PERFORMANCE OF SAND-FILLED TUBE SHORE PROTECTION TUKTOYAKTUK, NORTH WEST TERRITORIES, CANADA

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1. INTRODUCTION

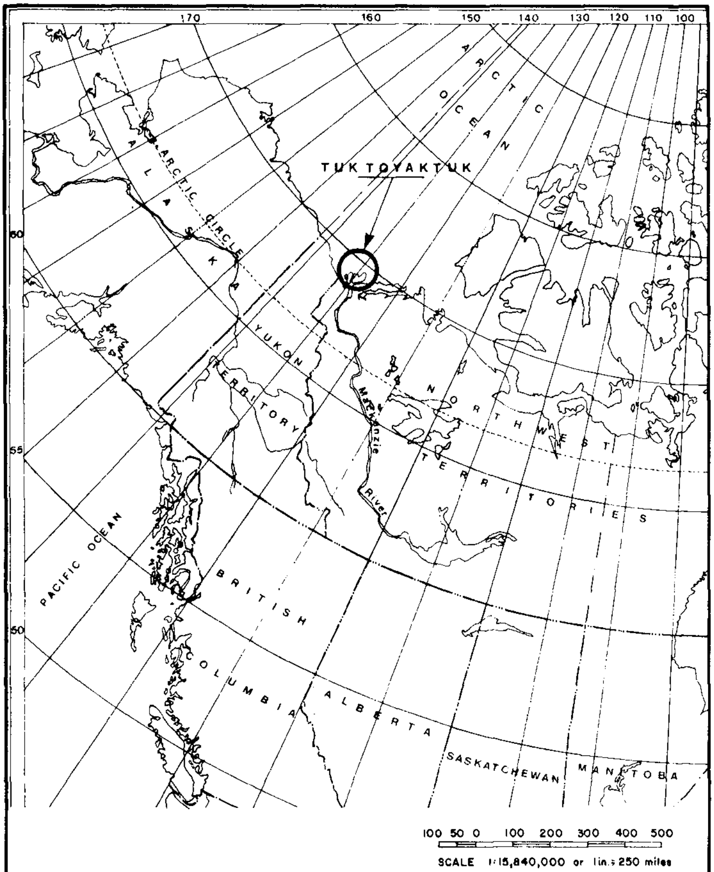
Seawalls, revetments and groynes designed to protect shorelines require normally timber, natural stone or concrete for their construction. In Tuktoyaktuk, none of these materials is available and to avoid excessive costs, an alternative form of construction, using long sausage shaped tubes filled with sand, was devised on an experimental basis.

Tuktoyaktuk is situated on the eastern side of Kugmallit Bay in the Western Arctic at north latitude of 69 deg. 27' and west longitude of 133 deg. 02'. It is approximately 90 miles north of Inuvik and 1450 miles northwest of Edmonton (figure 1). The area is mainly comprised of a long, narrow, boot-shaped peninsula oriented in approximately north-south direction, a complex lagoon, which has been developed as a harbour, east of the peninsula and an island straddling the mouth of the lagoon (figure 2). Certain dwellings exist at the southern and southeasterly shores of Tuktoyaktuk Harbour. A large majority of the inhabitants reside in settlements developed on the peninsula and the southern area linking the peninsula with the mainland. Tuktoyaktuk is used as a transfer point linking the Mackenzie River barge transport with coastwide shipping serving the western arctic seaboard and inland settlements and bases. As a result of this the TUK settlement has grown to be the largest of the western arctic coast settlements.

Tuktoyaktuk is receiving further prominence owing to the recent oil explorations in the Beaufort Sea and if oil is discovered in the area, Tuktoyaktuk will see considerably increased activity and prominence. Dome Petroleum and Gulf Canada have already committed large investments in administrative support facilities at Tuktoyaktuk and Exxon is moving its northern offices there. Tuktoyaktuk is thus likely to become the Beaufort Sea administrative support center for the oil and gas industry.

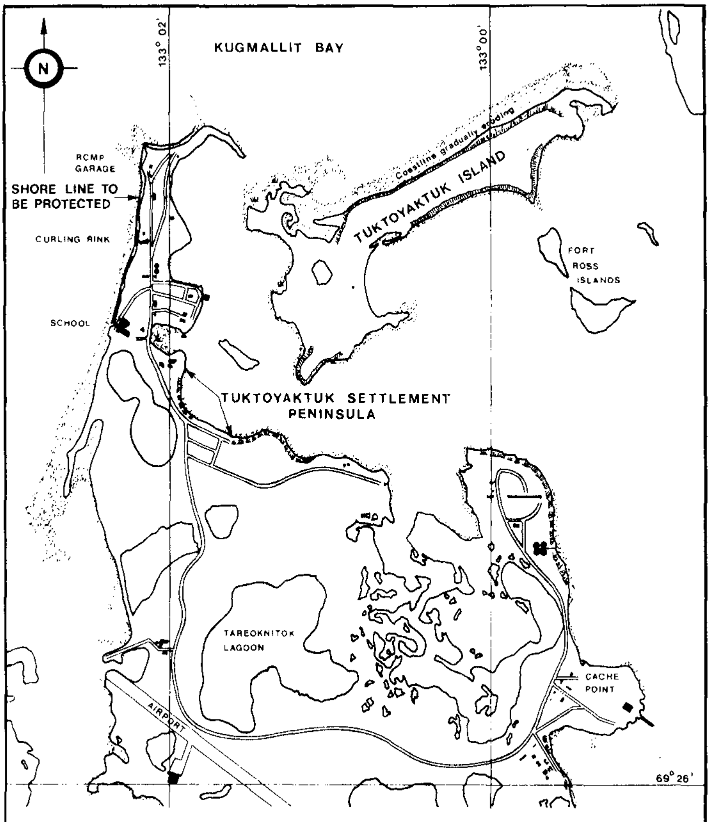
Tuktoyaktuk is generally flat. Its shoreline is demarcated by steep cliffs. The Tuktoyaktuk peninsula is approximately 4,400 feet long and 1,400 ft. to 300 feet wide. It is 5 to 25 feet above the sea level and covers an area of approximately 16 acres. The Tuktoyaktuk Island is approximately one mile long, and on an average 600 feet wide. The island is characterized by its flat top which is approximately 30 feet above the sea level and cliffs steeply plunging to the sea. The harbour runs inland in a southwesterly direction and is approximately 7 miles long. The terrain around the harbour is flat and contains numerous lakes.

The whole shoreline at Tuktoyaktuk has been receding at considerable rates. Reports indicate that similar erosion is occurring along much of the adjoining coastlines. The length of shoreline of immediate concern was the shoreline at the settlement peninsula where several buildings including a local school were under threat of being undermined. There were no precedents of shore protection works in the arctics where the erosion regimes are different from those in the south, and a decision was made to protect the school building as a prototype experiment to learn from and develop a design to protect the whole settlement peninsula.



TUKTOYAKTUK N.W.T.
SHORE EROSION & PROTECTION STUDY
LOCATION MAP

Figure 1



TUKTOYAKTUK N.W.T.
SHORE EROSION & PROTECTION STUDY
SITE PLAN

Figure 2

2. COASTAL GEOMORPHOLOGY

2.1 General

The coast of Tuktoyaktuk can be described as a shallow, embayed and receding coast. It is generally flat and contains narrow beaches and steep cliffs. The area is mostly underlain by fluvial sands and silts and fine grained deltaic sands. These deposits are capped by a thin layer of a mixture of sands, peat lacustrine deposits, gravel and clayey till like deposits. The subsurface includes permafrost and lenses and sheets of massive ice.

2.2. Subsurface

The analysis of test borehole samples and thermistor readings indicates that generally the subsurface can be divided into two zones. These zones are: (1) an active zone which is frozen in the winter and thaws out in the summer and (2) a permanently frozen zone below the active zone. The active zone consists of sands, silts and gravel, in places covered by peat or organic material. In areas where there is a cover of peat the thickness of the active zone as measured was small, varying from 1 to 2 feet. In the inorganic soils, the thicknesses of the active zones measured were relatively large, varying from 4 to 16 feet. The permanently frozen zone consists of layers of sands, silts and gravel together with ice crystals, lenses of ice and sheets of massive ice. The thickness of the permafrost zone was not determined. It is, however, known to extend from above to below the sea level, or in other words it straddles the sea level (figure 3).

3. EROSION REGIME

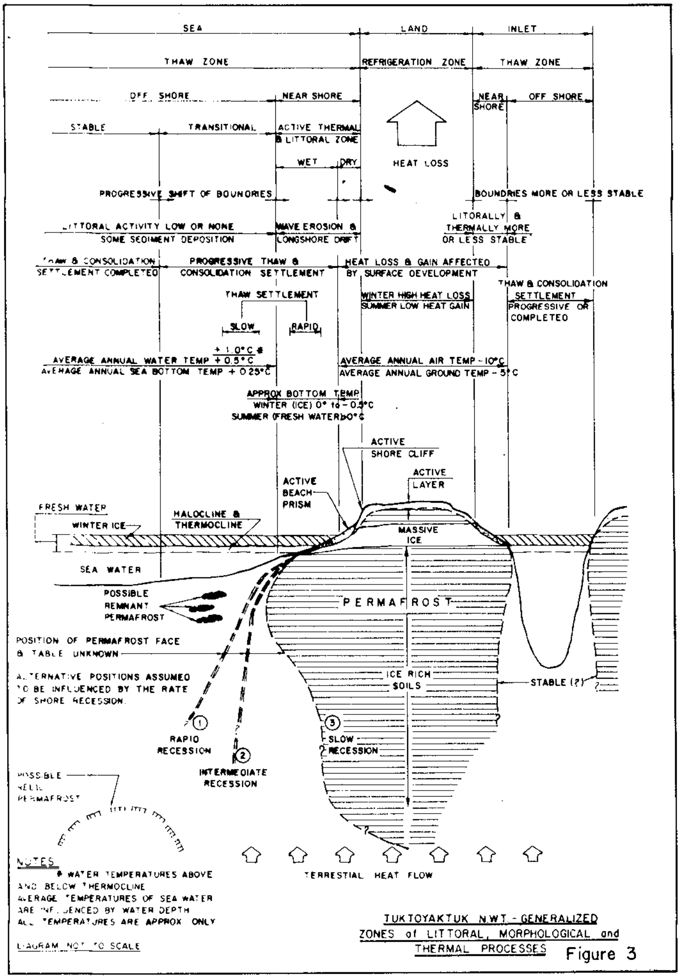
3.1 General

There are two major causes of the erosion occurring at Tuktoyaktuk. In the warm regions of the world the usual cause of erosion is the physical force of the waves. In the arctics, where ice rich soils and massive ice abound within the soil, thawing caused by the warmer temperatures in the summer and warmer sea water can be a major cause of shore recession and an accelerating factor in shore erosion. Both of these phenomena impinge on the Tuktoyaktuk coast.

3.2 Erosion by Waves

The erosion of Tuktoyaktuk shore, attributable to the physical forces of waves, can be seen to be taking place in two distinct ways depending upon the shore topography. In places where high cliffs exist, the cliffs are degraded by undermining and removal of slices from them. In areas where dunes occur, the dunes are shifted landward in varying alignments depending upon the direction of storms. The importance of these two shore erosion factors compared with the factors of thermal erosion discussed in the following section, cannot be precisely established.

The shore material transport rates calculated using a method known as the wave energy flux method do not reconcile with the large coastal recession rates of Tuktoyaktuk given by aerial photographs and surveys.



TUKTOYAKTUK N.W.T. - GENERALIZED ZONES of LITTORAL, MORPHOLOGICAL and THERMAL PROCESSES Figure 3

3.3 Thermal Erosion

Thermal erosion is considered to be the major contributory cause of the coastal recession occuring at Tuktoyaktuk. There are two ways in which the thermal action is affecting the Tuktoyaktuk coast. These are (1) the melting of the ice present in the coastal land by warm water waves at high storm water levels and (2) thawing of the permafrost and ice contained in the beach and underwater soils, by the warm summer environment (figure 4).

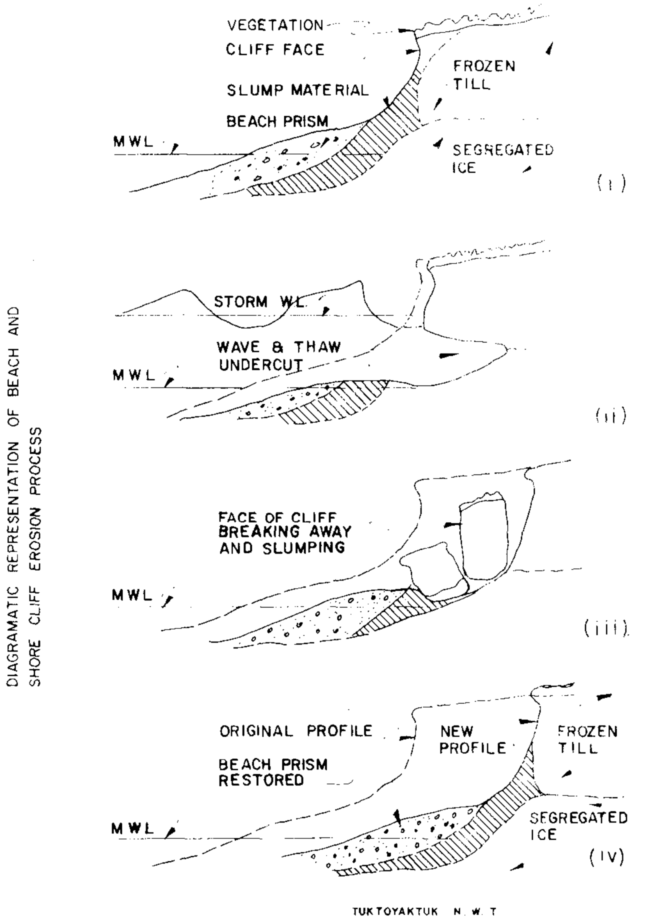
4. DESIGN

As discussed in the preceding section, the erosion occurring at Tuktoyaktuk is mainly as a result of an inadequate cover over the ice and permafrost present in the ground at the site. Direct solar heat and thermal action of warm water waves are the main agents that cause the erosion at Tuktoyaktuk. During normal weather conditions the water levels are low and the waves do not impinge upon the coast. In storm weather situations, high water levels occur and the beach and the coastal areas are rendered liable to direct thermal action of warm water and thermal and physical action of waves. To protect the beach and the coast from the thermal action, an insulating cover is required over the area. To abate the wave action a barrier is needed. The insulating cover and the barrier must be of flexible type to accommodate any initial and long term settlement.

The design wave length considered ranged from 60 feet to 100 feet. The design wave height (storm maximum wave height) adopted was 8 feet. The cover required to protect the permafrost and ice was estimated to be 7 feet.

Construction materials available locally are confined to sand and gravel. The materials ocur in offshore regions, along the coast and inland. While there are adequate supplies of sand and gravel within short distances from Tuktoyaktuk, there are no sites in the vicinity of the area for any rock. Experienced contractors and heavy construction equipment similarly do not exist in the area. To obtain the required materials other than sand and gravel, construction services and equipment, Inuvik and areas as far as Edmonton have to be relied upon. The logistics are further complicated by the inaccessibility of Tuktoyaktuk by land. Because of this, all the requisites must be either transported by water or flown by air.

Various alternative forms of construction were considered for the test installation, including a rock revetment, rubblemound bulkhead, steel sheet pile wall, timber crib wall, and certain patented steel wire gabions. A product known as the "Longard" tube was at that time being introduced into the North American market. The "Longard" tubes which are sausage shaped, merely require sand to fill them and had been found to be functioning well in Europe and in certain ice covered environments. The use of the "Longard" tubes as shore protection work units showed good possiblities and a decision was made to proceed with the test program using these.



TUKTOYAKTUK N. W. T
SHORE EROSION & PROTECTION STUDY
MECHANICS OF EROSION
Figure 4 .

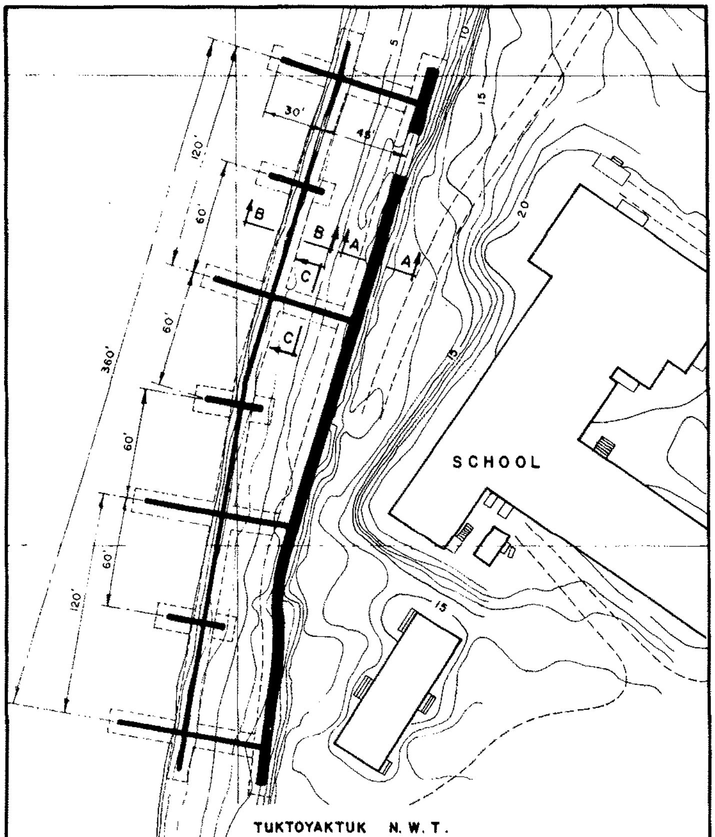
The test design devised utilised one metre diameter Longard tubes, Longard and Terrafix filter mats and Dura bags as sand bags. Basically, the design consisted of a bulkhead at the bottom of the cliff, another bulkhead lower down on the beach and four main groynes separated by three shorter intermediate groynes, at right angles to the bulkheads. The cliffside bulkhead consisted of a double tube. The beachside bulkhead and the groynes were built with single tubes. The bulkhead tubes were laid on filter mats held down during construction by sand bags. Originally the compartments formed by the groynes and the bulkheads were to be filled with beach material. Owing to lack of funding the compartments between the groynes and the bulkhead were left unfilled. Due to construction difficulties also the groynes were constructed without the filter mats. The length of the installation was approximately 360 feet (figures 5 and 6).

5. PERFORMANCE

The principal objectives of the test were to provide protection to the local school which was under threat of being undermined by the sea and to gain experience to develop a full scale system to protect the whole settlement peninsula of Tuktoyaktuk. Imperative in these objectives was longevity of the test installation. While the test installaton has protected the school as envisaged and provided considerable information om how we may proceed with further shore protection works in Tuktoyaktuk, the installation has been subject to an incredible amount of willful damage. The Longard tubes can withstand heavy pressures required to fill them with sand under pressure and adequately resist the natural environment. In their exposed condition they cannot, however, withstand vandalism. The groynes have been practically slashed open by vandalism. The beachside bulkhead has also suffered from deliberate cuts. The cliffside bulkhead, which was backfilled and has been covered has, however, survived.

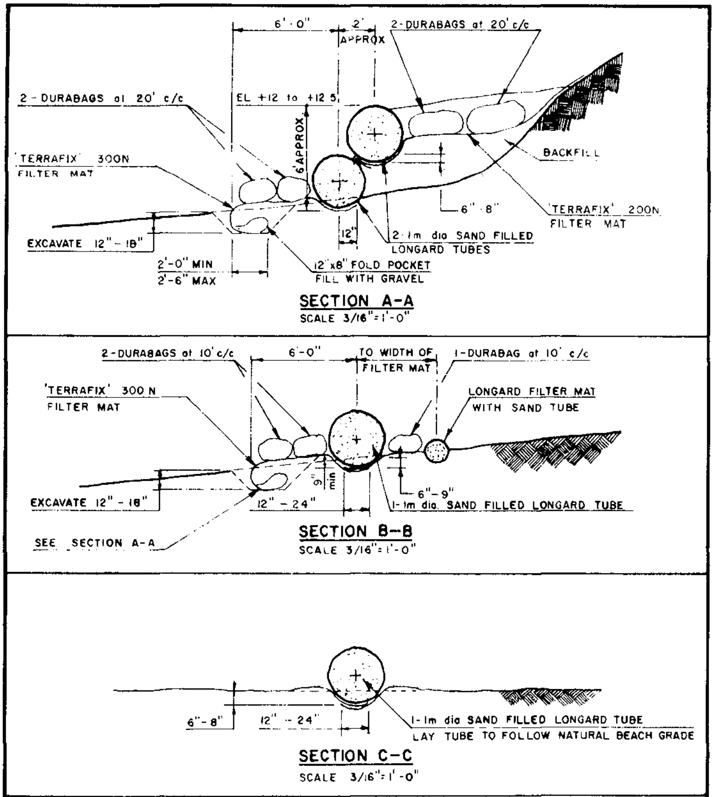
Technically, the installation has performed as envisaged. Erosion at the school has been completely halted. There has been, in actuality, accumulation of material between the bulkheads and between the groynes. There has been a greater accretion of material on the north end of the installation confirming littoral drift to be from north to south. Because of the lack of supply of material from the north, as would be anticipated, certain erosion has occurred of the southern end of the installation.

The performance of the test installation suggests that certain modifications can be made in the geometry of any full scale shore protection work in the area. The short intermediate groynes have been virtually ineffective in trapping material and can be eliminated. The long groynes have been allowing bypassing of material to occur and can be extended to deeper water. The cliffside bulkhead has remained virtually undisturbed and if an adequate bulkhead can be built at the beachside with backfill to the cliff, the cliffside bulkhead can be eliminated except at certain locations.



TUKTOYAKTUK N. W. T.
SHORE EROSION & PROTECTION STUDY
LONGARD TUBES
TEST PROTECTION WORK
Layout Plan

Figure 5



TUKTOYAKTUK N. W. T.
SHORE EROSION & PROTECTION STUDY
LONGARD TUBES
TEST PROTECTION WORK
Sections

Figure 6

Means are now available to protect the tubes against vandalism.

Basically, there are two steps that can be taken to make the design resistant to vandalism. These include coating the tubes with a hard shell and backfilling the installation with granular fill, covering the tubes to the top. The coating material available consists of an epoxy resin glue applied by painting rollers and sand which is either sprinkled manually or dumped onto the wet glue mechanically with dump trucks. The backfilling of the installation was a design requirement not accomplished in the test installation. Its purpose was to provide a blanket on the beach to protect the permafrost underneath from destabilization by the sea and the warm summer temperatures. In the final design the backfill will in addition protect the Longard tubes from damage from vandalism and from any sharp floating debris that can otherwise strike and damage the tubes with wave action.

To investigate the coating a length of one meter diameter Longard tube was obtained and assembled at the National Research Council of Canada for certain tests. Five different combinations of coating were applied to the tube. These were:

(1) uncoated
(2) one coat of epoxy glue, followed by sand
(3) two coats of epoxy glue followed by sand
(4) one coat of epoxy glue followed by sand and a second coat of epoxy glue followed by sand
(5) one coat of pre-mixed epoxy glue with sand

Several different types of tests were carried out on each section. These included resistance to slashing by hand, resistance to puncture by a knife with a proctor-needle assembly, flexure and bending tests at -40 deg.C and burning with a propane torch.

Hand slashing tests were carried out using a hunting knife. The uncoated tube offered very little resistance to hand slashing. Among the coated sections of the tube the double coating type 4 (glue - sand/glue - sand) offered the most resistance to slashing. Another advantage of coating observed during these tests was that the cuts made in the coated sections remained simply as closed cuts while the cuts made in the uncoated sections opened out allowing the sand-fill to run out.

PROTOTYPE TESTING OF SAND COATED TUBES USING A HUNTING KNIFE

PROTOTYPE TESTING OF SAND COATED TUBES FOR RESISTANCE AGAINST FIRES

Figure 7

The results of the penetration tests carried out using the hunting knife and Proctor Needle Assembly are tabulated below (figure 7).

Type of Coating	(1)	(2)	(3)	(4)	(5)
Pounds of Force for Knife Penetration	65	69	48	90	63
	62	63	53	100	77
	50	56	58	93	77
	43	57	63	120	
	62	62	59	96	
	45	61	64	89	
Average	55	61	58	98	72

The fire resistance tests with a propane torch showed the following results (figure 7).

Type of Coating	(1)	(2)	(3)	(4)	(5)
Time in seconds required to burn through coating	5	100	45	120	-

Flexure and blending tests were performed using samples from sections with type 2, 3 and 4 coating.

Relative comparisons of the results showed type (4) coating to be the most superior, both at room temperature as well as at -40deg.C.

The test results show the section with a double coating (one coat of glue followed by sand and a second coat of glue followed by sand) to be the most effective section and the final design for Tuktoyaktuk will include this double coating.

6. CONCLUSIONS

In remote areas of the Canadian north, sand filled tubes offer an attractive alternative compared with traditional materials in the design of flexible type shore protection works. The tubes in their uncoated form are vulnerable to vandalism. Techniques now exist to protect the tubes against damage and this feature should prove invaluable to guard against vandalism that can occur in remote areas.