CHAPTER 79

SYSTEMATIC STUDY OF COASTAL EROSION AND DEFENCE WORKS IN THE SOUTHWEST COAST OF INDIA

by

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ABSTRACT

The SouthWest coast of India is subjected to severe erosion due to attack by waves and tidal overflow. Through the years the problem has intensified as beach front areas have become more extensively developed and subject to greater damage from the force of the sea. More than 300 kms of the coast is subjected to severe erosion due to constant attack by waves and tidal overflow, resulting in continuous recession, loss of valuable property and affecting many aspects of its economy. The paper presents the problem at the proper perspective. It describes the various physical factors of the Southwest coast of India, namely the geomorphology, winds, waves, tides and currents, littoral drift, material characteristics, shore line and shore depth changes, effects of inlets and mudbanks. The study, evolution and development of different coastal defense works and their behaviour and effectiveness is also presented.

INTRODUCTION

The Southwest coast of India runs north - south along the Arabian Sea and extends 560 kms. This coast is characterised by a barrier strip of lowlying land between the Arabian Sea and a continuous chain of lagoons and backwaters. The coast line has helped in establishing a number of minor ports, in addition to maintaining a flourishing fishing industry. It is in this coastal strip, that the industrial, agricultural and other economic activities of this region are concentrated (Fig.1).

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It is estimated that out of the 560 km of coast line more than 300 km is subjected to erosion, due to the constant attack by waves and tidal overflow resulting in continuous recession, loss of property and affecting many aspect of the economy. Hence the problem is to stabilise the southwest coast of India in its present position by suitable protective measures after a detailed study.

PHYSICAL FACTORS

GEOMORPHOLOGY:

The Southwest coast of India is of recent age geologically, its formation dating back to the early tertiary period. Borings at Cochin show that there are deposits of alluvial material for 100 to 125m, overlying rock. It is also noticeable that the portion of the coast from Thottappalli to Quilandy (where the phenomenon ofmud banks is known to occur) is an alluvial belt backed by laterite deposits. Heavy mineral deposits ranked as world's largest and richest occur in the coastal area between Kayamkulam and Neendakara. There are forty four rivers, forty one of which flow westerly, from the mountains, to the low areas of backwaters and lagoons, near and at the coast. The average river length in 60 km. In the coastal region the rivers are generally interconnected and tidal (See Fig.1.).

TIDES AND STORM TIDES:

The mean tidal range varies from 0.9m at the south to 1.8m at the north. The tides are of the semidurinal type. The coast line is very low and coastal areas are flooded by storm tides in many sections, during the southwest monsoon. The storms raise the water level upto a meter or more at many sectors.

WAVES:

The sea is rough during the monsoon months (May to September) when the high waves with the storm surges attack the coast. The highest waves average 3.2m (highest ten percent) and the wave periods of 5 to 12 secs are observed. The direction of high waves is mostly from West during the monsoon period.

LITTORAL DRIFT:

Littoral drift is the beach material moved parallel to the coast in the near shore region of the sea caused

by waves approaching the beach at an angle. In the analysis of the coastal erosion problem, the direction, amount and character of littoral drift is of utmost importance for developing economical designs.

Direction and Quantum of Littoral Drift:

The following points are pertinent:

1) From the analysis of the developed data from charts, existing marine and coastal structures and position of headlands and embayments, it is found that the dominant direction of littoral drift in the Southwest coast of India is towards south.

2) The unimproved inlets in the region have the tendency to migrate to the southso also the sand spits at Periyar river outlet. These indicate southerly movement of drift. (Fig.7).

3) Mud banks are littoral barriers. The shore line of the most severely eroding sectors on the SouthWest coast are situated south of the general limits of migration of the two major mud banks - the Aleppey Mud-bank (now at Nirounnam) and the Narakkal mud bank. This indicates that the dominant direction of drift is towards south in these regions.

4) The curvature of the coast line of Kerala tending to form a line in the NNW - SSE direction is also conductive to form a southward drift, as the dominant waves are from due west during the monsoons.

5) So also the dominant direction of wind during the Southwest monsoon is from West and West North West, for most part of Kerala coast which aid in southerly drift.

6) The dominant direction of surface currents from April to September is from North to South on the West coast.

7) There is seasonal reversal of littoral drift all along the coast. The trend indicate southward movement during May to August (Southwest Monsoon period) and northward movement during the rest of the year.

8) Local reversal of drift due to topographical factors, inlet interferences, coastal works are also noted.

9) The quantum of gross littoral drift work out to (about) 1.25 million cubic meters per year.

CHARACTERISTICS OF BEACH MATERIAL:

Most of shores of Southwest coast of India are sandy. The average grain size of sand in these beaches ranges from fine to medium (0.15mm to 0.6mm). Adjacent to the coastal inlets it is fine sand (0.15mm)

EROSION

CAUSES OF EROSION:

A beach is in an eroding condition when more material is eroded away, than supplied. A permanent erosion is a result of a relative lack of supply of sand at the updrift end of the stretch in question. Usually there are two types of erosion namely (i) natural erosion from natural causes such as storms, tides, rise in sea level, due to tectonic upheavels etc and (ii) man made erosion. Man harnesses the rivers and bottles up their bed load. He builds breakwaters and jetties thereby, bar littoral drift, dredges huge quantities of sand and uses them for reclamation and thereby rob the coast. The building of fixed structures along the coast create excessive turbulence and increase the eroding action of waves. Both ~~cases~~ of natural erosion and man made erosion are existing in the Southwest coast of India.

The causes of severe coastal erosion in the Southwest coast of India is attributed to one or a combination of the following factors.

1) Early onslaught of the monsoon:

The southwest monsoon with its full fury enters the Indian peninsula at the Southwest Coast and this coast have to bear the brunt of the full blast of the monsoon storms with the incident high and steep waves, rise in water level, causing severe erosion and tidal overflow.

2) Geological Factors:

The Kerala shores is of subrecent to recent sediments. As a result, the coast is still in an unconsolidated stage and is yet to reach equilibrium conditions.

3) Level of Backshore and steepness of foreshore and inshore:

The back shore level is low (less than 1.5 meters above MSL) in many places causing severe tidal overflow during storms and during the monsoon season. The foreshore and inshore are comparatively very steep.

4) Mud Banks:

The mudbanks present along this coast are decisively influencing the shore processes and are effectively disturbing the equilibrium conditions of the coast adjacent to them, causing very severe erosion on its downdrift side. (eg. Purakkad, Chellanam).

HISTORICAL CHANGES:

Historical investigation of old and new maps and charts reveal specific locations of permanent erosion in the coast of Kerala. Comparison surveys prepared from authentic maps available from 1850 indicate, that there is consistent retrogression of shoreline. There is a net loss of land at the rate of 2m to 5.5m per year resulting in cumulative loss of precious land year after year. (Fig.2).

SEASONAL CHANGES:

Field observations at selected reaches for the past four years have indicated that there are seasonal changes also in the beaches of Kerala. Erosion is experienced from April to September (during Southwest monsoon). After this period the beach begins to accrete. The berm crest fluctuates to more than 50m in a season. Costly construction in this zone of seasonal fluctuations must be avoided. A typical example is given in Fig.3.

NATURAL EROSION:

Natural erosion is experienced in many parts of Kerala due to severe wave action, storm surges and also due to the numerous inlets present. These inlets act as littoral barriers causing leeside erosion at its south. (eg.) Muthalapuzhi, Kayamkulam, Azhikode, Chettua Velliyancode, Kallayi, Elathur, Murat, Azhikal etc.

MAN MADE EROSION:

Erosion is also caused as a result of man made marine

constructions for the development of ports and harbours. The construction of 5 km long approach channel for the development of Cochin port, the breakwaters at Neendakara and Mopla Bay had contributed to the disturbance of equilibrium conditions of the coast on either side of it. The reaction of the beach to the coastal constructions like groin system had caused downdrift erosion in many reaches.

OFFSHORE AND FORESHORE ZONES:

The continental shelf has a gradual slope upto 10 fathoms after which there is a steep fall. The distance of 100 fathom line from the shore varies, reducing from 82 km near Calicut to 45 km near Trivandrum. The offshore bottom profiles are gentle and uniform in gradient upto 45-50 fathoms line after which the slope of 1 on 5 to 1 on 12 above LW and 1 on 25 to 1 on 40 from LW to 3-4 m depth contour.

BEACH PROFILES:

The width of backshore and steepness of the beach profiles depend on the characteristics of the waves and the beach material. The beach material is generally of fine to medium sand with coarser fractions adjacent to bluff areas. Typical eroding profiles of the beach in the different sectors are given in Fig.4 Beach profiles are steeper in the eroding zones, with the foreshore having a slope of 1 on 5 to 1 on 12 above, with flatter under water slopes. Fig. 4 (a) shows the beach profile development at Thottappalli. The material eroded from the beach is deposited offshore and does not migrate to the south fast enough to balance the deposition. Fig.4 (b) shows the development of a profile at Chellanam where the beach is protected by a seawall, deep water erosion takes place and the profiles as a whole steepens. Fig.5 shows the difference in the beach slope within and adjacent to the mudbank at Aleppey.

MUD BANKS:

The formation and behaviour of 'mud banks' is a phenomenon peculiar to the Southwest coast of India. Similar phenomenon has not been reported in any other part of the world. The mud bank may be defined as an inshore area having a special property of dampening wave action and producing regions of calm water, even during the rough monsoon season, due to the dissipation of wave

energy in the large quantity of colloidal suspension in the region. The mud banks form part of the sediment activity along the coast. The mud bank region is considered to be a 'boon' by the local populace, as these areas, which are calm during the monsoon abound in Prawns, Sardines, Mackerals and Soles. Mud Banks are known to have existed in the Southwest Coast of India from ancient times and the earliest written account of the mud bank dates as far back as 1678 and 1723. There are four well known mudbanks - one near Alleppey and two near Kozhikode. (Ref. Fig.1).

Mud Banks affect the coastal processes in the following ways:

1) Traps the littoral material from the updrift side and there by prevent its down coast movement.

2) Causes accretion within the mudbank area. A typical profile showing the accretion of beach in the mud bank area is given in Fig.6.

3) Causes refraction and diffraction of waves on its sides.

It must be mentioned that the mud banks are decisively disturbing the equilibrium conditions of the coast adjacent to them. It is noteworthy to mention the fact that coastal erosion is historically severe in the coasts adjacent to the principal mudbanks, one south of Aleppey and the other south of Cochin. (Fig.2.).

COASTAL EROSION CONTROL

MEASURES AGAINST EROSION:

In selecting the shape, size and location of protection works, the objective should be to design the work which will accomplish the desired result most economically and with full consideration of its effects on adjacent shorelines. The analysis, of the data collected and field studies will permit the selection of structures that will attain the desired objective. The cost, maintenance as well as interest on amortization of first cost must always be evaluated. The types of coastal protective works adopted are the seawall, bulkhead, rivetments, jetties, groins, breakwaters (shore connected and offshore), artificially nourished and protective beaches and sand dikes, dune stabili-

sation by wind fencing and vegetation, uses of precast blocks (like tetrapods, tribars, hollow tetrahedron, stabit, Akmon, Svee, Dolos, Stapods etc.)

EARLY COASTAL PROTECTION WORKS:

Prior to 1953, the construction of shore protection works was only on a very limited scale. Groins of dumped granite rubble were constructed at a place called Chilakoor nearly eight years ago (1890) Bunds of laterite and granite rubble masonry with a sand core were raised north of Cochin outlet sixty years ago (1910-1914 before the construction of the approach navigation channel at Cochin).

DEVELOPMENT OF PRESENT COASTAL PROTECTION WORKS:

Although the problem of coastal erosion was existing for quite a long time, protection of coasts in a systematic way was initiated in the early fifties. The early pioneering structures were necessarily experimental.

Experimental Seawall at Cochin (1954-1957).

It was in 1953, when severe erosion caused serious damages particularly near Cochin, that recognition was given, for protection of this region. An experimental granite rubble wall for 1.6 km (one mile) was constructed during 1954-1957 at Mannassery, Cochin as a prototype study. The first 0.8 km (0.5 mile) of the seawall was of dumped granite rubble and the next 0.8 km (0.5 mile) was constructed with a sand core overlaid by rubble with cement grouting in the joints. Ten groins of different length and spacings were also constructed. Out of this, one groin was constructed with precast concrete blocks (0.61 m x 0.61 m x 0.3m) as armour stones and 20 to 40 dm^3 size stones as inner core. During the monsoon of 1956, the dry rubble portion of the seawall sank considerably. Noteworthy is the fact that the groyne constructed with cement concrete blocks has withstood the wave attack better than the other groins constructed with rubble.

Experimental Groins: (1959-1960).

Experimental groin with coconut piles was tried unsuccessfully in 1959 at Puthenthodu, Cochin.

of drainage facilities for overtopped water to flow back into the sea (v) The position of the seawall being close to the water line.

Sea walls constructed in the back shore with a beach infront gave better performance than those constructed in the forward portion (within the sweep zone). Hence seawalls may be located as far landward in the backshore beyond which further recession is not to be permitted. Considering the above factors the original section of the seawall was revised and a new design was evolved in 1970. This included a filter system, backfill and armour stones of increased weight and dimension. The fig. 10 gives details of the same. This design is now being tried in critical reaches.

ARTIFICIAL NOURISHMENT:

The problem that confronts the coastal engineer is 'what is the best and most economical method of protecting a beach that receives and inadequate supply of beach material' . The problem appears to be simple in that all that is required is to establish the supply material. Hence when studying an erosion problem it is always advisable to investigate the feasibility of mechanically placing beach material on the shore in such a manner than an adequate beach, will be maintained (in addition to the other remedial measures considered). An important advantage is, that this treatment remedies directly the basic cause of most erosion problems (ie; a deficiency in natural sand supply). Thereby it benefits, rather than damages the shore beyond the immediate problem area. Also it is the one system that maintain the balance of nature and is relatively free of the undesirable features of other systems. An obvious and important consideration is the availability of suitable sand for the purpose. The basic methods of nourishment are (i) stock pilemethod which is placing the fill at one point and allowing it to function as a feeder beach (ii) direct placement method which involves placing the material along the beach and creating an adequate beach width for immediate protection (iii) continuous supply method-where a fixed or semifixed plant interoepts and by passes the littoral drift to the down drift side and (iv) offshore dumping method.

Coastal protection by artificial nourishment was conducted at Purakkad (near Alleppey) during

Inclined groins, twenty in number were constructed in the Chellanam Coast, Cochin in 1959-1960. They were found to be not as effective as the groins normal to the shore.

Experimental Seawall with Bituminous Grouting:(1959)

As an experimental measure, a seawall with bitumastic grouting was constructed for 215 m at Soudhi, Cochin. A sand core, formed with a slope of 3:1 was covered with stones and the crevices filled with bitumastic grout. This seawall could not withstand the wave attack and failed within an year after construction.

Seawall and Groin System(1959-1963).

Dumped granite seawall and groins system as per design given Fig.8 was tried from 1959 at the critically eroding region at Chellanam. Between 1959 and 1963 nearly 40 kms of the worst affected reaches were protected by this method.

The seawall and groin system, helped to protect the coastal area behind it. However the groins trapped part of the littoral transport and therefore the downdrift region was depleted of its natural supply which caused severe erosion in the lee regions. Also, since there is time reversal of littoral drift all over the Coast, both the northern and southern extremities of the sewall and groin systems were affected and they posed new problems. As a consequence, continuous extension of seawall and groin system was found necessary in several regions (Thottappalli, Purakkad, Chellanam, Vypeen etc.)

Evolution of Seawall Design (1963):

In 1963 a design of seawall of a stabler section was evolved from the available data (Fig.9) Nearly forty kms of the coast was protected by the seawall (between 1963 and 1969). The speoial good features of this design are the flatter slopes and heavier armour stones. Prototype observations and studies conducted between 1964 and 1969 indicated the following: (i) A good filter at the bottom and on the land side is necessary (ii) Proper protection at toe with heavier stones and filter is necessary (iii) Low crest elevation cause overtopping by the waves, exposing the rivetment and the land behind to scour and consequent settlement (iv) Lack

during April - 1964. The reach selected was 1.6 km (1 mile) in length (north of the seawall and groyne system) which was severely eroding at the time of experiment. The direct placement method was adopted. The sand available at the outer channel of Thottappalli spillway was conveyed to the test by 5 tons trucks and placed in the reach directly. A total quantity of 47500 cum. of sand was dumped during the two months.

Even though the experiment was inconclusive, accretion was noted in this area in November-December 1964, subsequent to beach fill operations. Hence it can be inferred that if sufficient sand is available and if it can be placed at a rate fast enough to replenish the lost material, the shore line can be preserved in a satisfactory manner by this method. But a study of the collected boring charts of indicate that the availability of suitable sand that can be economically utilised is limited.

DUNE CONTROL:

Sand dunes act as barriers against action of the normal and storm tides and also reduce the action of onshore winds. Suitable stabilisation measures should be done by the use of fences, coats of crude oil or by dune vegetation to hold the sand that might otherwise migrate. The sand dunes not only act as protective barriers but also as stockpiles to feed littoral streams. The problems of dune control resolves itself to stabilisation and maintenance of dunes where they exist and inducement and stabilisation of protective dune where they do not exist naturally.

Wind Fencing:

The purpose of wind fencing is to arrest wind blown materials on the beaches and cause their accumulation at the fence, in locations where a sandy beach exist. Sand dunes will thus be created, which will raise the beach level and offer greater protection to the coast. Wind fences had been erected at two locations for trial length of 100m each at Munambam and West Hill as an experimental measure during the end of 1968. Two types of wind fencing are constructed. The one at West Hill is constructed using split bamboo where as the other at Munambam consists of prefabricated units using G.I.sheet strips.

Dune Vegetation:

A method of stabilisation of the dune is by vegetation. An experiment for a trial length of 100 m has been initiated in January 1969 at West Hill (Kozhikode) to study the use of beach grass (which is locally available) in stabilising the dune.

GABIONS:

In certain coasts, the placing of an impermeable object may cause boundary conditions of scour, and also cause uneven settlement due to poor subsoil condition. These difficulties can be mitigated by the use of a permeable and flexible structure. Gabions can be successfully used in such cases. They are metal cases (covered with protective plastic) or of high tensile steel mesh filled by natural stones of small size which are readily available. Crates of nylon are also used. Sand filled plastic or jute bags also used. Crates of 0.25 cum made of nylon nets and filled with small sized stones were tried with limited success at one groin location near Cochin.

USE OF PRECAST UNITS, AS ARMOUR LAYER OF SEAWALL, GROINS ETC.

Precast armour units have been developed in an effort to provide adequate armour units for seawalls, groins, jetties and breakwaters where stones of required size and durability could not be economically obtained. The first of these is the now famous tetrapod. Those which are subsequently developed and being used include tribars, hollow Tetrahedron, hollow square block, Tribars, Stabit, Quadriped, Akmon, Svee, Dolos, Stapod, Pentacon, Hexalegblock, Crossblock, Trilegs, Dugon, Hexapod etc. In the Southwest coast of India, the use of precast armour units is now confined to the armour units of breakwaters. The use of Precast interlocking concrete block rivetment is now suggested. Rectangular concrete blocks had been used with success in groin.

EVALUATION

The protection of the existing coast line of Southwest coast of India and their improvement is of importance. Through a great number of years, beaches have been lost and an all out effort is being made

to stabilise the coast line. It is too early to evaluate completely the coastal processes and the overall behaviour of the treatment effeced. It is hoped that the remedial measures evolved from the systematic study will help to stabilise the shores of SouthWest coast of India in the near future.

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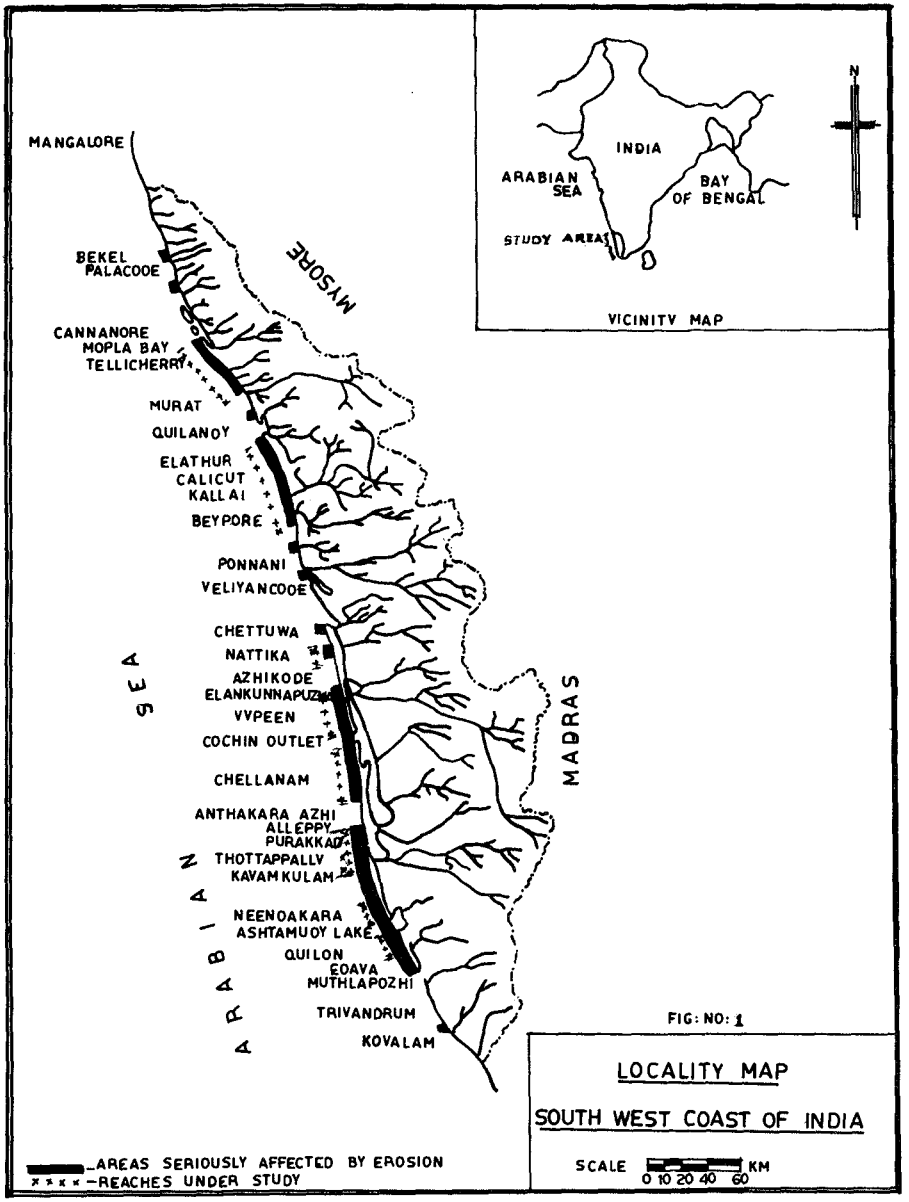
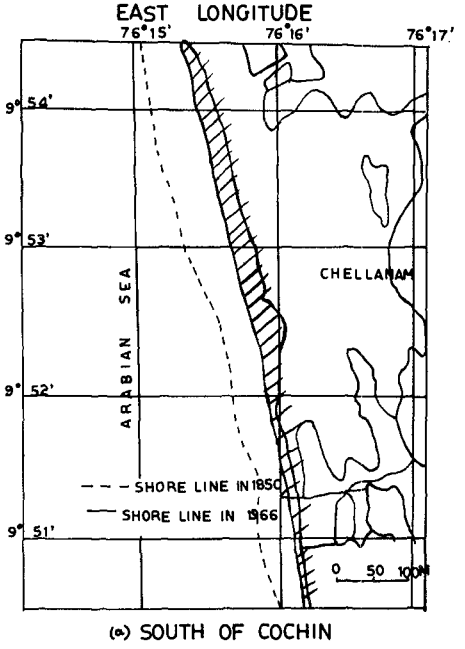
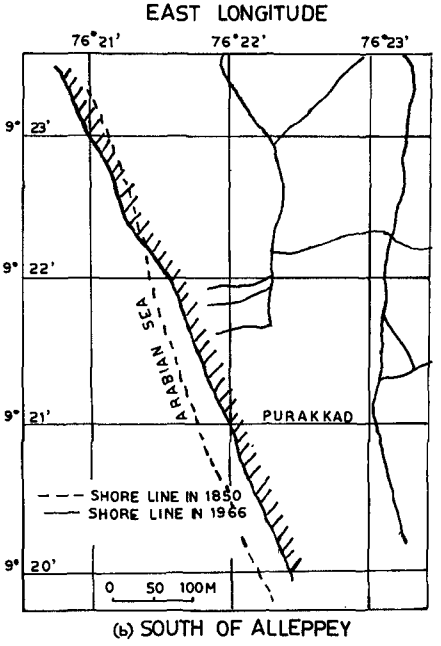

MANGALORE
BEKEL
PALACODE
CANNANORE
MOPLA BAY
TELLICHERRY
MURAT
QUILANDY
ELATHUR
CALICUT
KALLAI
BEYPORE
PONNANI
VELIYANCODE
CHETTUWA
NATTIKA
AZHIKODE
ELANKUNNAPUZ
VYPEEN
COCHIN OUTLET
CHELLANAM
ANTHAKARA AZHI
ALLEPPY
PURAKKAD
THOTTAPPALLY
KAVAMKULAM
NEENDAKARA
ASHTAMUDY LAKE
QUILON
EDAVA
MUTHLAPOZHI
TRIVANDRUM
KOVALAM
MYSORE
MADRAS
ARABIAN SEA
INDIA
BAY OF BENGAL
STUDY AREAS
N
VICINITY MAP
FIG: NO: 1
LOCALITY MAP
SOUTH WEST COAST OF INDIA
SCALE
0 10 20 40 60 KM
-AREAS SERIOUSLY AFFECTED BY EROSION
-REACHES UNDER STUDY



(a) SOUTH OF COCHIN

FIG:NO: 2(a)

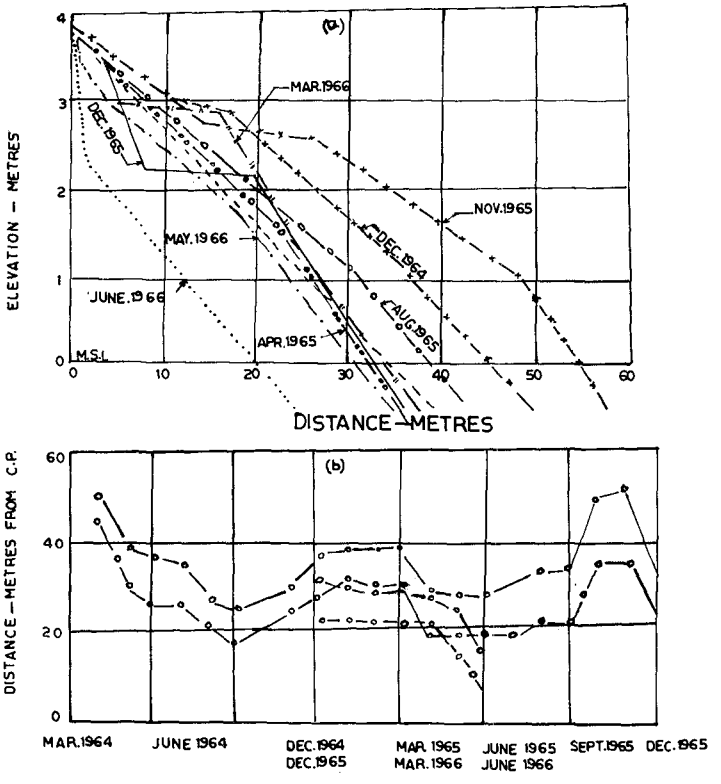
SHORE LINE CHANGES IN SOUTH WEST COAST OF INDIA



(b) SOUTH OF ALLEPPEY

FIG: NO: 2(b)

SHORE LINE CHANGES IN SOUTH WEST COAST OF INDIA

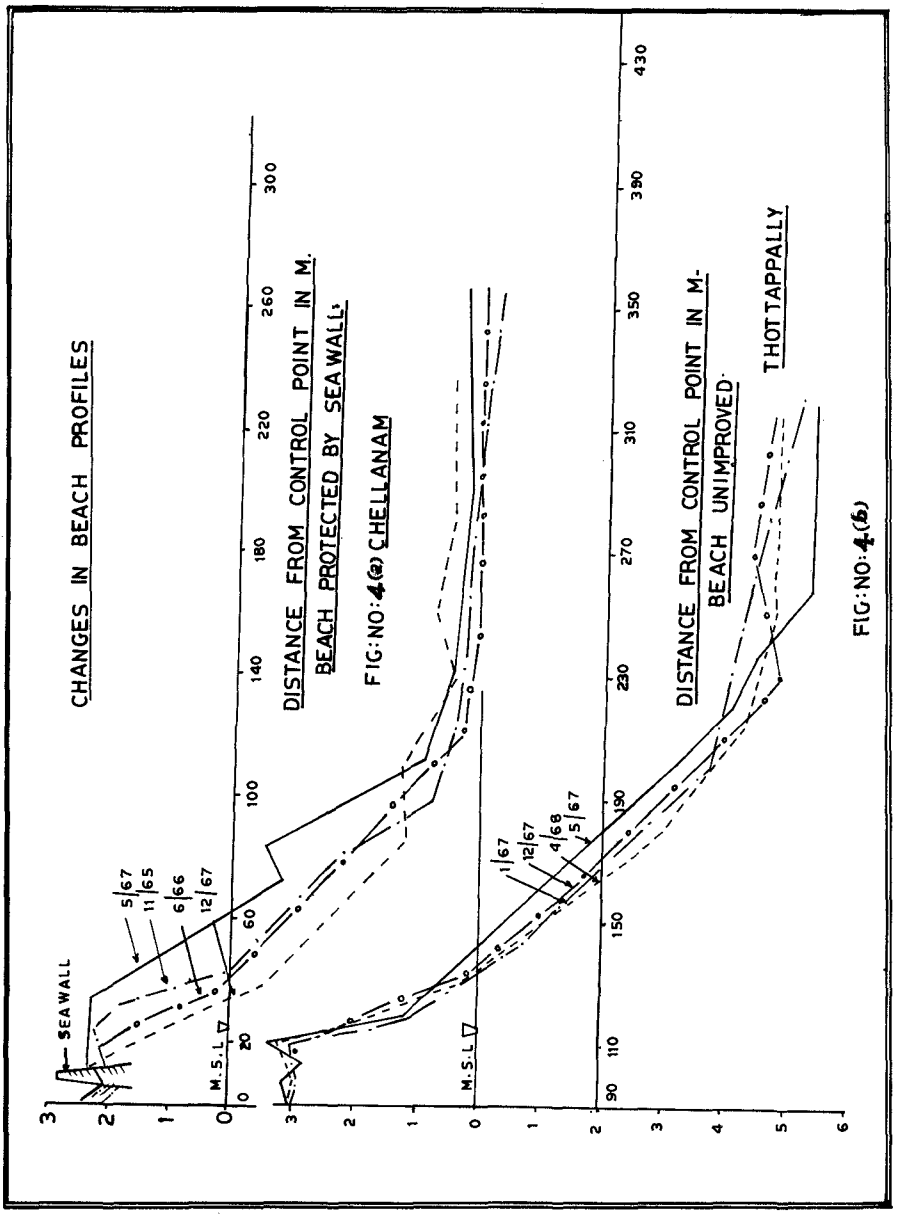


(a) PROFILE AT PURAKKAD

(b) CHANGES OF 1M AND 2M CONTOUR – PURAKKAD

FIG: NO: 3.

SEASONAL CHANGES OF BEACH PROFILE


CHANGES IN BEACH PROFILES
SEAWALL
5/67
11/65
6/66
12/67
M.S.L
DISTANCE FROM CONTROL POINT IN M.
BEACH PROTECTED BY SEA WALL
FIG:NO:4(a) CHELLANAM
1/67
12/67
4/68
5/67
M.S.L
DISTANCE FROM CONTROL POINT IN M-
BEACH UNIMPROVED
THOTTAPPALLY
FIG:NO:4(b)

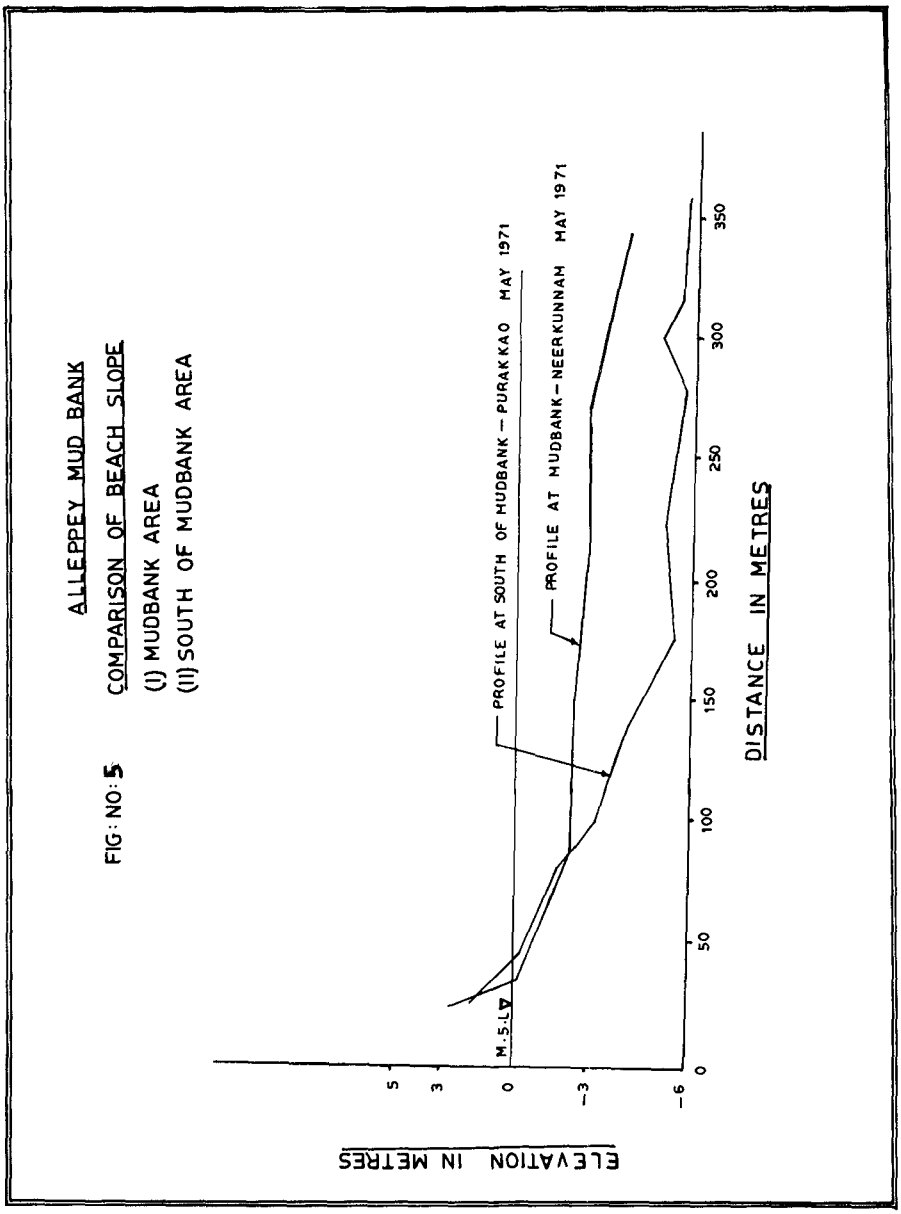

ALLEPPEY MUD BANK
COMPARISON OF BEACH SLOPE
(I) MUDBANK AREA
(II) SOUTH OF MUDBANK AREA
PROFILE AT SOUTH OF MUDBANK – PURAKKAO MAY 1971
PROFILE AT MUDBANK – NEERKUNNAM MAY 1971
M.S.L.
ELEVATION IN METRES
DISTANCE IN METRES
5
3
0
-3
-6
0
50
100
150
200
250
300
350

FIG: NO: 5

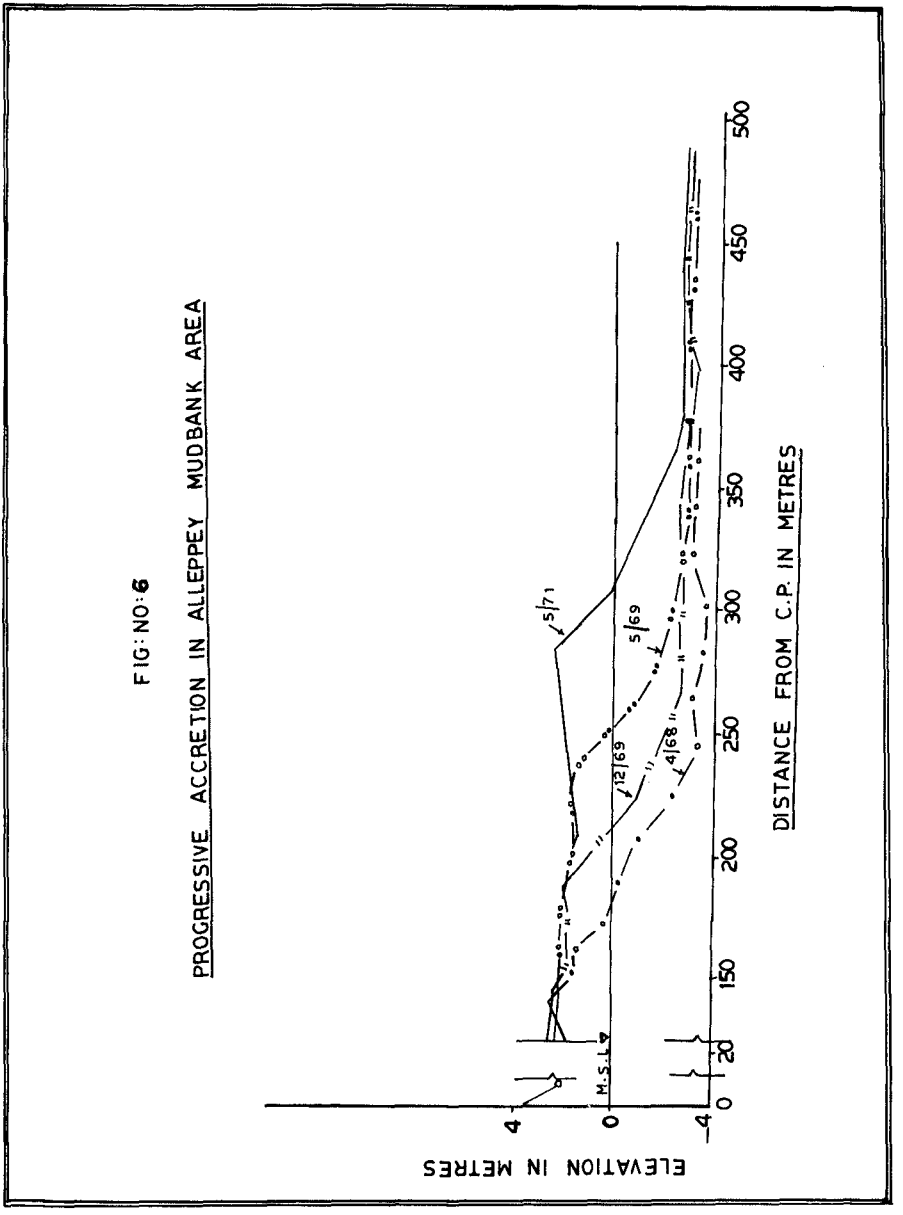
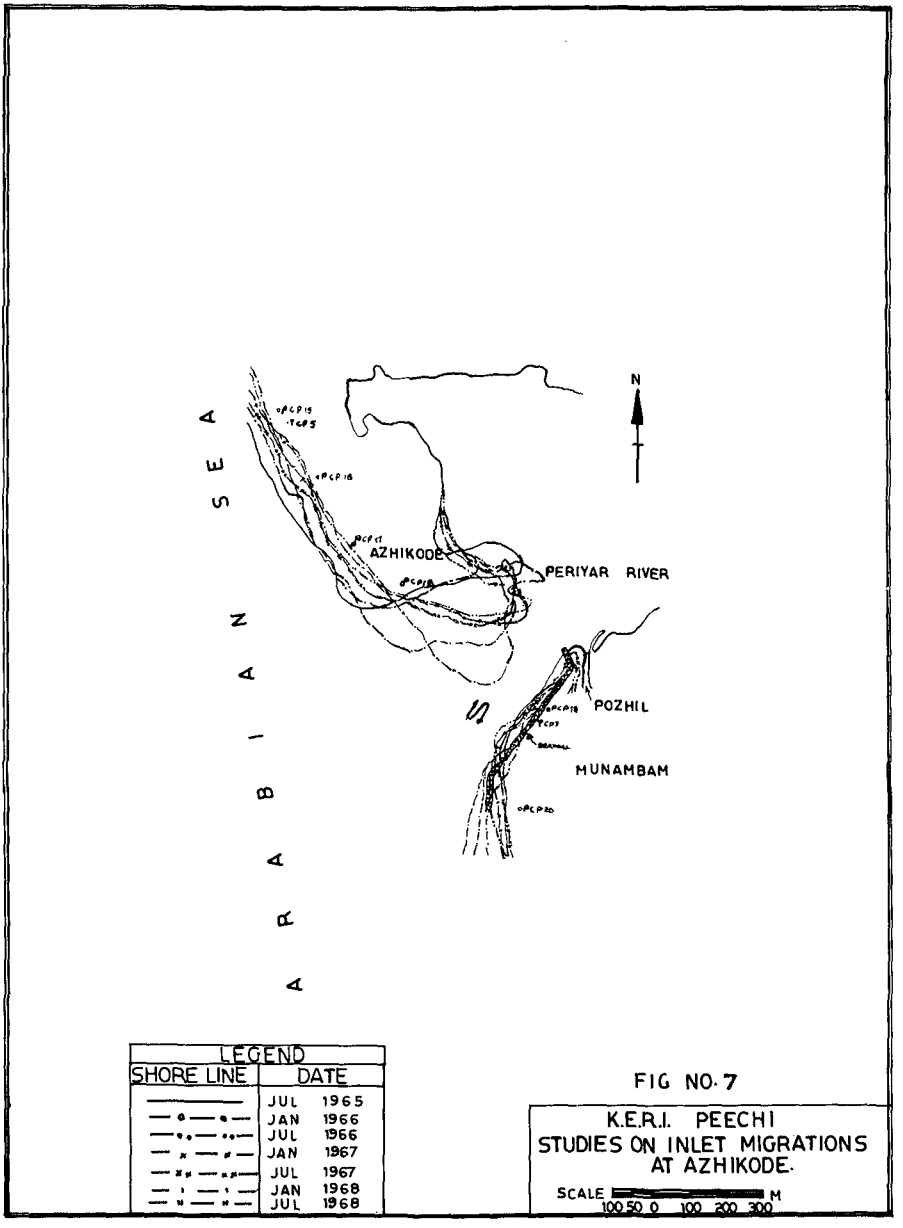
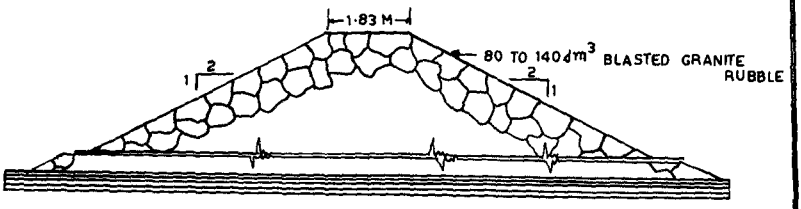


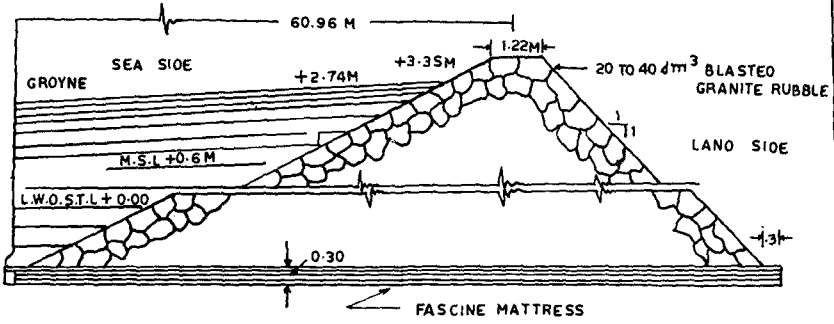
FIG: NO: 6
PROGRESSIVE ACCRETION IN ALLEPPEY MUDBANK AREA
ELEVATION IN METRES
DISTANCE FROM C.P. IN METRES
M.S.L.
5/71
5/69
12/69
4/68
4
0
-4
0
20
150
200
250
300
350
400
450
500


ARABIAN SEA
N
AZHIKODE
PERIYAR RIVER
POZHIL
MUNAMBAM
LEGEND
SHORE LINE
DATE
JUL 1965
JAN 1966
JUL 1966
JAN 1967
JUL 1967
JAN 1968
JUL 1968
FIG NO. 7
K.E.R.I. PEECHI
STUDIES ON INLET MIGRATIONS AT AZHIKODE.
SCALE
M
100 50 0 100 200 300



SECTION OF GROYNE

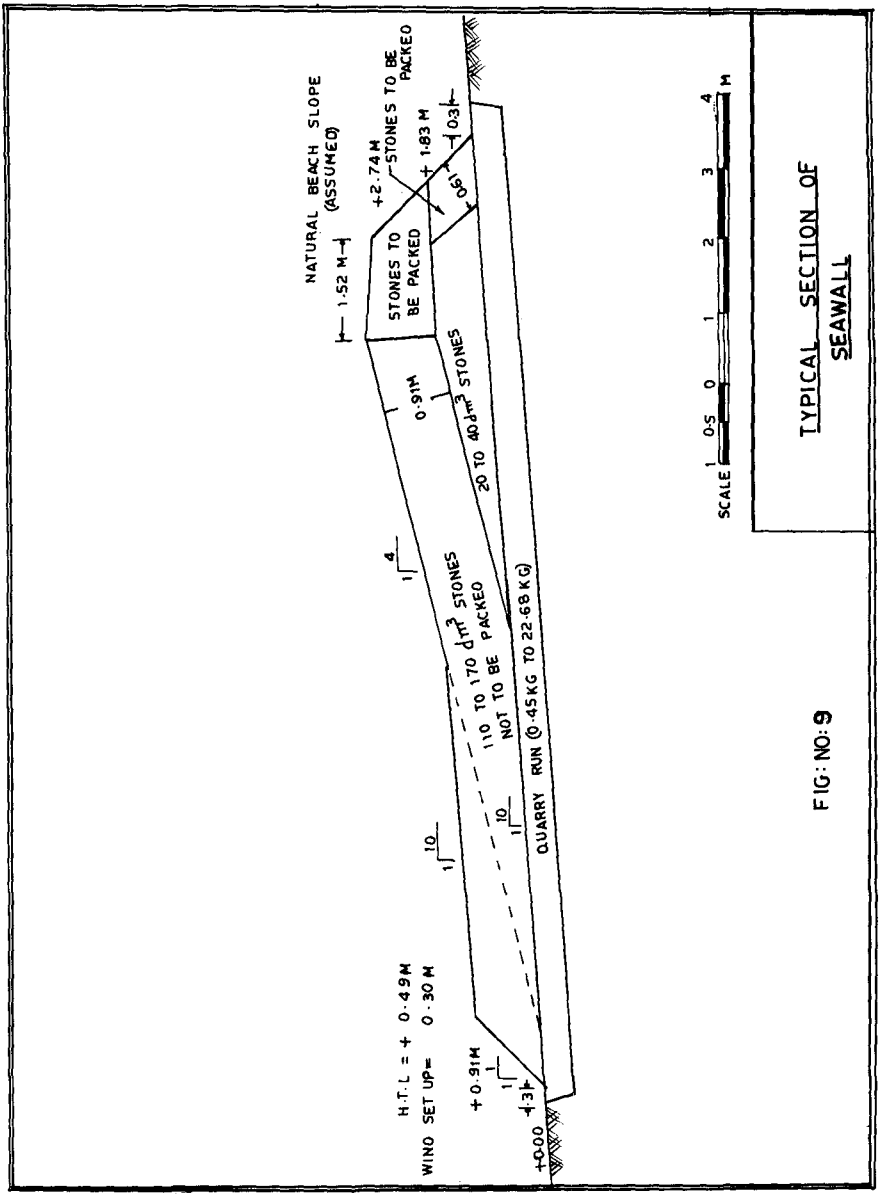
SCALE 1 0·5 0 1 2 3 4 M

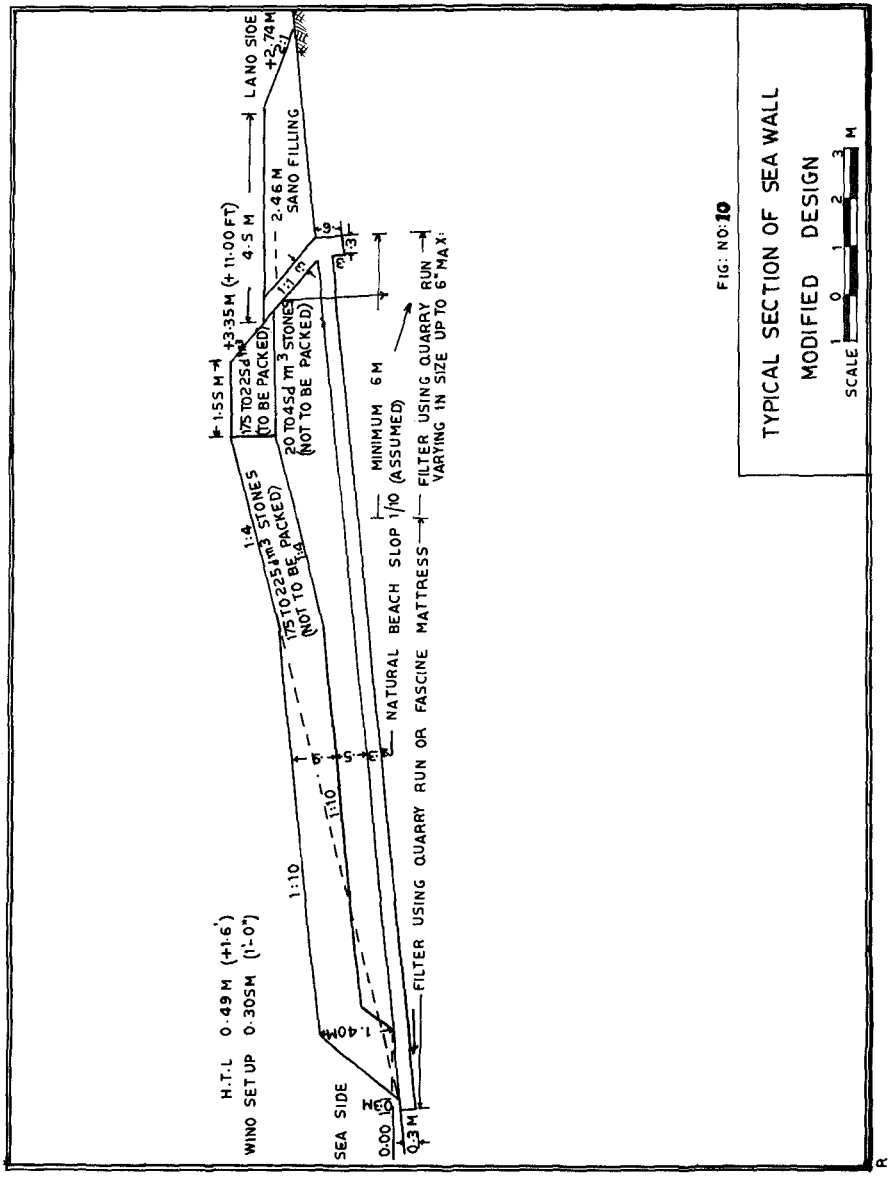


SECTION OF SEAWALL

SCALE 1 0·5 0 1 2 3 4 M

FIG:NO:8


NATURAL BEACH SLOPE
(ASSUMED)
1:52 M
+2.74 M
STONES TO BE PACKED
+1.83 M
0.3
0.6
STONES TO BE PACKED
0.91M
20 TO 40 dm³ STONES
4
1
110 TO 170 dm³ STONES
NOT TO BE PACKED
10
1
10
1
QUARRY RUN (0.45 KG TO 22.68 KG)
H.T.L = + 0.49M
WIND SET UP = 0.30 M
+0.91M
1
1
+0.00
1.3
SCALE
1 0.5 0 1 2 3 4 M
TYPICAL SECTION OF SEAWALL
FIG: NO: 9


TYPICAL SECTION OF SEA WALL
MODIFIED DESIGN
SCALE 0 1 2 3 M
LAND SIDE
+2.74M
2.46 M SAND FILLING
+3.35 M (+11.00 FT)
4.5 M
1.55 M
1.75 TO 2.25 m³ STONES (TO BE PACKED)
20 TO 45 d m³ STONES (NOT TO BE PACKED)
1.75 TO 2.25 m³ STONES (NOT TO BE PACKED)
1:4
1:1
1:3
1:10
1:10
MINIMUM 6 M
NATURAL BEACH SLOP 1/10 (ASSUMED)
FILTER USING QUARRY RUN OR FASCINE MATTRESS
FILTER USING QUARRY RUN VARYING IN SIZE UP TO 6" MAX
SEA SIDE
0.00 M
0.3 M
H.T.L 0.49 M (+1.6')
WIND SET UP 0.305M (1'-0")
FIG: NO: 10