
												Total Amount

41

INTERIM CONSTRUCTION SPECIFICATION

CONCRETE BLOCK ARMOR MAT*

SECTION 430

430.1 DESCRIPTION

This work consists of: 1) Placing concrete block armor mat and filter fabric in accordance with these specifications in reasonably close conformity with the lines, grades, configurations, and dimensions shown on the plans; 2) The necessary removal of material to accommodate placement of the concrete block armor mat.

430.2 MATERIALS

a. Filter Fabric and Miscellaneous

(1) Filter Fabric. Filter fabric material shall be a pervious sheet of plastic monofilament or multifilament yarn, approved by the Owner, woven into a uniform pattern with distinct and measurable openings. Specific Equivalent Opening Size and other physical requirements not addressed in this specification are given in the plans and/or special provisions. The plastic filter fabric shall provide an Equivalent Opening Size in accordance with the U.S. Standard Sieve series. EOS is defined as the number of U.S. Standard Sieve having openings closest in size to the filter fabric openings. The percent open area provided shall be 30 percent. Percent open area is defined as the summation of the open areas divided by the total area of the filter fabric and expressed as a percentage.

The plastic from which the filter fabric is woven shall consist of a long-chain synthetic polymer base plastic composed of either polypropylene or polyethylene. Stabilizers and/or inhibitors shall be added to the base

*Reprinted from the Hooper Bay project specifications.

plastic to make filaments resistant to ultra-violet radiation deterioration. The fabric should be finished so that the individual strands will retain their relative position with respect to each other. The edges of the fabric shall be selvaged or otherwise finished to prevent the outer strands from pulling away from the fabric.

All plastic filter fabric and all seams to be used shall be accepted on the following basis:

The Constractor shall furnish the Owner, in duplicate, a mill certificate or affidavit, signed by a legally authorized official from the company manufacturing the fabric. The mill certificate, or affidavit, shall attest that the fabric meets the chemical, physical, and manufacturing requirements stated in this specification.

The seams of the fabric shall be sewn with thread of a material meeting the chemical requirements given above for plastic yarn. The sheets of filter fabric shall be sewn together at the factory or another approved location to form sections approximately 36 feet wide.

(2) Securing Pins. Securing pins shall be 3/16-inch diameter, of steel, pointed at one end and fabricated with a head to retain a steel washer having an outside diameter of no less than 1.5 inches. The length of the pins shall be no less than 24 inches. The pins shall be sufficient to positively and securely anchor the filter fabric to sand embankments.

(3) Shipment and Storage. During all periods of shipment and storage, the fabric shall be protected from direct sunlight, ultra-violet rays, temperatures greater than 140°F, mud, dirt, dust, and debris. To the extent possible, the fabric shall be maintained wrapped in a heavy-duty protective covering. Fabric shall be rejected if it has defects, rips, holes, flaws, deterioration, or damage incurred during manufactured, transportation, or storage. It shall be received at job site in good order.

b. Armoring

(1) General. All cellular concrete armor mats shall be Armor-Flex or approved equal: An assembly of concrete grids connected by cables in a manner which provides for interlock through the use of cables.

(2) Source of Material for Concrete. The sources from which the Contractor proposes to obtain the material will be selected well in advance of the time when the material will be required in the work. Suitable concrete samples and a sample of the cable shall be submitted to the Owner for approval prior to delivery of any such material to job site. Unless otherwise specified, all test samples shall be obtained by the Contractor and delivered at his expense to the Owner prior to shipment of the armor mats from the Contractor's fabrication site.

(3) Manufacture. The cellular concrete grids shall be machine made by vibration and compression process, composed of approved and graded aggregates and a no slump concrete mix. The mix water used shall be clean, fresh, free from oil, acids, soluable salts, and organic impurities. Cement shall conform with ASTM 150 requirements (Portland Cement). All concrete must be consolidated and steam-cured.

Concrete blocks must meet the following minimum requirements:

Compressive strength (28 days)	4000 psi
Water Absorption	8% Maximum
Freeze-Thaw Test (50 Cycles)	No Visible Effect

Block shall be limited to the following size and characteristics:

Class	Approximate Weight in lbs/ft²	Approximate Size Base X ht. (sq. ft. X in.)
A	40-50	1 X 6 (with cells)
B	47-57	1 X 6 (solid)

Cables and Fittings: The cables shall be pre-formed galvanized aircraft cable with aluminum fittings. The cables and fittings shall be resistant to all chemicals in strengths normally encountered in natural water and soil conditions. Selection of cable and fittings shall be made by the Contractor in accordance with the weight of the mats, and of such strength as to support the mat if lifted from a single end.

Size of cellular concrete mats: The cellular grids shall be connected by cables in interlocking rows, forming mats having a nominal width of eight (8) feet and a nominal length as indicated in the plans. Cables shall be looped at the ends in such a manner as to enable a connection with anchors and adjascent mats.

The special size mats shall be provided built to the dimensions and to the quanitity indicated on the plans.

c. Anchors. Contractor shall provide anchors as specified in the plans. The anchors shall be connected to the mat with the same type cable as used to construct the mats.

430.3 CONSTRUCTION REQUIREMENTS

All armor mats shall be placed directly over at least one layer of filter fabric meeting all the requirements of this specification. The mats shall be neatly laid in place in the configuration and to the slope and grade shown in the plans in accordance with these specifications.

430.4 METHOD OF MEASUREMENT

The quantity of concrete block armor mat to be paid for shall be the number of square feet of mat constructed and placed in accordance with these specifications and plans.

430.5 BASIS OF PAYMENT

Payment shall be made at the contract unit price per square foot for concrete block armor mat. This price shall be full compensation for furnishing all materials including filter fabrics; all preparation, delivering, placing, and constructing of these materials; and for all labor, equiment, tools, and incidentals necessary to complete this item.

Payment will be made under:

Item 430 - Concrete Block Armor Mat - Per Square Foot.

CONSTRUCTION PLANS FOR

HOOPER BAY AIRPORT

EROSION CONTROL

S.C. NO. 81-170-01

CHEVAK AIRPORT

RUNWAY EXTENSION

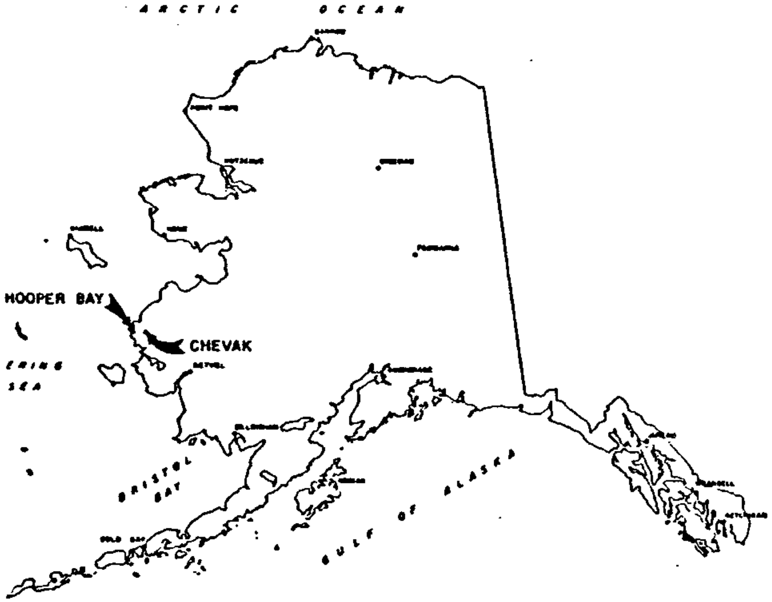
S.C. NO. 81-093-01

1981

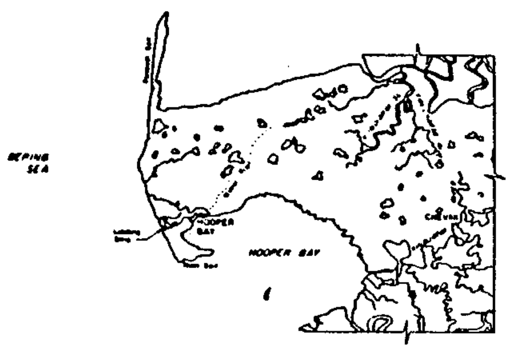
SPONSORED BY THE STATE OF ALASKA

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION and PUBLIC FACILITIES
DIVISION OF AVIATION - DESIGN & CONSTRUCTION

APPROVED [illegible] DATE [illegible]
CLAYTON C. HUENERS DIRECTOR



LOCATION MAP



VICINITY MAP

ESTIMATED QUANTITIES

NO.	ITEM	QUANTITY	UNIT
HOOPER BAY EROSION CONTROL		**SC. No. 81-170-01**	
100	MOBILIZATION AND DEMOBILIZATION	One Job	Lump Sum
125	ENGINEER'S VEHICLE	One Each	Per Each
330d	BORROW EMBANKMENT	6,033	Cu. Yds.
430	CONCRETE BLOCK ARMOR MAT	21,967	Sq. Ft.
910	SODDING	3,200	Sq. Yds.
3000	PETROLEUM ESCALATION	All Required	Cont. Sum
CHEVAK RUNWAY EXTENSION		**SC. No. 81-093-01**	
100	MOBILIZATION AND DEMOBILIZATION	One Job	Lump Sum
125	ENGINEER'S VEHICLE	One Each	Per Each
150a	EQUIPMENT RENTAL - CRAWLER TRACTOR / DOZER	225 Hours	Per Hour
150b	EQUIPMENT RENTAL - CRAWLER TRACTOR / DOZER	225 Hours	Per Hour
150c	EQUIPMENT RENTAL - LOADER	200 Hours	Per Hour
150d	EQUIPMENT RENTAL - OFF HIGHWAY HAULER	200 Hours	Per Hour
150e	EQUIPMENT RENTAL - OFF HIGHWAY HAULER	200 Hours	Per Hour

INDEX

SHEET TITLE	SHEET NO.
HOOPER BAY AIRPORT	
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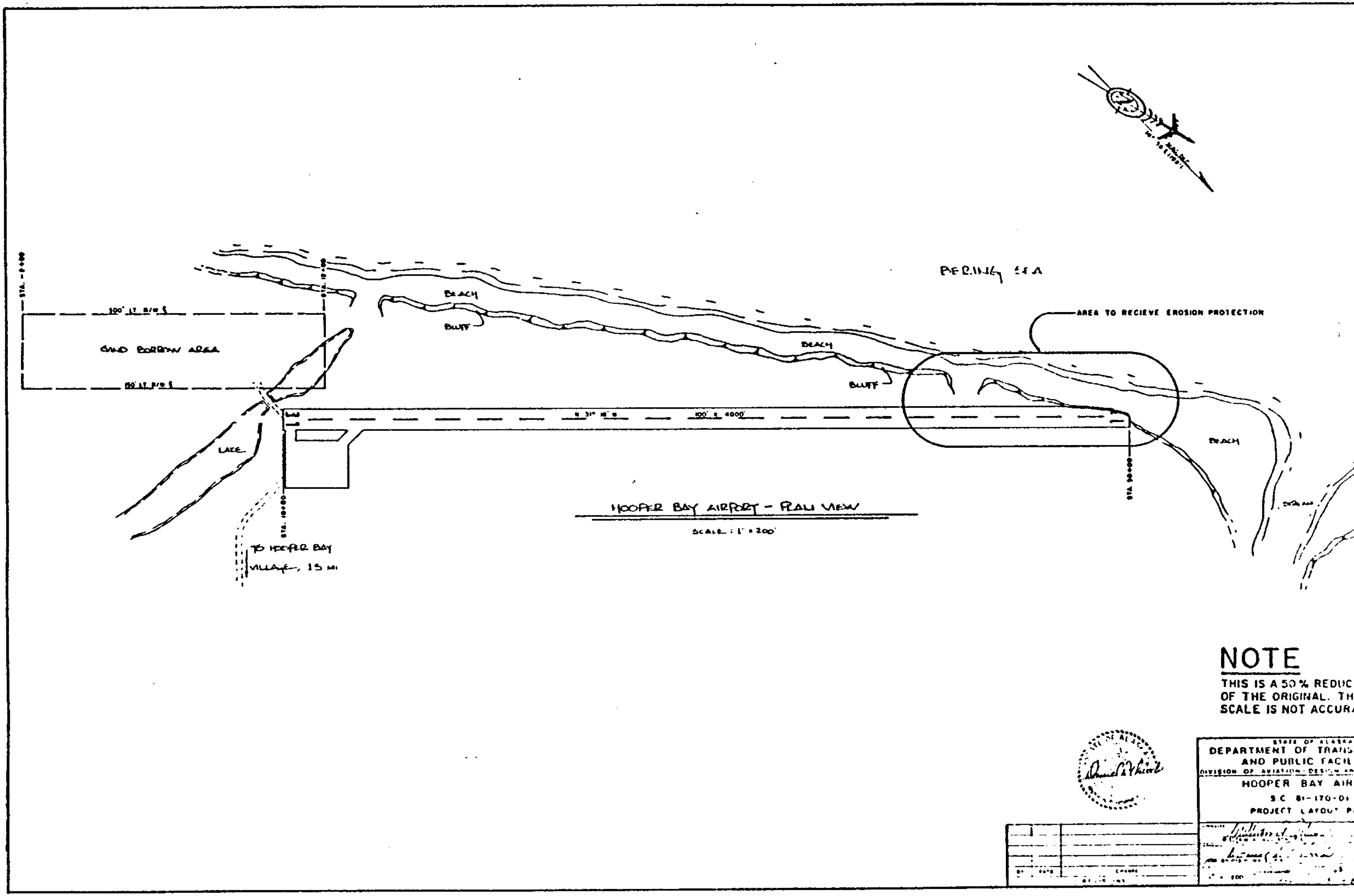
PROJECT LAYOUT PLAN	3
MAT PLAN SHEET	4
MAT DETAILS	5
ANCHOR DETAILS	6
CHEVAK AIRPORT	
RUNWAY PLAN AND PROFILE	7
TYPICAL SECTIONS	8

NOTE

THIS IS A 50 % REDUCTION OF THE ORIGINAL. THE SCALE IS NOT ACCURATE.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF AVIATION - DESIGN AND CONSTRUCTION
HOOPER BAY AIRPORT
S.C. 81-170-01
LOCATION AND VICINITY MAPS, INDEX AND ESTIMATED QUANTITIES

SHEET 2



BERING SEA
AREA TO RECIEVE EROSION PROTECTION
BEACH
BLUFF
BEACH
BLUFF
BEACH
SAND BORROW AREA
LAKE
100' x 4000'
TO HOOPER BAY
VILLAGE, 1.5 MI
HOOPER BAY AIRPORT - PLAN VIEW
NOTE
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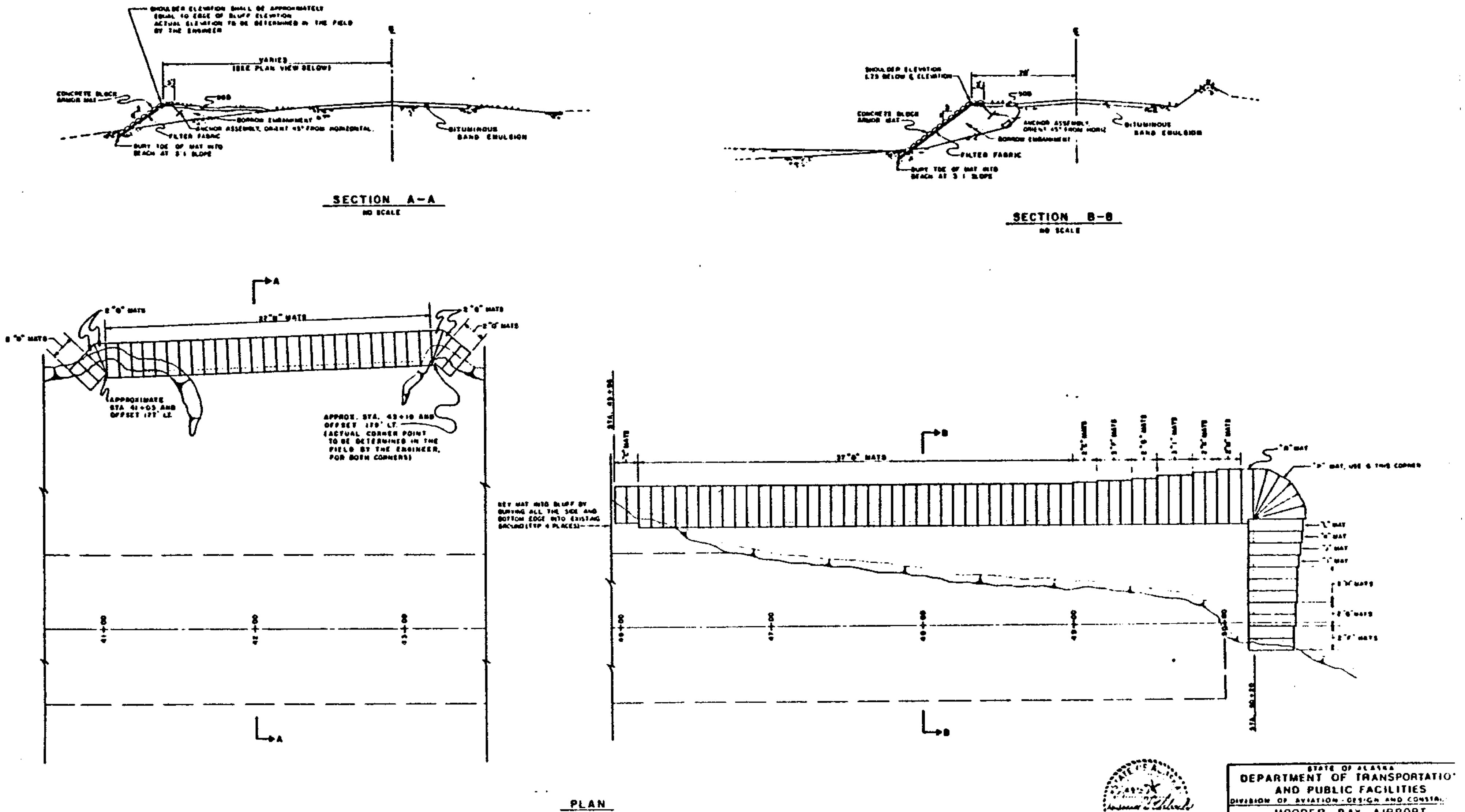
DEPARTMENT OF TRANSP
AND PUBLIC FACILIT
HOOPER BAY AIRP
PROJECT LAYOUT PLA



STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF AVIATION - DESIGN AND CONSTR.
HOOPER BAY AIRPORT
S.C. 81-170-01
MAT PLAN SHEET

NOTE

THIS IS A 50% REDUCTION OF THE ORIGINAL. THE SCALE IS NOT ACCURATE.

REGULAR MATS			
MAT	QUANTITY	DIMENSIONS	AREA (Sq. Ft.)
[illegible]	[illegible]	[illegible]	400
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
"R"	1	SEE DETAIL	[illegible]
			[illegible]

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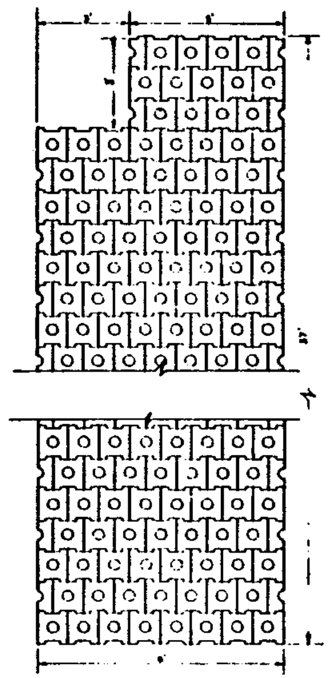
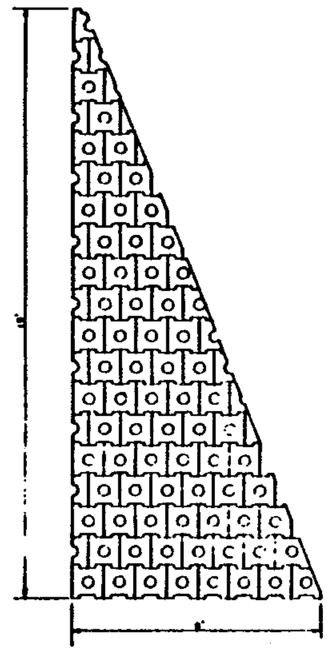
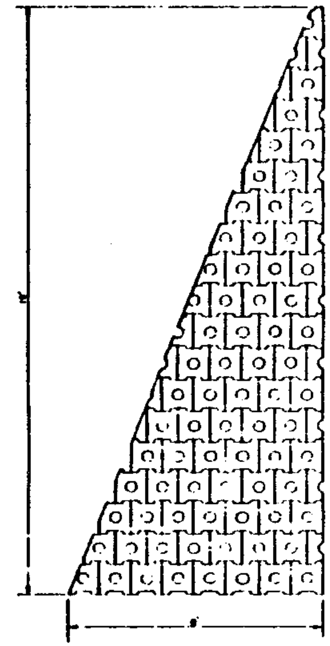
CORNER MATS			
MAT	MAT TYPE	QUANTITY	AREA (Sq. Ft.)
[illegible]	[illegible] - RIGHT	[illegible]	[illegible]
[illegible]	[illegible] - LEFT	[illegible]	[illegible]
[illegible]	"A" - RIGHT	[illegible]	[illegible]
[illegible]	"A" - LEFT	[illegible]	[illegible]
			[illegible]



"R" MAT



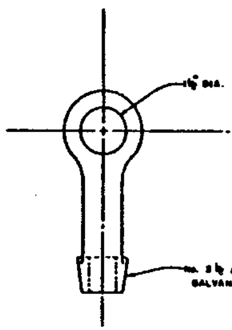
TYPE "A" MAT-LEFT



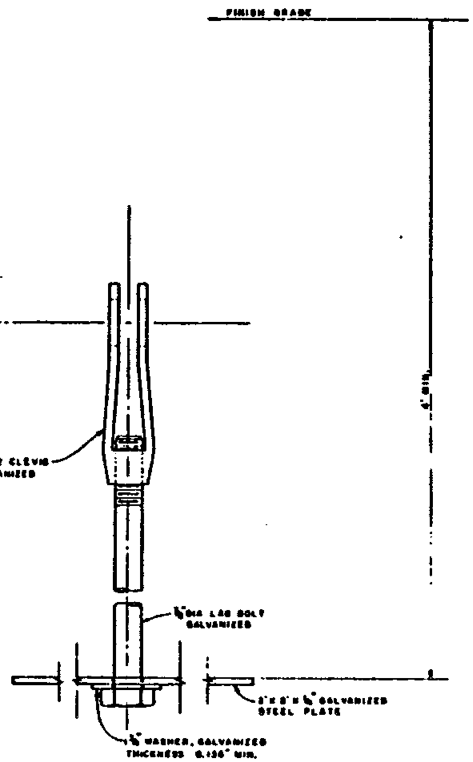
TYPE "A" MAT-RIGHT

STATE OF ALASKA
DEPARTMENT OF TRANSPORTA[illegible]
AND PUBLIC FACILITIES
DIVISION OF AVIATION-DESIGN AND CONS[illegible]
HOOPER BAY AIRPORT
SC 81-170-01
MAT DETAILS

REVISIONS



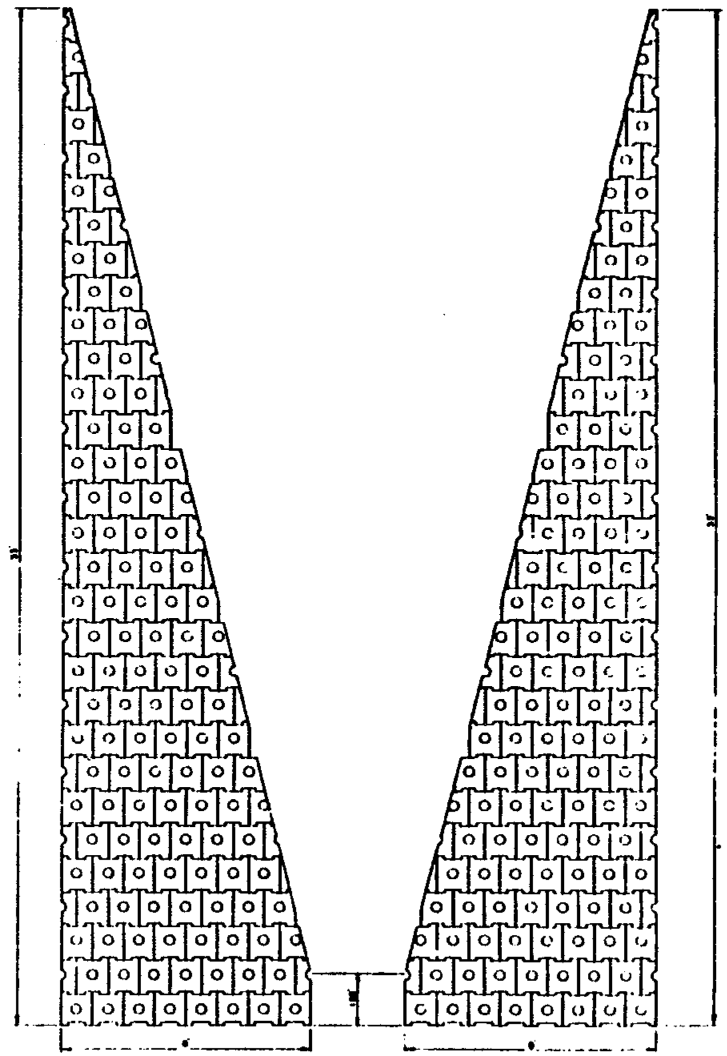
CLEVIS SIDE VIEW
NO SCALE



ANCHOR ASSEMBLY
NO SCALE

NOTES:

1. DIA. HOLE IN CENTER OF PLATE, GALVANIZE AFTER MAKING HOLE.
2. ATTACH ANCHOR ASSEMBLY TO MATS WITH MACHINE BOLT AND CABLE.
3. ATTACH ONE ANCHOR ASSEMBLY TO SHOULDER OF MAT ASSEMBLY EVERY 24'.



TYPE "B" MAT - LEFT

TYPE "B" MAT - RIGHT

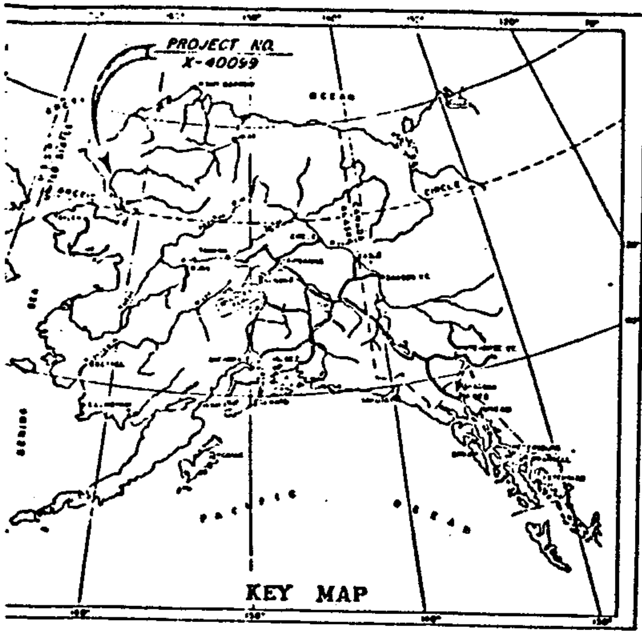
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
DIVISION OF AVIATION - DESIGN AND CONSTR.

HOOPER BAY AIRPORT
S.C. 81-170-01
MAT AND ANCHOR DETAILS

REVISIONS

APPENDIX C

Plans and Specifications for ARMORFORM Erosion Control System at Noatak



STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
&
PUBLIC FACILITIES

PLAN AND PROFILE
PROPOSED HIGHWAY PROJECT

X-40099
NOATAK BANK PROTECTION
PHASE II

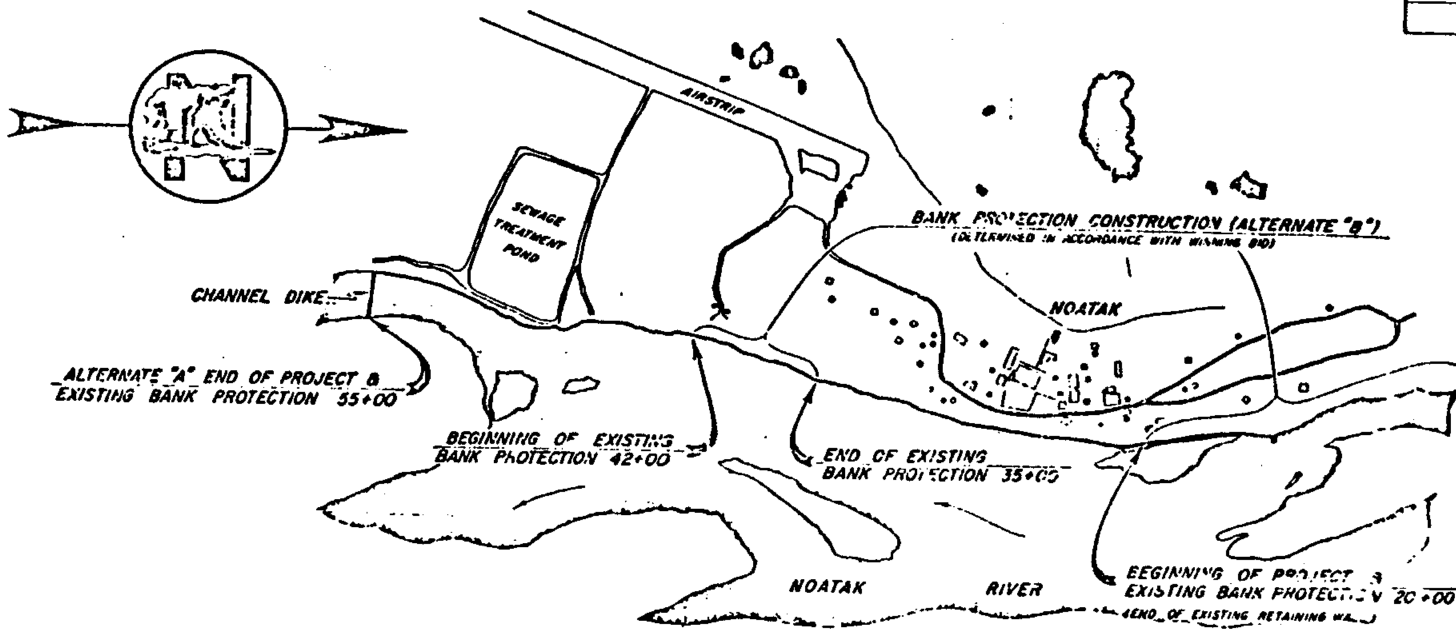
INDEX OF SHEETS	
SHEET NO.	DESCRIPTION
1	TITLE SHEET
2	TYPICAL SECTION & DETAILS
3	SUMMARY OF QUANTITIES

The following standard drawings apply to this project:

A-1,

PROJECT SUMMARY		
	ALTERNATE "A"	ALTERNATE [illegible]
WIDTH	10'	[illegible]
LENGTH OF BANK PROTECTION	3500'	[illegible]

54

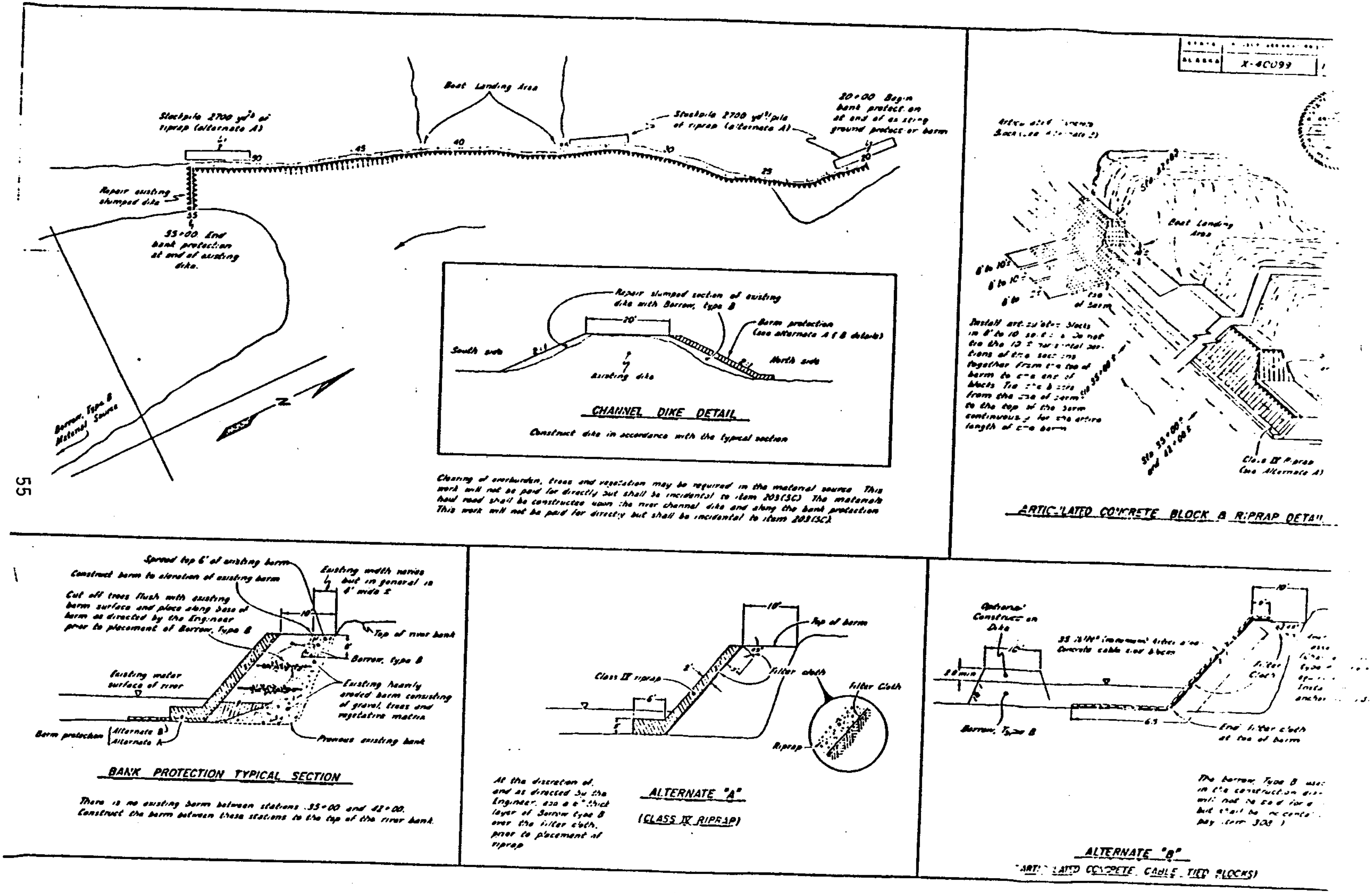


Plans Developed by ____________

Under the Supervision of

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
&
PUBLIC FACILITIES

APPROVED


X-4C099
Boat Landing Area
Stockpile 2700 yd³ of riprap (alternate A)
Stockpile 2700 yd³ pile of riprap (alternate A)
20+00 Begin bank protection at end of existing ground protection berm
Repair existing slumped dike
35+00 End bank protection at end of existing dike.
Borrow, Type B Material Source
Repair slumped section of existing dike with Borrow, type B
20'
Berm protection (see alternate A & B details)
South side
North side
2:1
Existing dike
CHANNEL DIKE DETAIL
Construct dike in accordance with the typical section
Clearing of overburden, trees and vegetation may be required in the material source. This work will not be paid for directly but shall be incidental to item 203(SC). The materials haul road shall be constructed upon the river channel dike and along the bank protection. This work will not be paid for directly but shall be incidental to item 203(SC).
Boat Landing Area
Sta 33+00
6' to 10'
toe of berm
Install articulated blocks in 6' to 10' sections. Do not tie the 10' horizontal sections of the sections together from the toe of berm to the end of blocks. Tie the blocks from the toe of berm to the top of the berm continuously for the entire length of the berm
Sta 33+00 and 42+00
Class IV Riprap (see Alternate A)
ARTICULATED CONCRETE BLOCK & RIPRAP DETAIL
Spread top 6' of existing berm
Construct berm to elevation of existing berm
Existing width varies but in general is 4' wide ±
Cut off trees flush with existing berm surface and place along base of berm as directed by the Engineer prior to placement of Borrow, Type B
10'
Top of river bank
Borrow, type B
Existing water surface of river
Existing heavily eroded berm consisting of gravel, trees and vegetative matrix
Berm protection (Alternate B / Alternate A)
Previous existing bank
BANK PROTECTION TYPICAL SECTION
There is no existing berm between stations 35+00 and 42+00. Construct the berm between these stations to the top of the river bank.
10'
Top of berm
Class IV riprap
Filter cloth
Filter Cloth
6'
Riprap
At the discretion of and as directed by the Engineer, a 6" thick layer of Borrow type B over the filter cloth, prior to placement of riprap
ALTERNATE "A"
(CLASS IV RIPRAP)
Optional Construction Dike
10'
Concrete cable tied blocks
Filter Cloth
Borrow, Type B
End filter cloth at toe of berm
ALTERNATE "B"
(ARTICULATED CONCRETE CABLE TIED BLOCKS)

ESTIMATE OF QUANTITIES

ITEM NO	DESCRIPTION	UNIT	QUANTITY ALTERNATE "A"	QUANTITY ALTERNATE "B" Estimated Quantities of Incidental Items	QUANTITY ALTERNATE "B" Allocated Amount for Pay Items
110(1)	Mobilization	L.S.	All Req'd	—	$400,000
114(1)	Construction Surveying by the Contractor	L.S.	All Req'd	All Req'd	
116(1)	Furnishing & Maintaining a Field Office	L.S.	All Req'd	All Req'd	
116(2)	Furnishing & Maintaining a Field Laboratory	L.S.	—	All Req'd	
203(5C)	Borrow, Type B	C.Y.V.M.	40,700 total	40,?00 total	
207(3)	Filter Cloth	S.Y.	14,060 total	4.9 per foot	
308(1)	Constructed Bank Protection	L.F.			$1,723,000
611(4)	Stockpile riprap, class II	C.Y.V.M.	8,100	—	
611(3)	Riprap, Class II	C.Y.V.M.	12,400 total	—	
637(1)	Articulated Concrete-Cable Tied Block	S.Y.	—	7.56 per foot	
637(2)	Screw Anchor	Each	—	1 per eight feet	

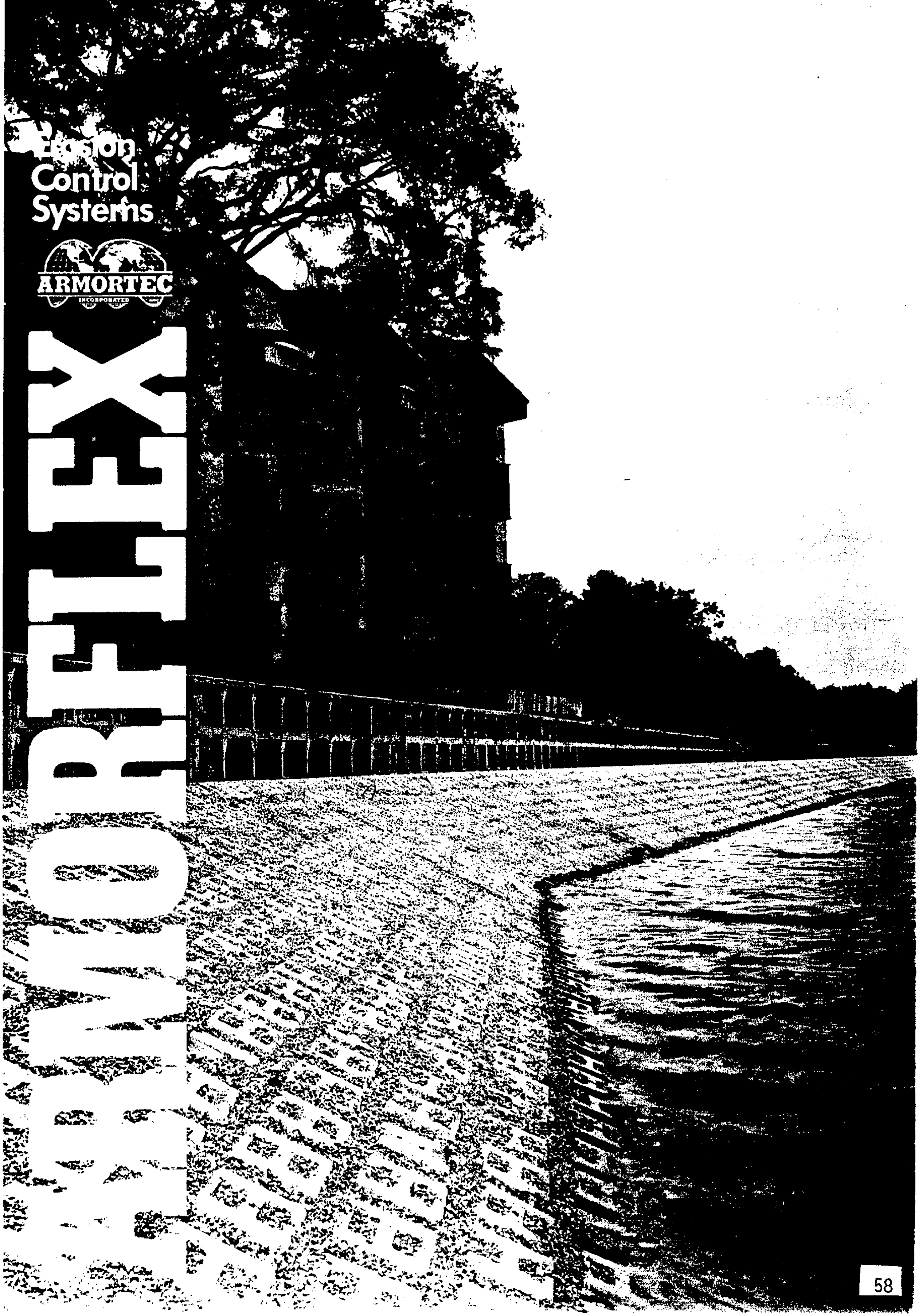
NOTES

1. All materials and labor [illegible] for items listed in "Estimated Quantities of Incidental [illegible]" under Alternate "B" shall not be [illegible] for directly but shall be [illegible] to pay item 308(1). (See section 308 of the Special Provisions.)

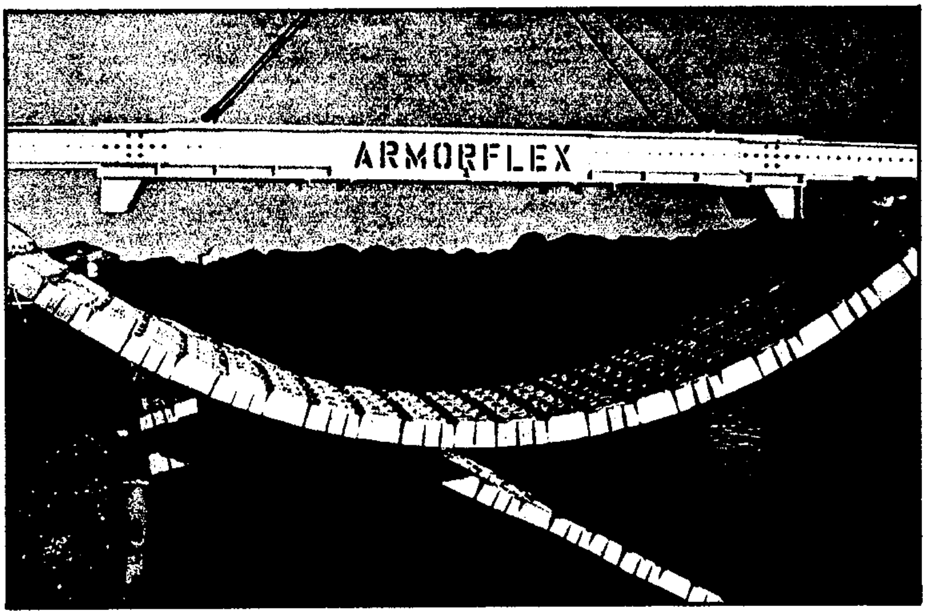
2. The exact location of the three riprap stockpiles (alternate A) shall be designated by the Engineer.

APPENDIX D

ARMORFLEX Information Brochure


Erosion
Control
Systems
ARMORTEC
INCORPORATED
ARMORFLEX

PERFORMANCE TESTED/COST EFFECTIVE ARMORFLEX EROSION CONTROL SYSTEM



Armorflex articulating precast concrete mats erosion control system.

ARMORFLEX Erosion Control System provides the engineered alternative to conventional erosion control materials for revetment and channel protection.

ARMORFLEX combines its specially designed interlocking precast concrete grids, cables and filter system to provide stable, articulated and permeable erosion protection, which maintains its integrity in the event of subgrade deformation or severe dynamic loading.

ARMORFLEX is placed by conventional construction equipment directly on the prepared subgrade of the structure as a system of factory pre-assembled mats of interlocking grids interconnected with cables.

ARMORFLEX results in a stable erosion control system available in a range of classes to accommodate various wave climates and stream flow conditions with aesthetic and ecological advantages.

ARMORFLEX, whether vegetated or otherwise, provides durable, flexible and permeable erosion protection for:

- Coastal Shorelines
- Earthen Dams
- Storm Channels & Ditches
- Bulkhead, in lieu of
- Pipeline Crossings
- Lakes & Reservoirs
- Rivers, Streams, & Bayous
- Dikes & Levees
- Bridge Abutments
- Water Control Structures
- Ponds & Holding Basins
- Sand Dunes
- Embankments
- Spillways
- Subaqueous Pipelines
- Boat Launching Ramps

ARMORFLEX has been proven technically and economically superior to traditional protective materials. When conditions such as poor soils, limited access, aesthetic and environmental considerations or a short construction season or schedule are primary factors, ARMORFLEX has proven to be the design solution.

Characteristics.

STABILITY. ARMORFLEX provides a continuous erosion protection that acts as an articulated mattress to withstand the destructive forces of water. The proper ARMORFLEX class is determined by the design velocity or wave height to which it shall be subjected.

FLEXIBILITY. ARMORFLEX grids are interconnected by flexible cables which provide articulation between adjacent grids. The walls of the ARMORFLEX grid are designed with beveled relief to allow for flexibility in all directions.

PERMABILITY. ARMORFLEX is generally placed on filter fabric and/or conventional graded filter. The permeability of the filter system and grids relieves hydrostatic pressures while its capability for soil retention prevents leaching of subsoils through the installation.

FLOW RESISTANCE. ARMORFLEX is available with open cell grids or with closed cell grids to provide a combination of unit weight and surface roughness. The ARMORFLEX Manning Roughness Coefficient, "n", has a value ranging from 0.026 to 0.044, depending upon the grid used, material filling the cells, and vegetative cover.

VEGETATION. When vegetation is desired, ARMORFLEX's open cells are filled with soil, then sown or planted. The open cells provide a perfect environment for the establishment of vegetation. Even roots of grass and small shrubs can penetrate the filter system, providing a permanent anchor for the installation while beautifying the landscape. ARMORFLEX, with closed cells or open cells filled with stone, ($d_{50} <$ .75"), precludes vegetative cover.

ACCESS. ARMORFLEX is free of dangerous projections thus providing safe access for pedestrians, animals, vehicles, boats, and other small craft to the water's edge.

Preparation and installation.

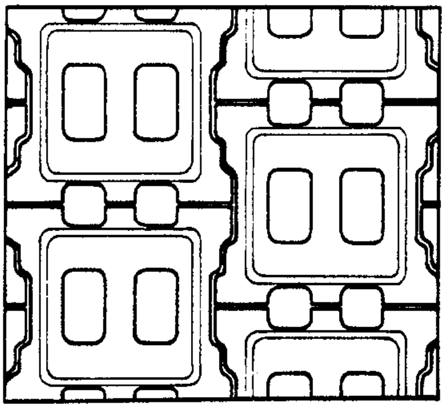
ARMORFLEX is delivered on trailers or barges as prefabricated mats, of up to 480 ft.^{2} per mat.

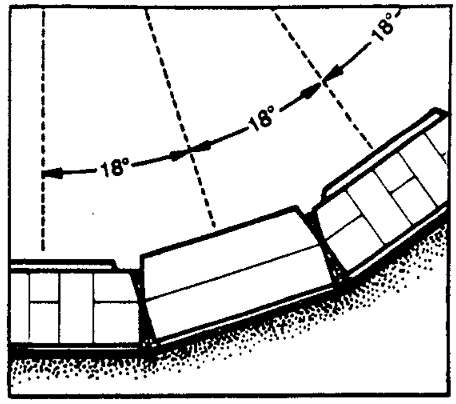
Construction begins with site preparation of the area to be protected. Vegetation and obstructions, such as roots and projecting stones are removed. Holes, soft areas and large cavities are filled and compacted with suitable materials.

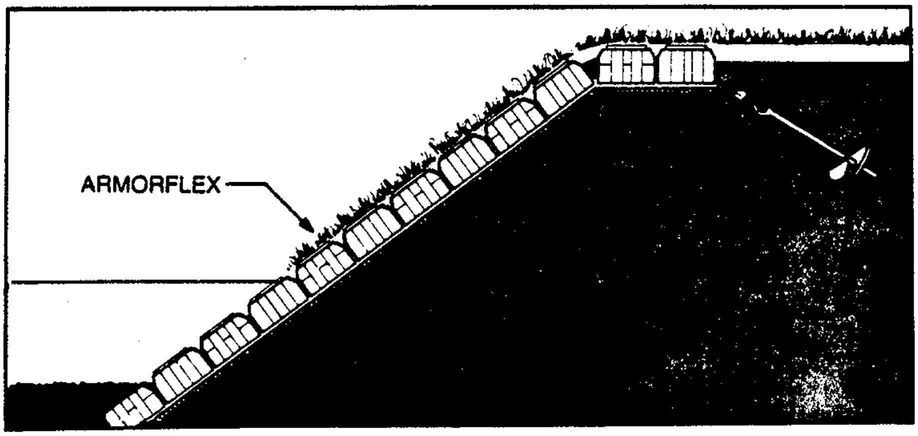
- Excavate toe, terminals and upper bank protection trenches as required.
- Filter fabric and/or graded filter material, is placed over the prepared subgrade.
- The first row of mats are placed side by side on the structure by attaching the cable loops at both ends of the mat to a spreader bar for placement by a crane or backhoe.
- Adjacent mats are connected by pouring side connecting keys and/or by fastening side connecting cables and end loops.
- Optional anchors are placed at the top of the slope.

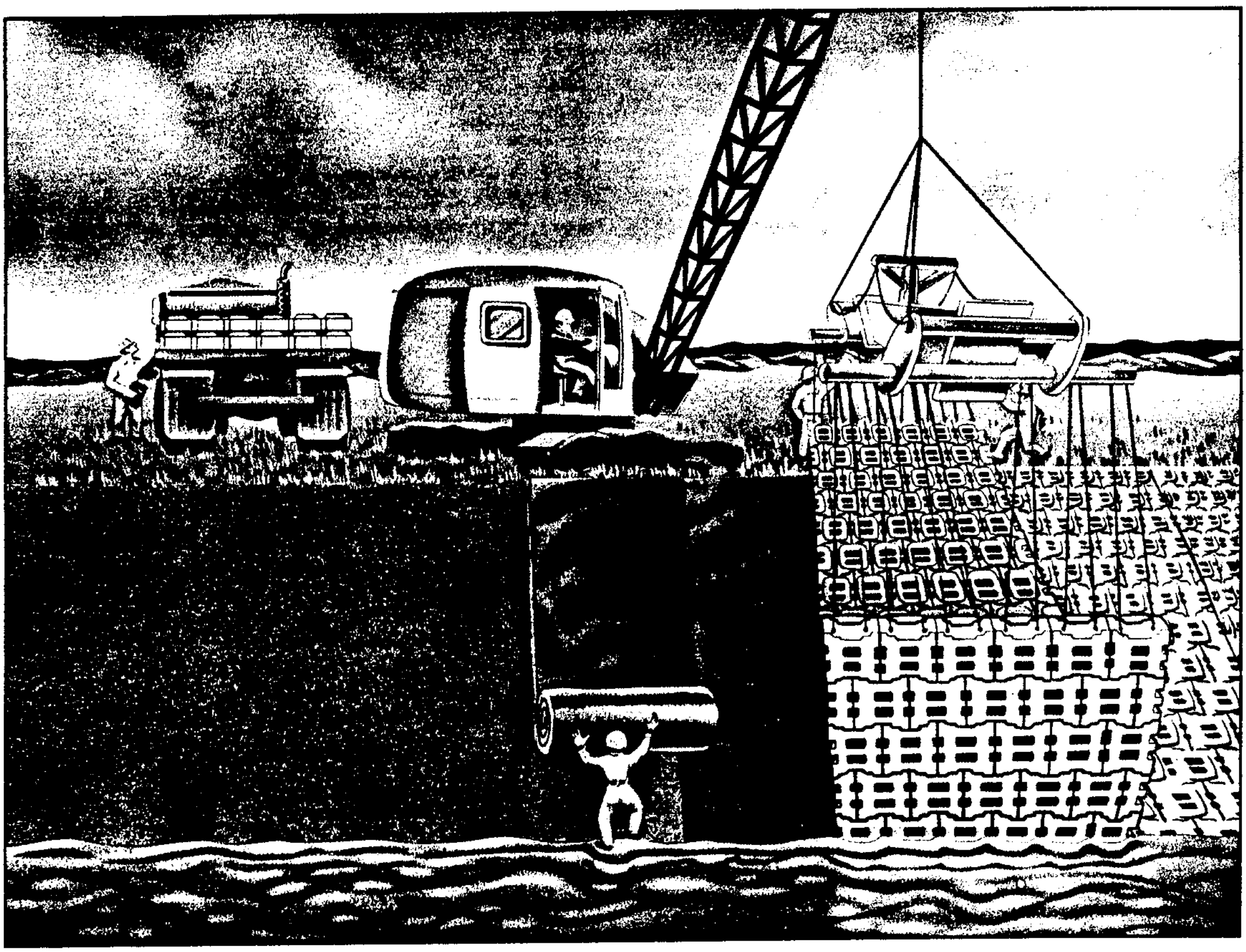
- Backfill and compact the trenches as mat placement proceeds.
- Additional sections of mats are placed and connected until the desired limits of protection are reached.
- Backfill is spread over the mats and into the open cells, then sown or planted as desired.

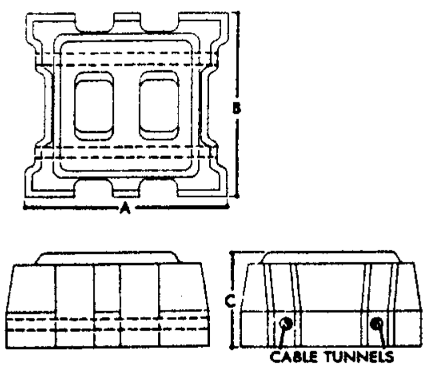
ARMORFLEX MATS CAN BE EASILY INSTALLED UNDERWATER. The spreader bar can be fitted with special, remote release clamps, which allow the mat to be released from the surface. There is no need to de-water the work area. The positioning of the mats can be done from the surface in shallow water or by divers in deep water. in addition, a structure can be easily built on a environmentally restricted site because there is no need for expensive cofferdams that disturb the natural environment surrounding the project site.



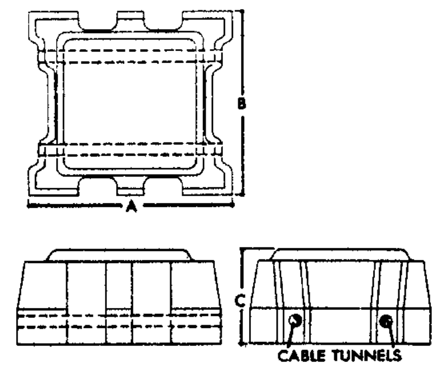








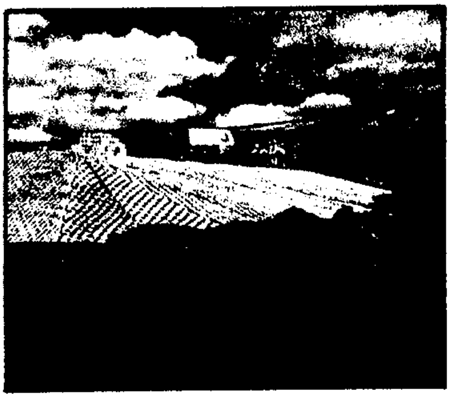
OPEN CELL GRID

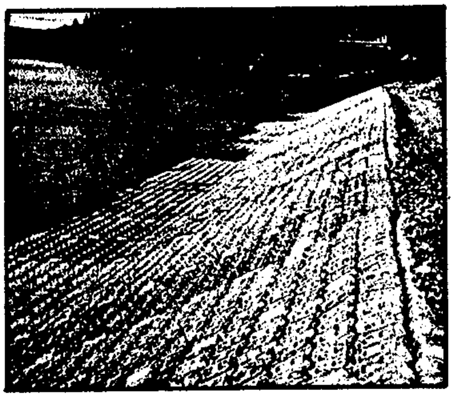


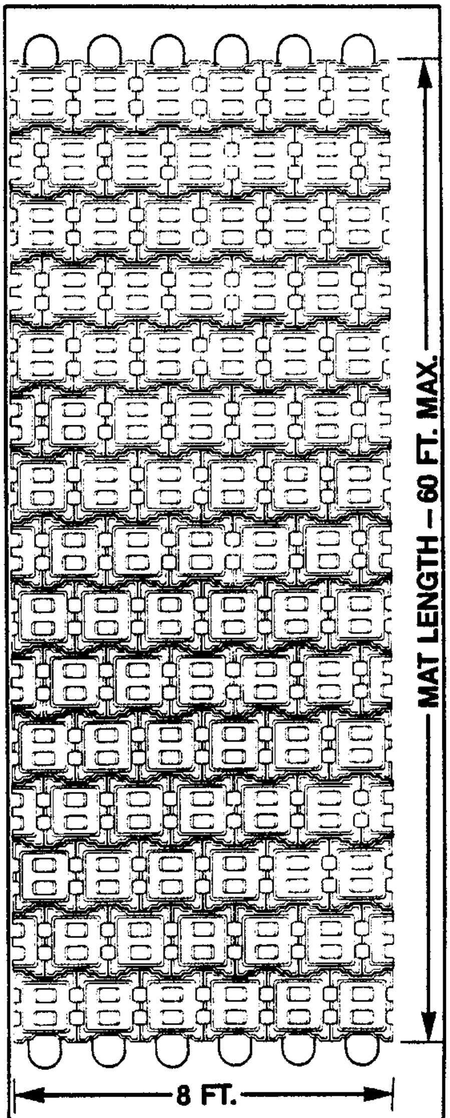
CLOSED CELL GRID

ARMORFLEX GRID SPECIFICATIONS

	CLASS	TECHNICAL DATA: SPECIFIC WEIGHT LBS./CU.FT.	TECHNICAL DATA: COMPRESSIVE STRENGTH LBS./SQ.IN.	% MAXIMUM ABSORPTION	DIMENSIONS & WEIGHTS: NOMINAL DIMENSIONS IN. A	B	C	GROSS AREA/ GRID SQ.FT.	WEIGHT/ GRID LBS.	WEIGHT/ AREA LBS./SQ.FT.	OPEN AREA %
OPEN CELL	30	130-150	4000-5000	5	13.0	11.6	4.75	0.98	31-36	32-37	25
	50	130-150	4000-5000	5	13.0	11.6	6.0	0.98	45-52	46-53	20
	70	130-150	4000-5000	5	17.4	15.5	9.0	1.77	120-136	68-78	20
CLOSED CELL	45	130-150	4000-5000	5	13.0	11.6	4.75	0.98	39-45	40-46	10
	55	130-150	4000-5000	5	13.0	11.6	6.0	0.98	53-61	54-62	10
	85	130-150	4000-5000	5	17.4	15.5	9.0	1.77	145-167	82-96	10







Components.

GRIDS. The grids are precast concrete blocks, available in a range of classes to accommodate various applications. The range of classes allows the selection of the proper combination of unit weight, surface roughness and open area for stability and hydraulic relief.

CABLE & FITTINGS. Cables are galvanized steel aircraft cable or polyester; stainless steel has been used for special applications.

The compression fittings used to make cable splices and to confine the grids are selected to match the cable strength and are composed of materials suitable for the cable employed.

FILTER FABRIC. The filter fabric is a pervious sheet of woven and/or nonwoven fabric selected in accordance to the gradation and permeability analysis of the soil and/or fill material on which the mats are to be placed. If a graded filter material is selected for use, it must be carefully designed and installed to prevent movement of the gradation through the protection cover layer.

MAT ANCHORS. For structures with steep side slopes, helix type corrosion resistant anchors are installed at the top of the slope to provide additional stability.

Technical Assistance.

ARMORTEC is staffed by qualified civil engineers to aid in the preparation of designs and cost estimates for potential projects. If approved, ARMORTEC's engineering department will prepare shop drawings for the engineer's review and approval. Pre-bid and pre-construction conferences with contractors and on-site construction assistance are also provided by ARMORTEC's construction services group.

Manufacturer and Supply.

ARMORFLEX erosion control mats are available in six classes to accomodate the conditions prevailing in a given application. ARMORFLEX grids are manufactured on standard concrete block machines located around the world. ARMORFLEX mat cabling machines are portable and can preassemble mats at the concrete block plants or on the construction site. Mat dimensions are selected to meet the area required for the ARMORFLEX installation.

ARMORTEC Erosion Control Systems are currently in service around the world. Their uses range from channel linings to riverbanks and from subaqueous pipeline protection to major shoreline revetments. The positive results achieved by ARMORTEC in providing revetment and bank protection systems for civil engineering projects supply convincing proof of the benefits you may reap from ARMORTEC's broad spectrum of erosion control systems.

For further information on our erosion control systems and their varied applications, contact:

ARMORTEC
INCORPORATED
A subsidiary of NICOLON, Corporation

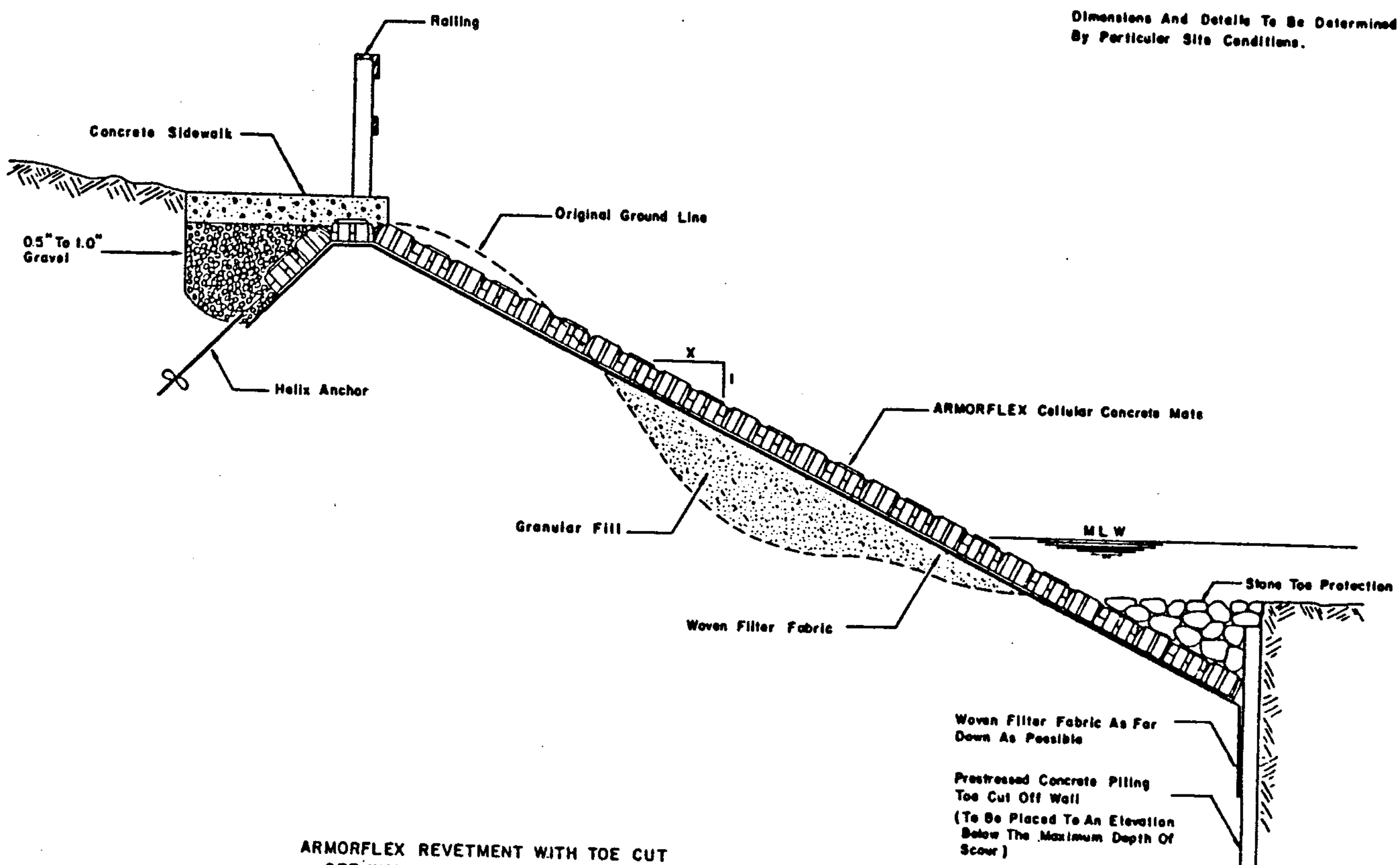
3150 Holcomb Bridge Rd.
Suite 300
Norcross/Atlanta Georgia 30071

(404) 447-6272
Telex: 804453

LOCAL REPRESENTATIVE

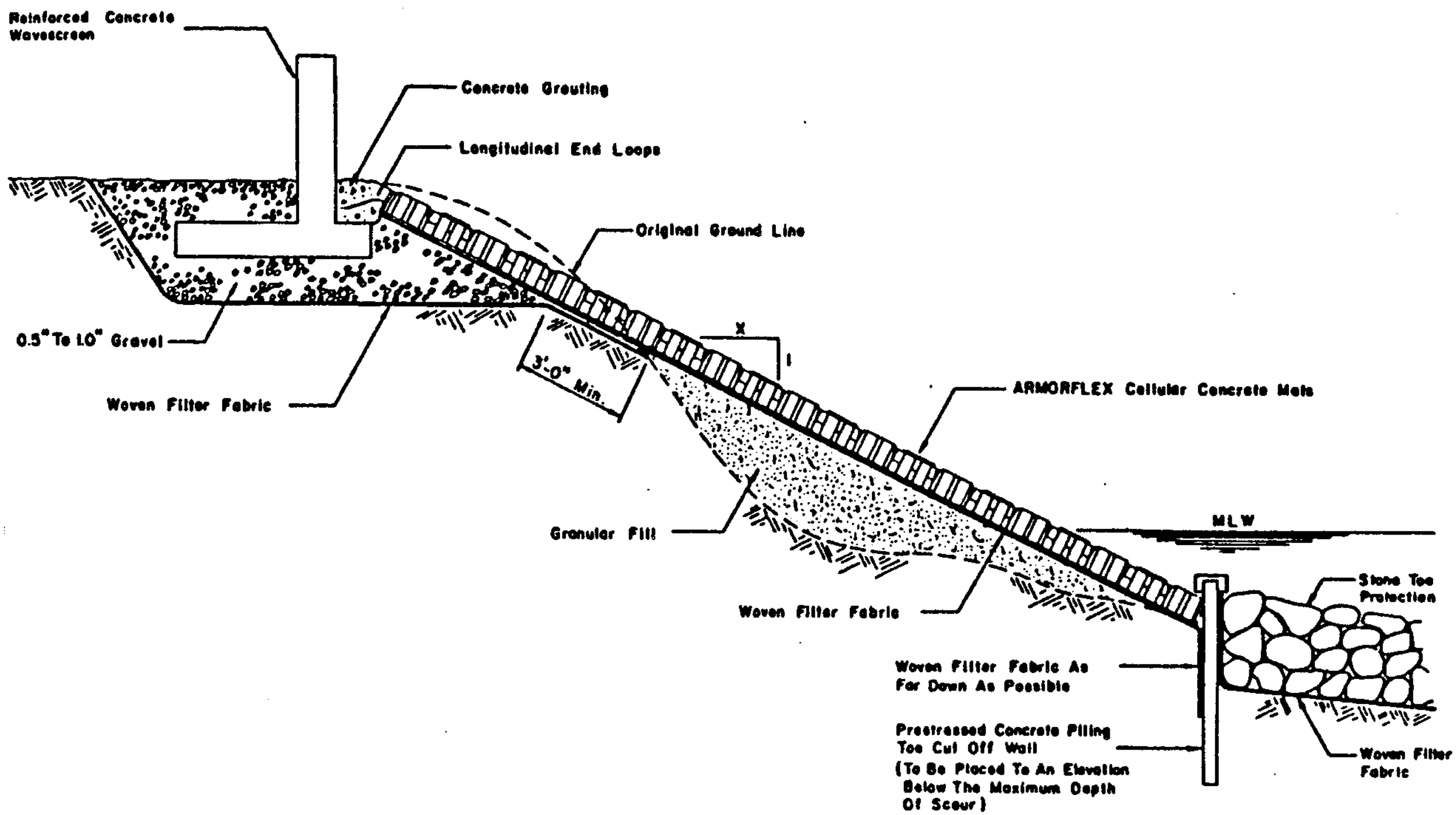
U.S. Patent No. 4,370,075 Canadian Patent No. 1,141,554 Other U.S. and foreign patents issued and pending

To the best of our knowledge, the information contained herein is accurate. However, Armortec, Incorporated, cannot accept liability of any kind for the accuracy or compleatness thereof. Final determination of the suitability of any information or material for the use contemplated, of its manner of use, and whether the suggested use infringes any patents, is the sole responsibility of the user.



ARMORFLEX REVETMENT WITH TOE CUT OFF WALL AND CONCRETE SIDEWALK

Dimensions And Details To Be Determined By Particular Site Conditions.



ARMORFLEX REVETMENT WITH TOE CUT OFF WALL AND CONCRETE WAVESCREEN

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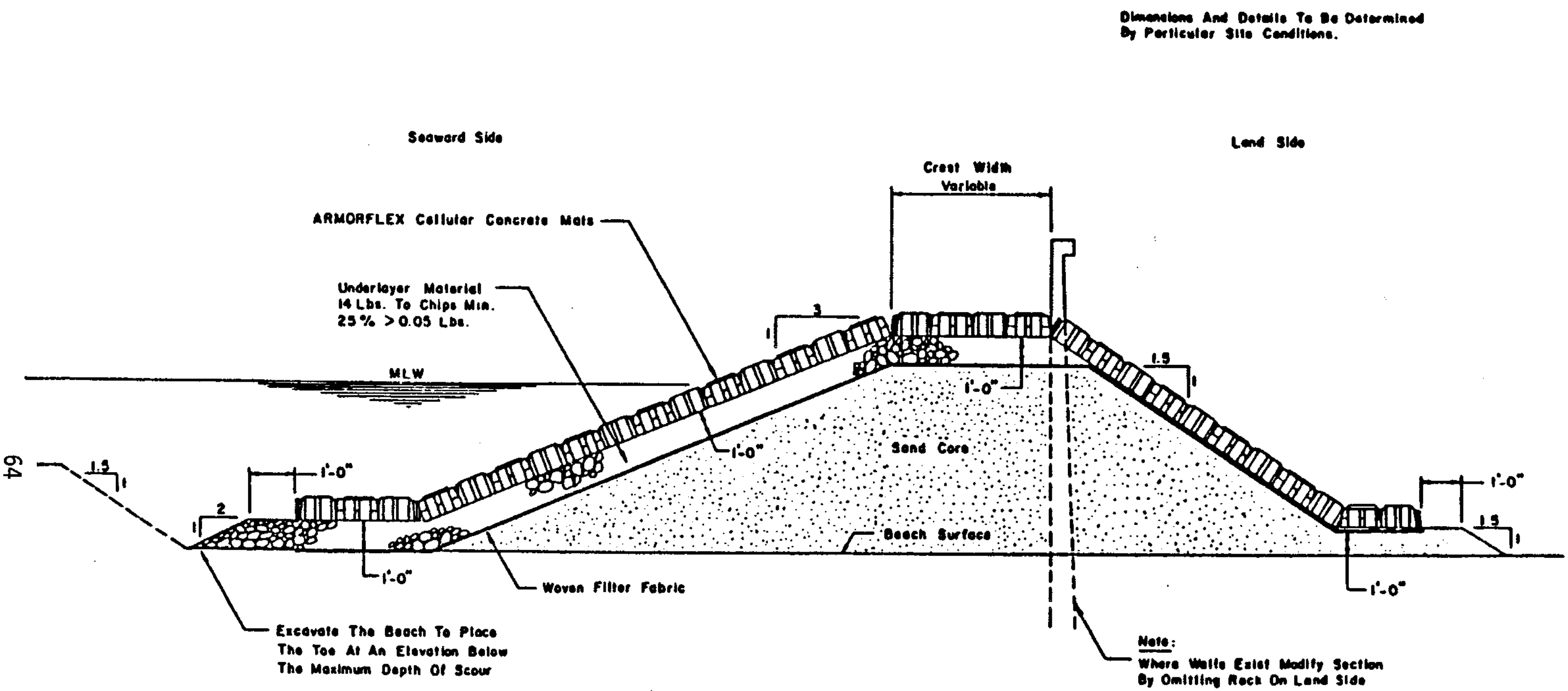

ARMORFLEX - MOUND SEAWALL

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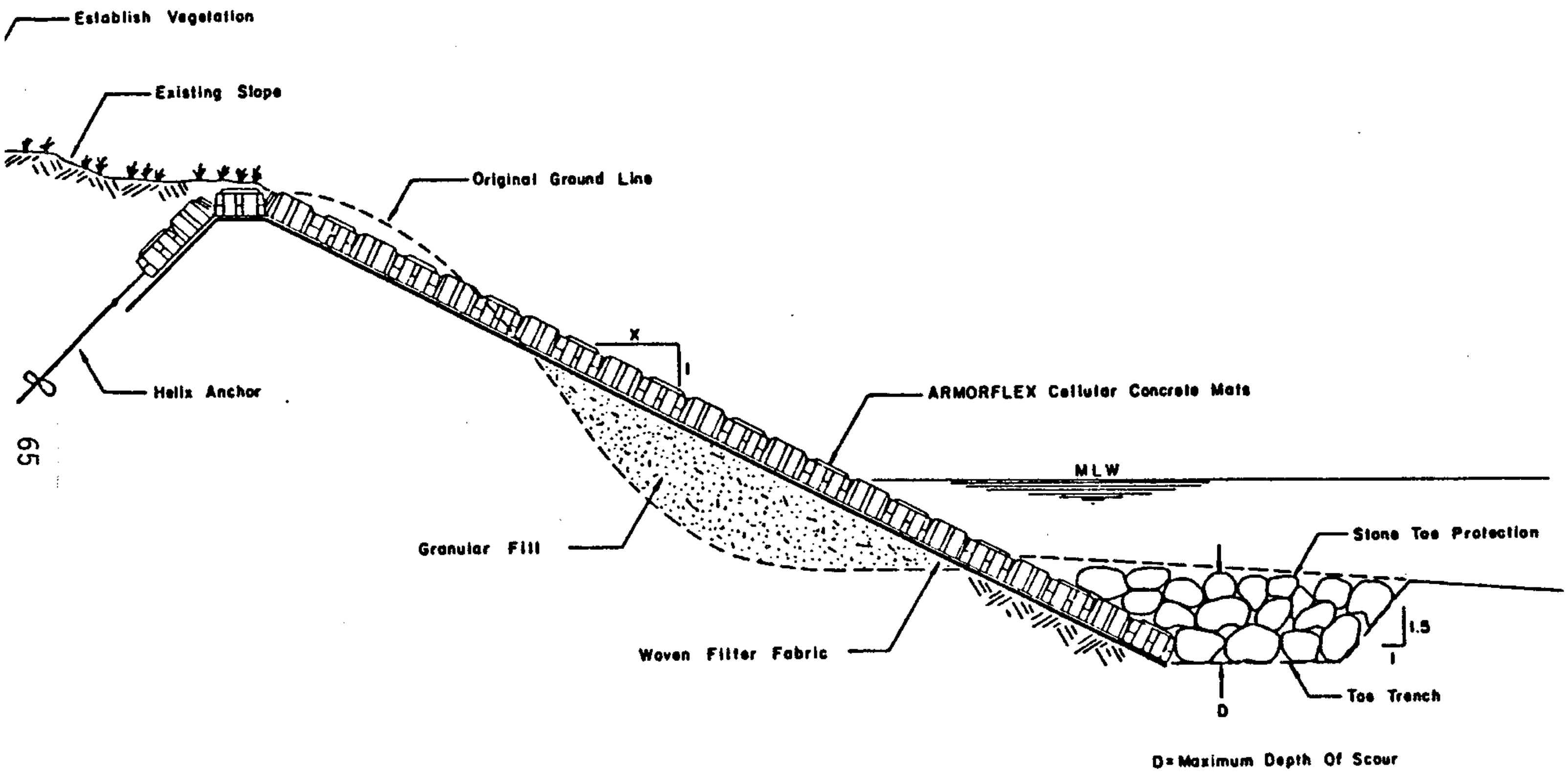
Dimensions And Details To Be Determined
By Particular Site Conditions.

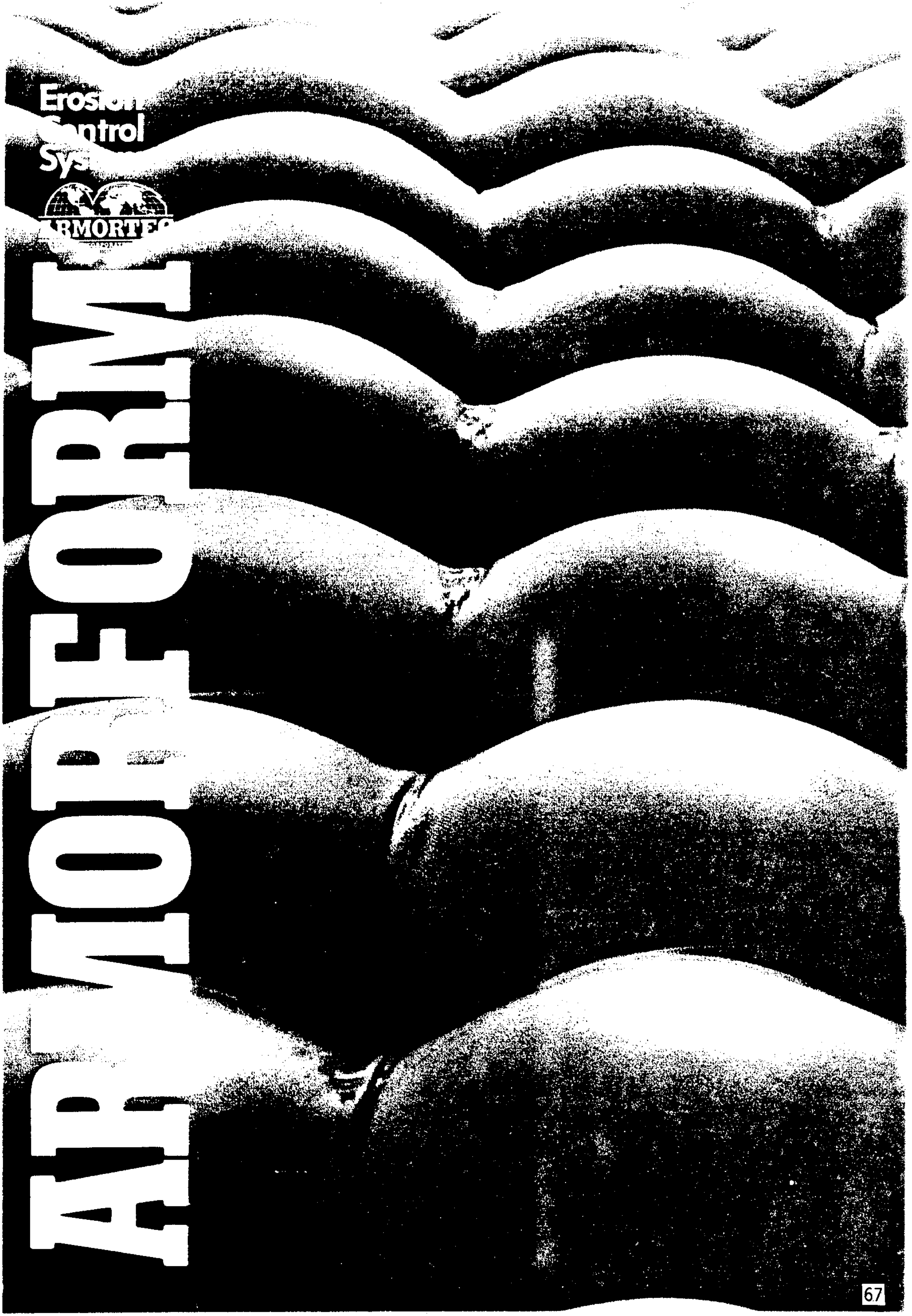


ARMORFLEX REVETMENT WITH TOE TRENCH

To the best of our knowledge, the information contained herein is accurate. However, Armortec, Incorporated cannot accept liability of any kind for the accuracy or completeness thereof. Final determination of the suitability of any information or material for the use contemplated and of its manner of use is the sole responsibility of the user.

APPENDIX E

ARMORFORM Information Brochure


Erosio
ntrol
Sys
ARMORFORM

Armorform fabric formwork.
Erosion control systems.

ARMORFORM Erosion Control Systems were developed by Amortec Engineers to meet the requirement for cast-in-place concrete erosion control mats that are easily installed both above and below water.

ARMORFORM is a permeable, continuously woven panel of double-layer synthetic fabric joined together to form a formwork for placing sand/cement mortar. The permeable fabric restrains the loss of mortar during underwater placement, allows excess mixing water to escape; assuring a low water/cement ratio, accelerating hardening, and producing a durable concrete structure.

ARMORFORM installations do not require dewatering. Formwork panels can be positioned and filled from the surface in shallow water or by divers in deep water. Piles, dolphins, and other obstructions can be accommodated by using panels prefabricated to meet field measurements.

ARMORFORM has been proven techincally and economically superior to traditional erosion control methods. Where conditions such as limited access, remote region construction, quick delivery for a short construction season or schedule require fast installation using unskilled labor, even under water, ARMORFORM is the design solution.

ARMORFORM results in a stable erosion control system available in three types; Filter Point, Uniform Section, and Articulating to accomodate various design conditions for:

coastal shorelines, lakes, reservoirs, and holding basins; rivers, streams, bayous, channels, ditches, culvert inlets and discharges, spillways and water control structures; pipeline crossings and suba-

- Ponds & Holding Basins
- Earthen Dams
- Storm Channels & Ditches
- Lakes & Reservoirs
- Bulkhead, in lieu of
- Pipeline Crossings
- Rivers, Streams & Bayous
- Dikes & Levees
- Coastal Shorelines
- Bridge Abutments
- Water Control Structures
- Embankments
- Spillways
- Subaqueous Pipelines
- Culvert Inlets and Discharges
- Boat Launching Ramps

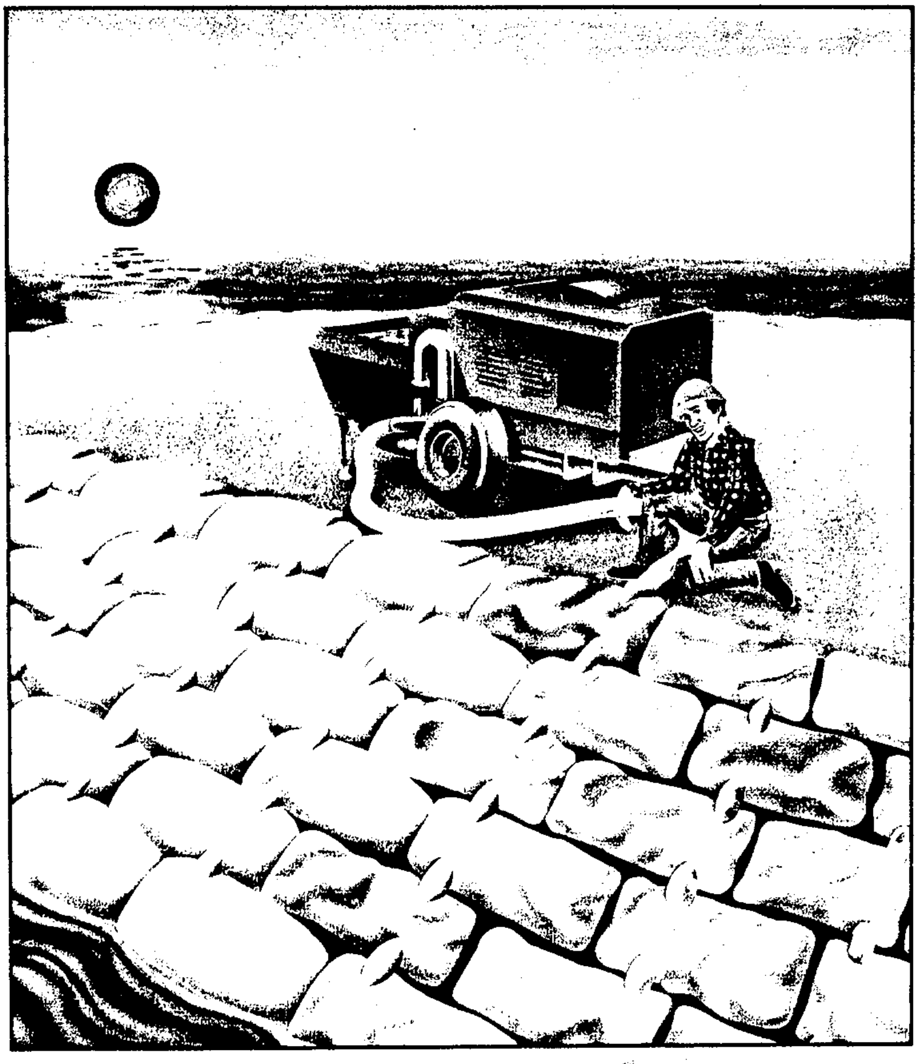
Armorform Filter Point Mats (FPM).

The double-layer fabric formwork is woven together at spaced filter points. The filter points function to relieve hydrostatic pressure and form a cobblestone appearance in the surface of the mortar filled mats. The resulting Manning Roughness Coefficient, "n", has a value ranging from 0.025 to 0.030, for moderate reduction of effective water velocity.

- Available with Filter Point spacing of approximately 8" and a nominal thickness as pumped of 3.5".
- Filter Point Mats (FPM) are used where velocities are low, bedload and ice formations are light.
- Filter Point Mats (FPM) are used for inland bodies of water with light wave action and ice formations.
- Filter Point Mats (FPM) are ideal for underwater placement.
- Filter Point Mats (FPM) are adaptable only to well compacted soil conditions.

Armorform Uniform Section Mats (USM).

The double-layer fabric formwork is maintained in parallel relationship by interior spacer cords to form a lining of uniform nominal thickness. In order to relieve hydrostatic pressure, weep holes are installed at required centers. The resulting Manning Roughness Coefficient, "n", has a value of 0.015, for minimum reduction of effective water velocity.



- Available with weep hole spacing as required and a nominal thickness as pumped of 4".
- Uniform Section Mats (USM) are used where velocities are low to moderate, bedload and ice formations are light and a low roughness coefficient, n = 0.015, is required.
- Uniform Section Mats (USM) are used for inland bodies of water with light wave action and ice formations, requiring a nominally impermeable liner.
- Uniform Section Mats (USM) are ideal for underwater placement.
- Uniform Section Mats (USM) prevent seepage losses in reservoirs, holding basins, and canals.
- Uniform Section Mats (USM) are adaptable only to well compacted soil conditions.

Armorform Articulating Block Mats (ABM).

The double-layer fabric formwork is woven into a matrix of rectangular compartments, each separated by a narrow perimeter of interwoven fabric. The compartments contain pre-installed interconnecting strands of high strength cable/rope extending longitudinally through each column and optionally through each transverse row of compartments. The high strength cables/ropes become embedded in the mortar filled compartments, tie the blocks together and enable the system to resist tension in all directions. The narrow perimeter of interwoven fabric allows each block to articulate and relieves hydrostatic pressure. The resulting Manning Roughness Coefficient, "n", has a value ranging from 0.045 to 0.050, for maximum reduction of effective water velocity.

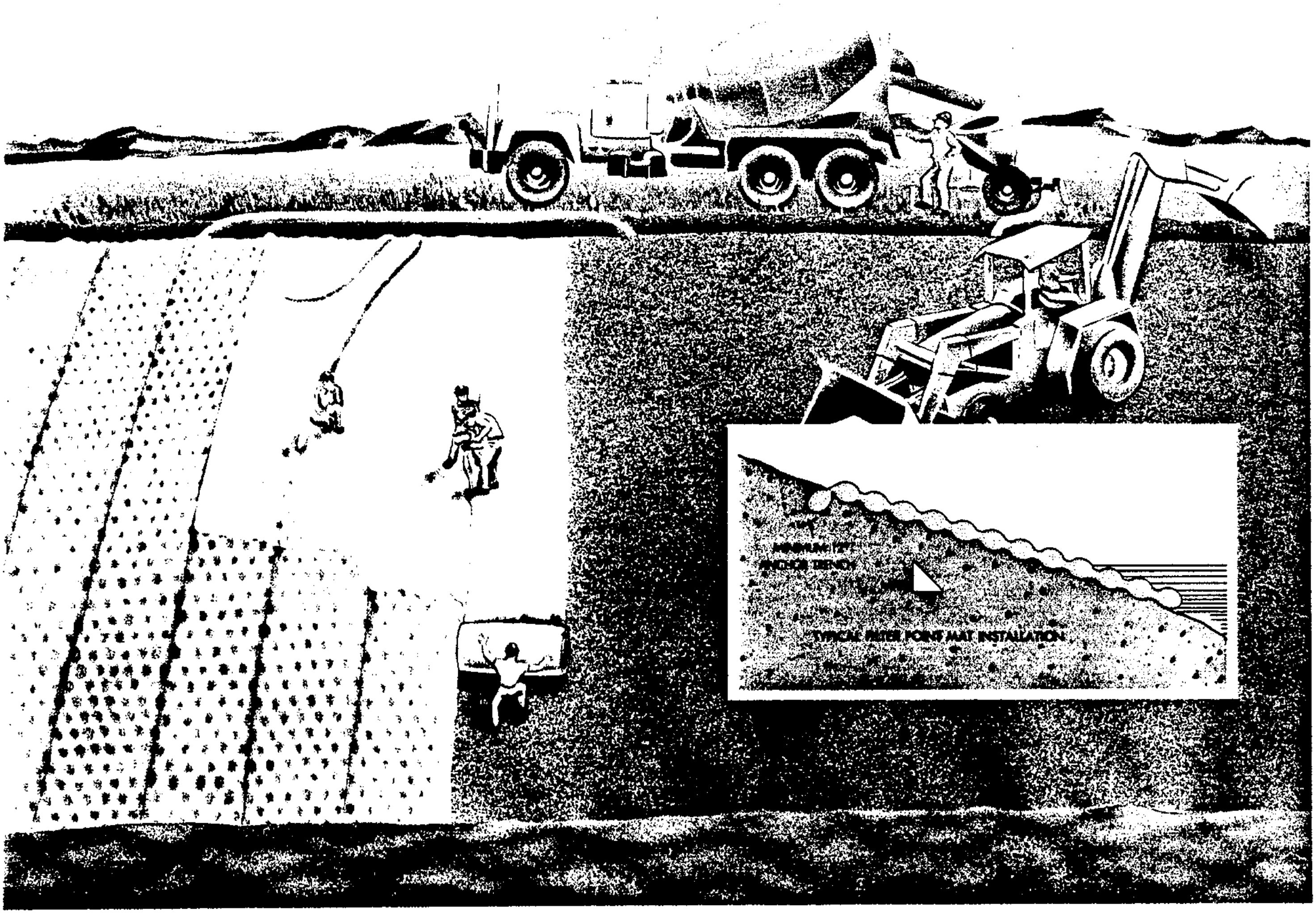
- Available as blocks with nominal dimensions of 24" x 12" x 4" or 30" x 18" x 6" and with interconnecting strands of galvanized steel aircraft or polyester cable/rope.
- Articulating Block Mats (ABM) are used where velocities are low to moderate, bedload and ice formations are moderate.
- Articulating Block Mats (ABM) are used for coastal and inland bodies of water with moderate wave action and ice formations.
- Articulating Block Mats (ABM) are ideal for underwater placement.
- Articulating Block Mats (ABM) are adaptable to any type of soil condition.

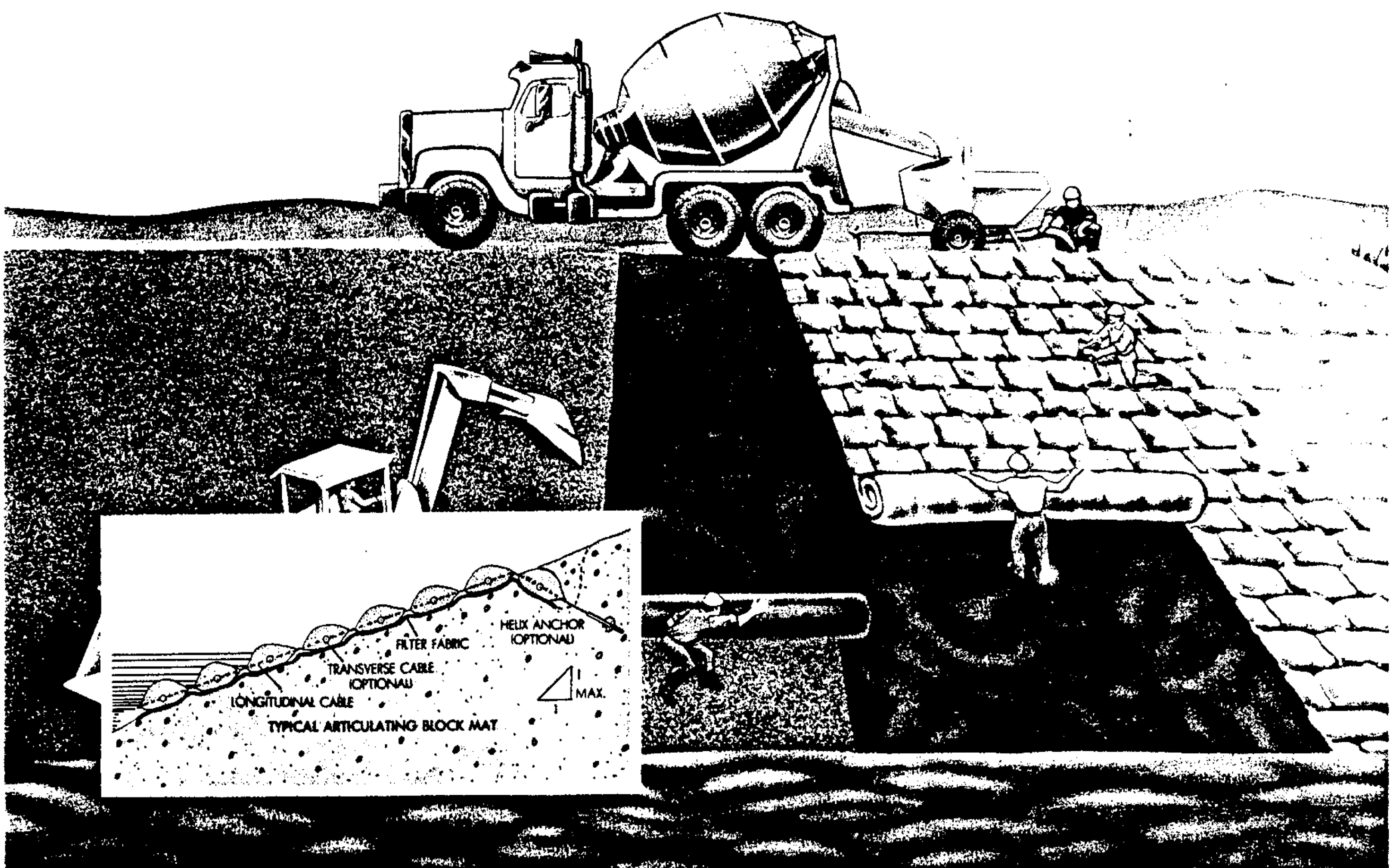
Preparation and Installation.

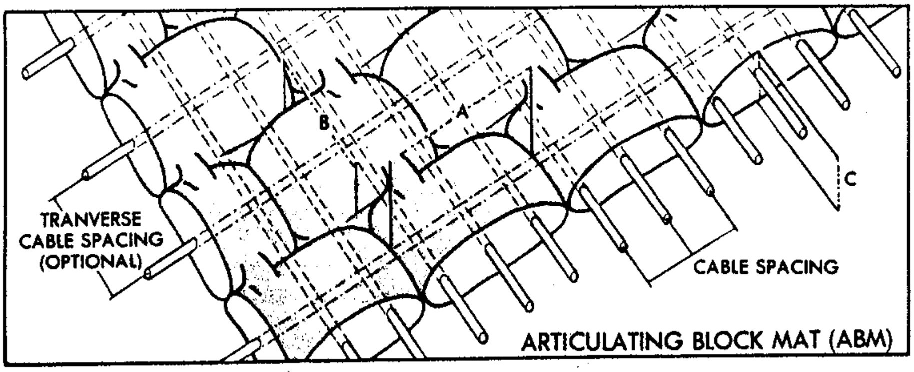
ARMORFORM type and style are selected and delivered as prefabricated panels of up to 4,000 ft.^{2}

Construction begins with site preparation of the area to be protected. Vegetation and obstructions, such as roots and projecting stones are removed. Holes, soft areas, and large cavities are filled and compacted with suitable materials.

- Excavate toe, terminal and upper bank protection trenches as required.
- Fabric formwork panels are positioned on the subgrade and joined edge to edge with a portable sewing machine. ARMORFORM (ABM) installations with optional transverse cables require that they be spliced prior to panel joining.
- Cut a small hole in the top layer of formwork and insert a 1-1/2" pump hose nozzle. Place a piece of coarse fabric around the nozzle to form a pressure tight seal with the formwork.
- Start by pumping transit mix mortar into the formwork positioned in the upper bank trench. This will anchor the rest of the formwork on the slope. Mortar is then redirected to the lower portion of the formwork, progressing upward until section is completed. The process is repeated throughout the installation. Pumping capacity should be 10 to 12 cu. yds. per hour. Lateral flow within the panels is controlled by mortar stops. ARMORFORM (ABM) is filled by pumping mortar through fabric sleeves connecting compartment in a column.
- Optional ARMORFORM (ABM) anchors are placed at the top of the slope.
- Backfill and compact the trenches as mortar placement proceeds.


ANCHOR TRENCH
TYPICAL FILTER POINT MAT INSTALLATION


HELIX ANCHOR
(OPTIONAL)
FILTER FABRIC
TRANSVERSE CABLE
(OPTIONAL)
LONGITUDINAL CABLE
1
1
MAX.
TYPICAL ARTICULATING BLOCK MAT



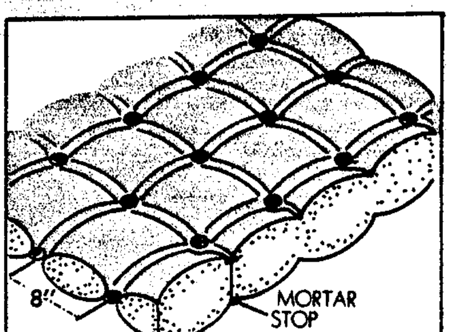
ARTICULATING BLOCK MAT (ABM)

Articulating Block (ABM) Technical Data:

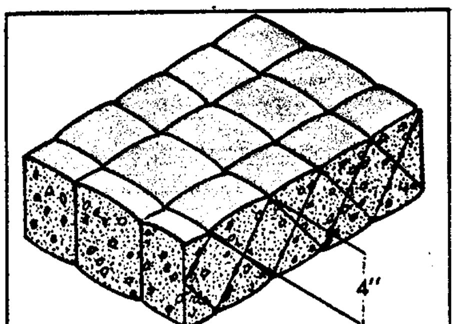
Designation		Nominal Dimensions In.			Weight/ Block	Weight/ Area	Coverage/ Cu. Yd. Of Mortar
Style	Fabric	A	B	C	lbs.	Lbs./Sq. Ft.	Sq. Ft.
4″ ABM	N	24	12	4	90-100	40-45	71-80
6″ ABM	N	30	18	6	250-278	60-68	47-53

PP-Polypropylene N-Nylon and/or polyester

NOTE: Dimensions of finished mats, weights, and mortar quantities shown above are approximate. Variations from these values may occur as a result of application and installation procedures.



FILTER POINT MAT (FPM)



UNIFORM SECTION MAT (USM)

Filter Point (FPM) Uniform Section (USM) Technical Data:

Designation		Filter Point & Weep Hole Spacing	Average Thickness	Weight/ Area	Coverage/ Cu.Yd. Of Mortar
Style	Fabric	In.	In.	Lbs./Sq.Ft.	Sq. Ft.
8″ FPM	N	8	3.5	40-43	73-80
4″ USM	PP	As received	4.0	42-45	70-75

PP-Polypropylene N-Nylon and/or polyester

NOTE: Dimensions of finished mats, weights, and mortar quantities shown above are approximate. Variations from these values may occur as a result of application and installation procedures.

Technical assistance.

ARMORTEC is staffed by qualified civil engineers to aid in the preparation of designs and cost estimates for potential projects. If approved, ARMORTEC's engineering department will prepare shop drawings for the engineer's review and approval. Pre-bid and pre-construction conferences with contractors and on-site construction assistance are also provided by ARMORTEC's construction services group.

Manufacturer and supply.

ARMORFORM fabric formwork panels are available in three types to accomodate the conditions prevailing in a given application. An inventory of standard sizes is carried at our manufacturing facilities and can be shipped to any jobsite around the world.

Fabric properties are selected to meet the structural requirements of the ARMORFORM type specified.

ARMORTEC Erosion Control Systems are currently in service around the world. Their uses range from channel linings to riverbanks and from subaqueous pipeline protection to major shoreline revetments. The positive results achieved by ARMORTEC in providing revetment and bank protection systems for civil engineering projects supply convincing proof of the benefits you may reap from ARMORTEC's broad spectrum of erosion control systems.

For further information on our erosion control systems and their varied applications contact:

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U.S. and foreign patents pending

ARMORFORM REVETMENT SYSTEM TECHNICAL INFORMATION*

GENERAL DESCRIPTION

The ARMORFORM Revetment System is a flexible, tendon-reinforced mat constructed by pumping Portland Cement Grout into a fabric form placed on the shoreline slope. Flexibility in the ARMORFORM System is achieved by providing compartments in the fabric formwork to section the mat into individual units or cells which can move independently and allow the revetment to adjust to movement of the underlying soils. Polyester ropes or steel cables positioned in the fabric forming grid-work pattern become embedded in the grout to reinforce the mat, tie the individual cells together, and enable the system to resist tension in all directions.

PHYSICAL PROPERTIES

1. The Material which is employed in the manufacture of ARMORFORM is a woven polymide monofilament fabric with a weight of 6.8 oz./sq.yd. and a thickness of 85 mils. The woven fabric exhibits a tensile strength of 425 lbs./in. in the warp direction and 400 lbs./in. in the fill direction.

2. The polyester rope which is employed in the ARMORFORM System is a multi-filament parallel rope construction. A urethane impregnated polyester fabric jacket holds the core fibers together. Connections are made by using aluminum splicing sleeves, which are compressed with hand tools. The cables are held in position at the edges of the panel by use of a plastic washer and an aluminum stop sleeve.

3. A fabric guide tube constructed with a woven fabric is provided in each row of cells to facilitate the insertion of the grout pump discharge hose. This tube is withdrawn and discarded as each row of cells is completely filled.

*Reprinted from manufacturer's technical information sheet.

AREA COVERAGE

1. Fabric panels are assembled in accordance with shop draws submitted by the manufacturer. Panel sizes are determined by the length and width, which will provide a reasonable weight for the handling method to be used.

2. In preparing area coverage estimates it is necessary to allow approximately 20% for fabric assembly contraction caused by filling of the individual cells with cement grout. Example: To cover a slope area 50 feet wide by 100 feet long would require an ARMORFORM panel approximately 60 feet long and 120 feet wide.

EARTHWORK AND SLOPE PREPARATION

1. Any work which is necessary to construct embankments or other structures should be done in a manner which will provide for the long term stability of the earthen structure in the absence of the damage caused by surface erosion which the ARMORFORM is designed to prevent.

2. The slope should be graded to a reasonably smooth surface, removing any organic material and compacting any fill areas to limit any drastic settlement in the system. The ARMORFORM System is designed to conform to minor irregularities in grade and still remain totally effective.

3. In many cases an anchor trench is excavated at the top of the slope to hold the system firmly in place on the slope. If it is desirable to provide further anchorage by tieing the tendons provided in the ARMORFORM to a structural anchor system, that system may be installed in the earth at the top of the slope before or after the ARMORFORM placement.

4. Once the slope is graded, a woven plastic filter cloth designed to meet the filter criteria for the protected soil should be placed on the slope to be protected. Care should be taken to insure that seams in the filter layer are sufficiently overlapped to provide protection.

5. If slope material contains a high percentage of fines, it may be necessary to provide an underlayment of non-woven filter fabric.

ARMORFORM PLACEMENT

1. Position the ARMORFORM panels loosely along the bank before the grout is placed. If the lower portion of the ARMORFORM panels are underwater it may be necessary to attach sinking weights to the lower edge of the panel. Pinning the fabric to the slope at various points may be helpful for holding the panels in position prior to placement of the grout fill.

2. Fabric panels are spliced together in the field with a hand held sewing machine. Since the edge of each panel consists of a double layer of fabric, it is only necessary to lap the two edges of adjacent panel and sew down the seam. The fabric employed in the manufacture of the bags is very pliable so the panels may be easily sewn together on the dry portion of the slope and then drawn out into the water.

3. For projects where there are obstructions in the slope area, custom shapes can be sewn in the field from unassembled fabric panels.

PORTLAND CEMENT

1. The Portland Cement Grout should be a very fluid mixture of sand and cement. Depending upon the pumping equipment employed, a quantity of aggregrate can be added to the mix. Air entraining admixtures will improve the flow of the mix as well as enhancing the freeze-thaw resistance of the hardened mortar. Pozzolithic admixtures also increase the pumpability of the grout mixture as well as the strength and durability of the hardened grout.

2. Since the fabric which serves as the form for the fluid is permeable, water from the grout mix will be expelled through the fabric and the net volume of the consolidated grout will be reduced by approximately 10% upon hardening.