CHAPTER 201

COASTAL PROBLEMS IN SRI LANKA

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ABSTRACT

As an island state with about 900 miles of coastline, Sri Lanka is endowed with a large natural resource: its 720 miles of sandy beaches. The coastal zone is under stress by a burgeoning population, living in the coastal belt,and a variety of other demands with conflicting interests. Due to natural causes and interference of men, erosion is a serious problem in the densely populated southwest part of the island.

This paper describes the principal characteristics of the coastal environment and discusses the nature of some of the basic problems. In the recommendations, emphasis is placed on the setting up of an organizational structure to study the problems, both in the field and in the laboratory, with respect to the management aspects in the coastal zone.

INTRODUCTION

The island of Sri Lanka, 25,000 square miles in area with a coastal perimeter of about 900 miles (at least 80% of which are sandy beaches) is located at the southern tip of India; it lies between 6° and 10° north latitudes and between 79° and 82° east longitude. It has a population of 13 million and of this as many as two million are concentrated in the southwestern coastal belt up to a distance of 100 miles south of the capital city of Colombo (see map, Fig. 1).

A coastal retreat, due to erosion by the sea (at one point up to 1,000 ft in the last 50 years), has resulted in the loss of several square miles of the coast especially in the densely populated southwestern region. Of the several protective structures, viz. boulder revetments, sea walls and later on groins, erected in the last few decades only some were successful in combatting the erosion problem. In more recent times the problem has been aggravated by both the direct and indirect consequences of sand and coral mining and other engineering and industrial activity in the coastal zone by numerous individuals and organizations. The rapid development of the country's tourist industry in the last decade has had its impact on the coastal zone. The preservation, restoration, and environmental control of the beaches and above all the effective management of the coastal zone has high priority in the country's development plans.

It was obviously futile to permit illegal and uncontrolled operations to continue on the coast and then spend large sums of money to protect the coast. In addition, existing legislation for seashore protection was weak, while a solution was also necessary for the socio-economic problem of those engaged in the illegal mining of sand and coral for a livelihood. In this connection,

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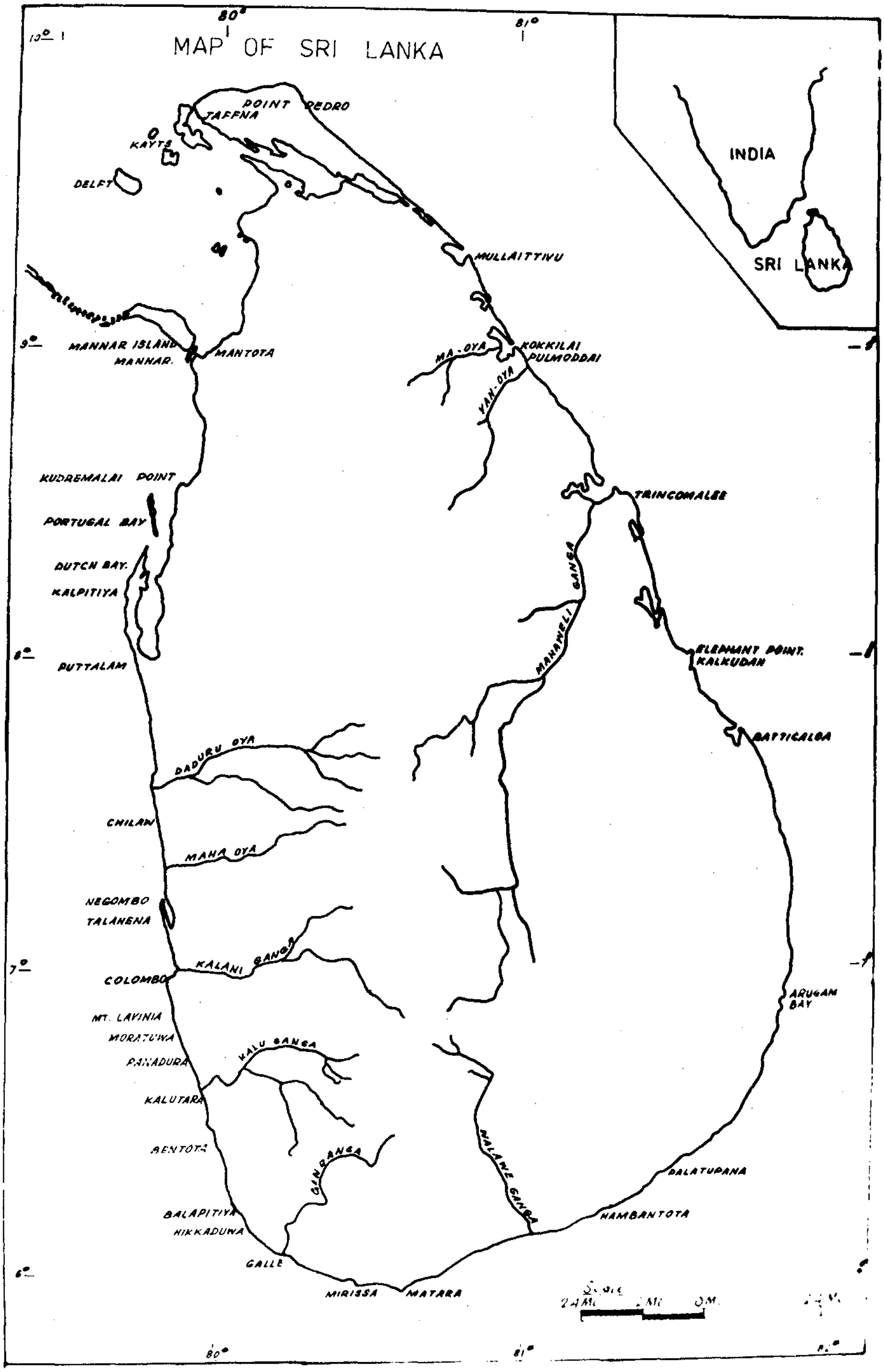

FIG. 1 MAP OF SRI LANKA

proposals made by the Ministry of Shipping and Tourism three years ago and accepted by the government consisted broadly of: (a) the creation of a single authority to control, regulate and coordinate all activity within the coastal zone which may have adverse effects on coast conservation in Sri Lanka; and (b) the framing of separate legislation for the conservation of the country's coast.

Action as proposed above was pursued by seeking assistance from the United Nations for the services of an expert in coastal engineering. In this capacity the senior author spent three months in Sri Lanka (July - September, 1974) to study the coastal problems, to recommend solutions and to make appropriate recommendations for a Coastal Zone Management Program in Sri Lanka. Furthermore, the Colombo Port Commission and the Ministry of Shipping and Tourism, in collaboration with the country's Legal Draughtsman's Department drafted new legislation for coast conservation in Sri Lanka. This draft legislation is now awaiting debate in the country's National State Assembly.

DISCUSSION OF ENVIRONMENTAL FACTORS

Prior to discussing the particular coastal problems in the State, this section provides information on the environment and the general characteristics of the littoral drift.

Geology

The major portion of the island (about nine-tenth) consists of crystalline rocks of Archaean age, with narrow belts of sediments in the coastal zone [1]. Extensive development of sedimentary rock is found along the northwest coast of the island, where limestones of Miocene age are found. Beaches are found all around the island. Along considerable portions of the west coast a shallow coastal reef of sedimentary sandstone of recent age is found. This reef has been a stabilizing factor against beach erosion. The reef runs parallel to the shoreline between Colombo and Mt. Lavinia; at other locations (Negombo, North of Colombo) it makes a small angle with the present shoreline.

Along the greater part of the southwestern and eastern shoreline, beaches are situated between rocky headlands of gneis or granite. In many locations, beaches are backed by lagoons, estuarine deltas and marshes indicative of progradation and coastal rectification that followed a phase of submergence [1]. Cliff coasts occur in the south of the island between Dondera and Tangalle and in the Trincomalee area on the northeast coast.

As to the possibility of tilting of the island around an east-west axis (between Colombo and Pottuvil) with the southern portion of the island going down, this theory has been dismissed by Swan [1]. Instead there seems more evidence for a steady rise in sea level in post Würm times, with minor oscillations superimposed thereon.

The present phase of increased erosion seems due to a slight rise in sea level since the mid-19th century.

Coral reefs are found along parts of the west and east coast. Most coral beds are dead but live coral is still found near Hikkaduwa on the southwest coast and near Trincomalee on the east coast.

Winds and Waves

There are two distinct climatological periods--the southwest monsoon from May to September and the northeast monsoon from November to January. Waves from the southwest are predominant during the southwest monsoon, although waves from the northwest occur occasionally. Winds from the southwest are considerably stronger than from the northeast and the wave conditions on the west coast during the southwest monsoon are more severe than on the east coast during the northeast monsoon. In both cases, the height and period of the significant waves are somewhat reduced during periods of high wind speed due to a limited fetch length, so that the condition of a fully-developed sea will not be reached (Fig. 2).

Waves from the southwest have a median significant height of about 5 ft with a significant period of 5 1/2-6 sec; whereas, waves from the northeast have a median significant wave height of about 3 ft with a significant period of approximately 4 1/2 sec.

In addition to the waves generated by the wind there is the southern swell (from directions between south and southeast), originated by winds and storms on the southern hemisphere. It has a significant effect on the direction and magnitude of the littoral drift.

Tides and Currents

Tides are predominantly semi-diurnal; the tidal range varies approximately between 1.5 and 2.0 ft during spring tides and between 0.3 and 0.8 ft during neap tides [2]. In addition, there is a small seasonal variation.

General ocean circulation around Sri Lanka depends on the monsoon season, as shown in Fig. 3. In a study on oceanographic conditions [3] currents along the west coast were found to run in northerly direction during the southwest monsoon and in southerly direction during the northeast monsoon. The strength of these currents was usually less than 0.5 ft/sec in the Colombo area, but got as high as 1.7 ft/sec in the Galle area. Occasionally considerably higher values (up to 2.9 ft/sec) were observed for no obvious reasons.

Tidal currents become important in the vicinity of tidal inlets and at the mouths of bays and lagoons. Near the breaker zone, wave induced currents become significant and are a primary cause for the movement of sand along the shoreline.

Rainfall and Hydrology

Rainfall is heavy in the mountain areas of the central part of the country, about 100 inches per year, and very heavy on the southwestern slopes of the central hills (up to 200 inches per year). In the coastal belt it averages 50 inches per year. The extreme southeast and northeast coastal zones are dry; the annual rainfall there is below 50 inches.

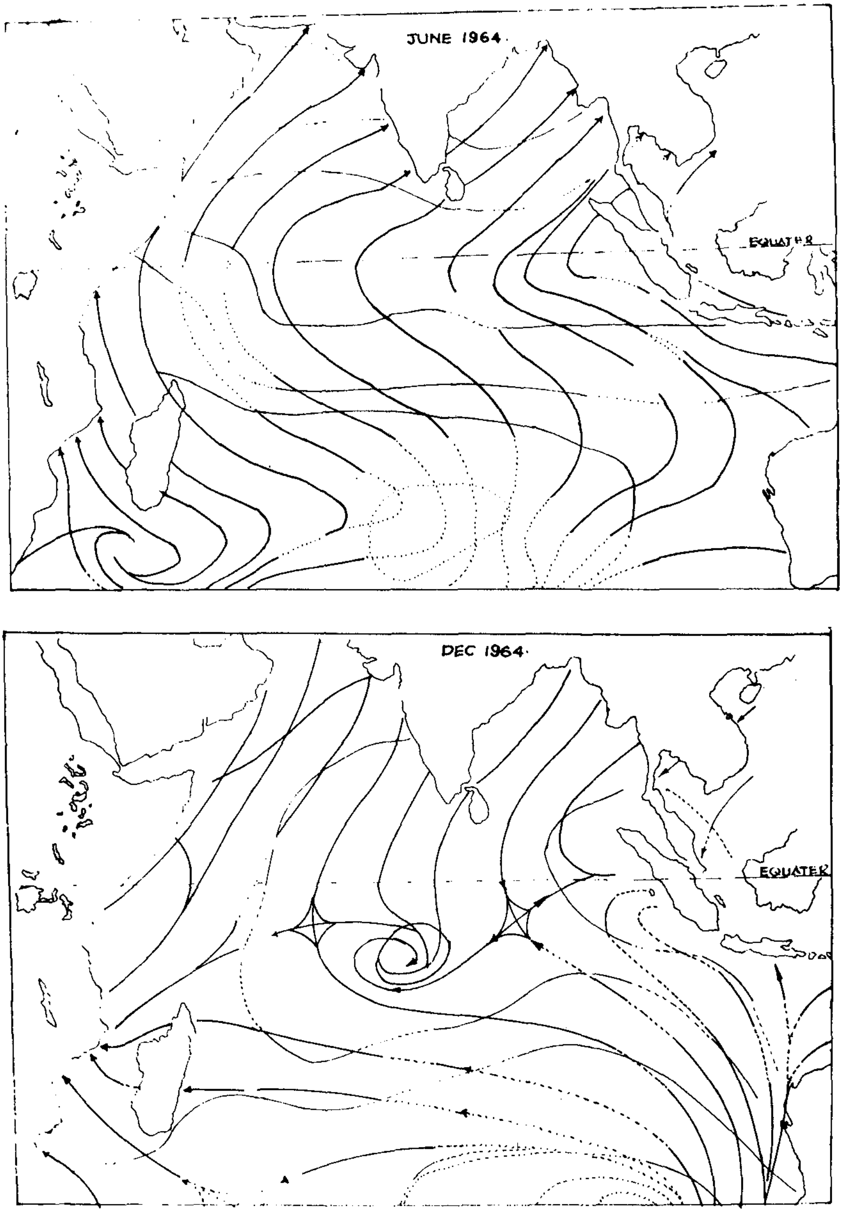

FIG. 2 WIND CIRCULATION PATTERNS IN INDIAN OCEAN

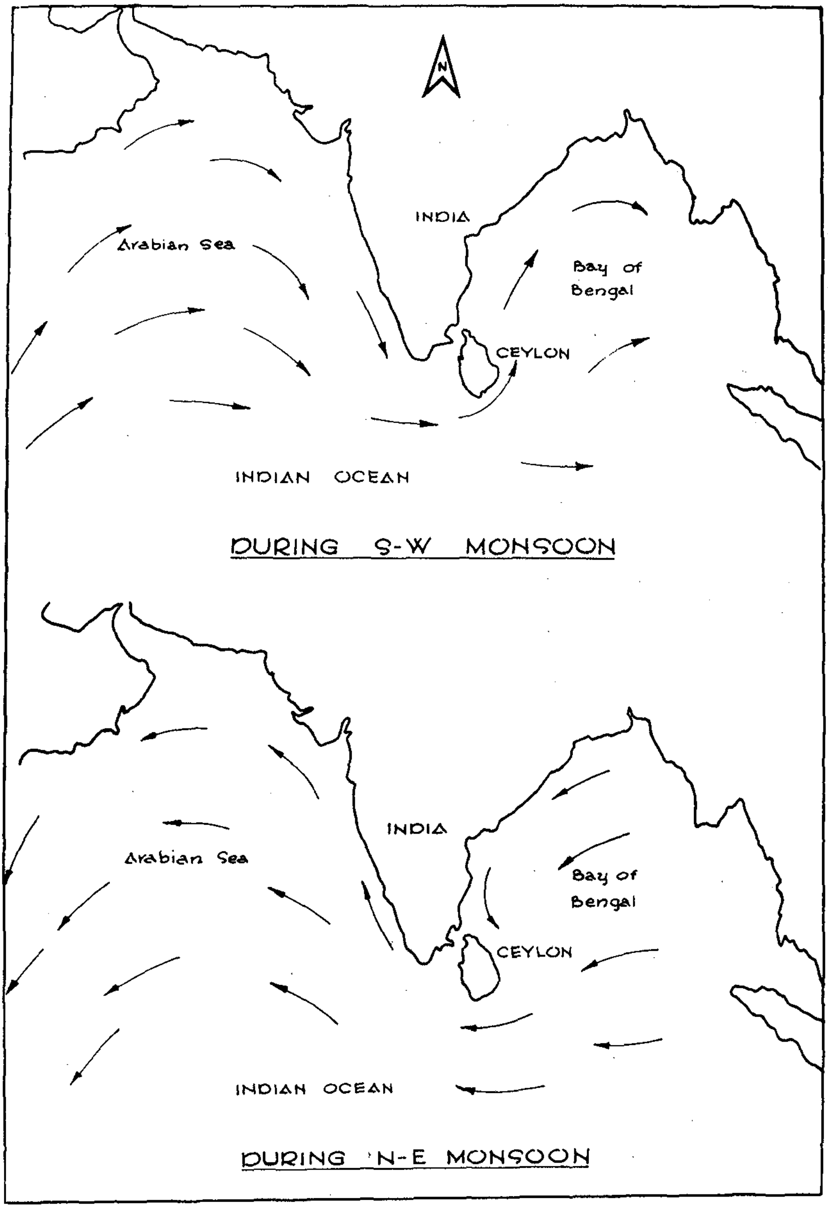

FIG. 3 OCEAN CURRENTS OFF SRI LANKA

The greater part of the precipitation in Sri Lanka returns to the atmosphere through evatransporation [2]. The remaining part is discharged to the ocean by a number of rivers of different sizes, which originate in the central highlands and flow toward the coastline. The largest rivers are the Dadura Oye*, north of Chilaw; the Kalani Ganga*, north of Colombo; and the Kalatura Ganga, all on the west coast and the Mahawela Ganga, flowing into Trincomalee Bay on the east coast. These rivers carry large amounts of sediment (sand) to the various coastal sections.

In a number of locations the rivers discharge their sediments into a coastal lagoon where part of the sediment load is temporarily deposited. The steeper the river, the greater the current velocities and the larger the size of the sediment particles that can be transported.

Littoral Drift

The wave climate responsible for the littoral drift along Sri Lanka's shoreline is strongly related to the monsoon periods. Along the west coast the southwesterly waves induce a littoral transport in a northerly direction. Occasionally the drift is reversed during periods of northwesterly storms. The northerly drift is reinforced by the effect of the southern swell for most of the west and southwest coasts. Locally the littoral drift is reversed due to wave refraction and/or diffraction.

During the southwest monsoon, the southwest coast of the island has a nodal point of the littoral drift in the vicinity of Hikkaduwa (see Fig. 1). North of this point the waves are moving sediments in northwesterly direction, south of there in southeasterly direction. In the vicinity of a nodal point the sediments transported by the waves must be supplied from upland or from local sources and often this supply is not adequate to meet the demand. The rate of erosion in this area is the largest in the State (see Fig. 4); in addition, natural erosion here is reinforced by offshore mining of coral. Along the east coast the drift is predominantly to the north during the southwest monsoon under the effect of the southern swell. During the northeast monsoon the transport is basically southward under the predominant effect of the wind-generated waves from the northeast. The southeast coastal area of the state is an area of deposition, as is the northeast coast of the Jaffna Peninsula.

PROBLEMS IN THE COASTAL ZONE

Erosion

The causes of erosion in Sri Lanka can be broadly classified as due to: (a) natural erosion, (b) erosion and sedimentation due to man-made activity, and (c) erosion due to biological activity.

Natural erosion has manifested itself in the formation of a series of bays on the southwest coast suspended by rocky headlands most of which form reasonable stable shorelines. The eroding tendencies of convex shorelines have also resulted in the long term in the creation of several exposed reefs especially on the southwest coast where beach material has been removed by currents over the years. These shorelines have had to be protected by the construction of revetments and in some places by groins.

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*Local words for "river".

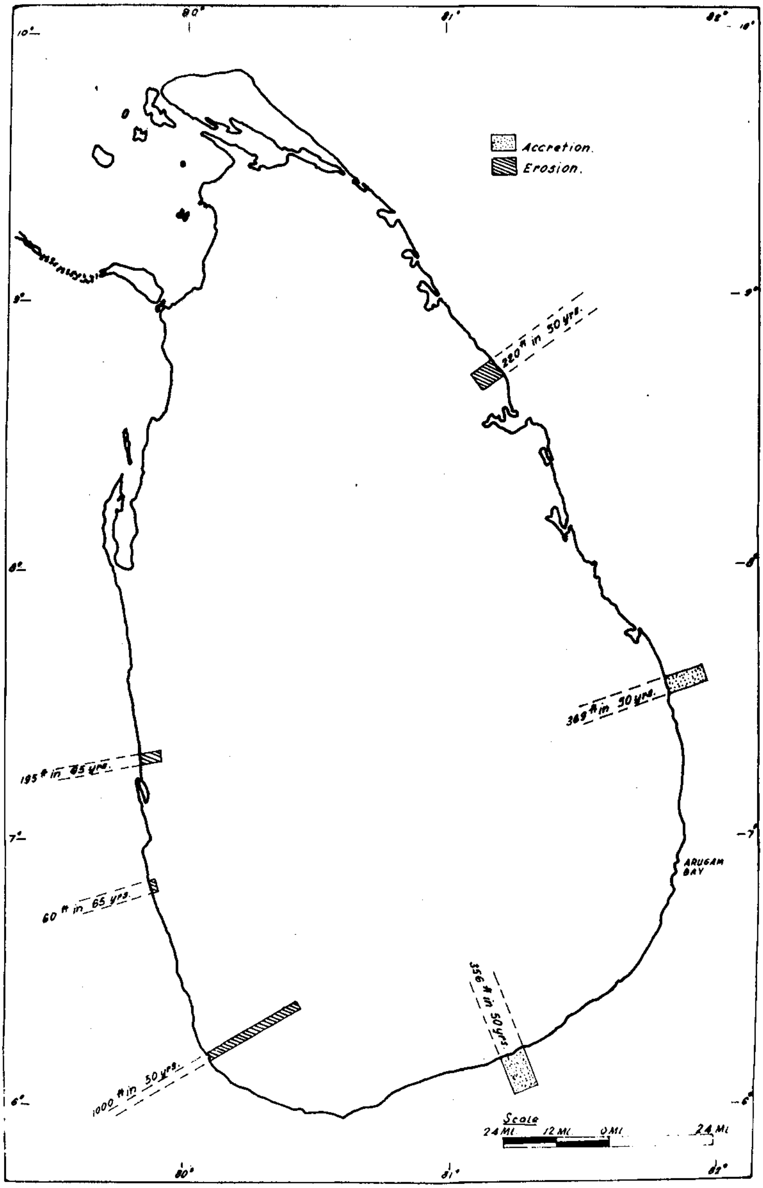

FIG. 4 TYPICAL SHORELINE CHANGES (rates of erosion or accretion) SINCE 1910

Another aspect of natural erosion is the cyclic changes of shorelines adjacent to tidal inlets. An example of the latter is the erosion pattern at the Kalutara inlet where the Kalu Ganga, which discharges the largest volume of water in Sri Lanka, has a fluctuating river mouth. Coast erosion of the adjacent shoreline occurs either on the north or south shores depending on the position of the inlets and the mechanism of the littoral drift in its vicinity. The inlet or river mouth is also called outfall because it allows the discharge of flood water into the ocean. Reference is made to the following section for further discussion.

The existence of a deep canyon or a deep harbor entrance traversing the coastline may act as a barrier to the littoral drift resulting in erosion of the downdrift shoreline. Such a barrier most likely exists in the entrance to Trincomalee Harbor on the east coast, where the predominantly northerly drift caused by the southern swell is interrupted by the over 100-fathom deep entrance to Trincomalee Harbor. Erosion of the shoreline to the north of Trincomalee as seen in Fig. 4 seems to be the result of this condition.

By far the largest contribution to problems of erosion and sedimentation of the island's shoreline has been made by the interference by man with the natural processes that occur in the coastal zone. Such activity in Sri Lanka has consisted of: (a) the legal and illegal mining of sand and coral from the coastal zone, the latter usually by the destruction of reefs; (b) construction of training works at outlets of rivers and streams for drainage purposes without adequate consideration of the consequences to the adjacent shoreline; (c) construction of fishery harbors to meet demands of national priorities without adequate investigation and study; and, (d) the construction of emergency protective works against sea erosion, such as groins and seawalls, to satisfy pressures resulting from the density of human habitation in the coastal zone and which in the long term have adverse consequences on adjacent coastal areas. The problem has been aggravated in recent years especially with the development of the tourist industry and the consequent demand for beach-oriented recreation areas. These and the siting of several activities conflicting with one another in coastal areas, with little concern for coast conservation, have led to the urgent need for coastal area planning. Examples of some of these problems are described later in this section.

The biological reason for erosion mentioned earlier is the destruction of some of the reefs in the Trincomalee area of the east coast by the coral eating starfish *(Acanthastar Planci)*. The starfish found abundantly in this region are since 1974 being collected and destroyed under a program executed by the Fisheries Department. In 1974 a team of six divers collected and buried about 24,000 starfish in a period of about three months. It has been suggested that a likely cause for the outburst of starfish attack since about 1972 is a direct consequence of the collection of tropical fish for export (an expanding activity in recent years), some of which are the natural predators of the starfish larvae. Investigations made by the Fisheries Department over the last two years have revealed that the presence of starfish is fortunately confined only to the Trincomalee region of the island's coastal waters giving rise to the hope that the present program of eliminating this menace would have successful results.

Coastal Inlet Problems

Kalutara Inlet

An excellent example of unplanned activity in a coastal area resulting in multiple-use conflicts is found at the outfall of the Kalu Ganga, one of the island's major rivers. Figure 5 shows five significant positions of the outfall between 1921 and 1976. In 1921 the outfall was at the northern extremity of the barrier beach and the lagoon had been enclosed by the sandbar to form a lake. Changes between 1921 and 1931 resulted in the re-opening of the lagoon and the migration of the outfall to the south combined with a seaward shift of the southern sandbar. The migration to the south continued until 1940 when the outfall was close to the southern extremity, at which stage the outfall was diverted back to the north by artificially opening up a channel close to the northern end. The migration to the south increased rapidly thereafter and the outfall shifted back to the southern end by 1943 where it remained until after 1954, when once more a northerly shift was affected by artificial means. From 1926 to 1940 the position of the outfall oscillated between north of mid-way to the northern end. It was during this period that severe erosion was experienced on the shoreline to the north of this area, necessitating the construction of a field of groins which was successful to arrest the local erosion. After 1940 the southerly migration commenced once more up to the present position of the outfall at a point south of the mid-way mark. This time, however, the effects were going to be disastrous as an entrepreneur had obtained a lease of the land on the southern sandbar from the Government Agent of Kalutara (the Chief Executive of the Government's district administration) in 1973, and with foreign collaboration had commenced the building of a 72-room hotel (to service the growing tourist industry), at an estimated cost of one million US dollars. He then found to his alarm that the outfall was migrating towards his hotel site and his land area was dwindling daily until in 1976 the distance of the outfall from the hotel had reduced to 410 feet. Based on a plan prepared by the Coast Conservation Division of the Colombo Port Commission, the entrepreneur undertook the construction of a combination of boulder groins and rubble revetments to hold the head of the southern spit from further recession and to train the outfall of the river at this point. The first phase of the project has been successfully completed and the immediate danger seems to have receded. These protective works are estimated to cost 50,000 US dollars, which is 5% of the main investment on the hotel. An interesting aspect of this problem was that in view of the heavy river discharge and the periodic flooding of low-lying land in the coastal zone upstream, the need to train the outfall was always under consideration by the Department of Irrigation (vested with the responsibility for inland waterways). The need for costly and time-consuming hydraulic studies and the absence of habitation and activity on the migrating sandbars presumably lent low priority to the study of this project. The lack of coastal area planning becomes apparent when considering the fact that neither the Department of Irrigation nor the Coast Conservation Division were consulted prior to the commencement of the hotel project either by the entrepreneur or the local approving the project. To complicate matters further, a fishery harbor consisting of a channel from the sea to the lagoon, its entrance protected by two breakwaters projecting to the sea complemented by an offshore breakwater parallel to the shoreline was proposed for construction at a point south of the hotel, with a view to using the lagoon for the mooring of craft. The obvious consequence of this proposal would have been downdrift beach erosion north of the breakwaters to additionally affect the hotel from the seaside. Even if the hotel project was not undertaken, it was clear that the fishery harbor proposal had to be studied together with the project of training the outfall and an investigation of the effect on the adjacent shoreline, in order to obtain a meaningful solution. Fortunately, action on the harbor proposal has been deferred pending further study. The total problem of the Kalutara inlet demonstrates so very well the need for and importance of integrated field and laboratory studies, as well as coastal zone management.

Panadura Inlet

The Panadura outfall (Fig. 6) drains the waters of a large inland lake bordered by several acres of cultivated paddy land. The runoff being low during the non-monsoonal period on the west coast (i.e. from October to April), the outfall tended to close up with the formation of a sandbar as the tidal prism is insufficient to keep it open by means of tidal flushing. The consequence of this situation was the destruction of vast tracts of paddy land by flooding, usually at the commencement of the monsoonal rains. It was usual to open the sandbar by mechanical means to drain the flood waters, but this was too late to prevent the damage. The Department of Irrigation therefore constructed a groin or jetty on the south bank of the outfall to train the waters to keep the outlet always open by means of tidal flushing. This project was completed a few years ago and has successfully achieved the objective of a permanently open outfall. In addition, this has facilitated the navigation of fishing boats to mooring areas within the river throughout the year; a boon to dwellers of this area engaged in the fishing industry. An adverse consequence of this project, however, has been the severe erosion of the shoreline to the north caused by a partial interruption of the littoral drift (despite the beneficial effect on a "clair voie", an opening in the updrift jetty, that promotes sand bypassing to the downdrift coast) and a change in the littoral drift gradient along the downdrift coast. The Coast Conservation Division has since been engaged in the construction of protective works in the affected area utilizing its own funds. Artificial nourishment would provide an attractive solution in this case, dredging sand deposits from the inlet and from the lagoon and pumping these to the downdrift shore. A small dredge suitable for this work is presently available in Sri Lanka. The outfall scheme had obviously not taken into account the problem of this consequence when studies for the outfall design were carried out--another example of poor coastal area planning. The economic evaluation of the original project needs then to be reviewed to accommodate the additional cost of the coast protective works. Several problems of a similar nature exist, while the construction of several outfall works schemes around the island are envisaged. It is hoped that this short fall in planning would be recognized and corrected in the design of future works.

Fishery Harbors

As an example of a coastal fishery harbor, the harbor at Tangalle will be discussed (Photo. 4). Tangalle is a seaside town, 22 miles east of the southern tip of the island; it has an expanding fishing industry, therefore, the site was chosen for the construction of a fishery harbor in 1964, as one of the first of a network of such harbors planned for the development of the island's fishing industry. Local pressures compelled the government to direct the immediate construction of this harbor precluding the apparent luxury of time-consuming pre-design studies. Based on a hydrographic survey chart, the layout was planned to consist of a main breakwater parallel to the shoreline partially enclosing the bay and a second minor breakwater at right angles to the shoreline and within the shadow of the main breakwater. Adequate depths existed in the bay to accommodate the class of craft catered for and the need for dredging was minimal. The usually closed outfall of an apparently small stream (but with an appreciable sediment carrying capacity during heavy rainfall), was presumably ignored as inconsequential during the short time available for planning and design, and the design seemed to lay stress on protection of the harbor from wave attack only. There was, in addition, a littoral drift from east to west during the northeast monsoon to be reckoned with. The result of the construction (the main breakwater first) was the rapid silting-up of the harbor even while construction was progressing. A quick solution was necessary and it was decided to block the littoral drift and divert the river discharge by the construction of another breakwater normal to the shoreline on the west bank of the outfall. Providentially, success was immediate, when in addition to overcoming the sediment problem, a beach built itself up between the breakwaters normal to the shoreline, and this proved to be an excellent spending beach for the dissipation of wave energy. Dredging of the harbor has since been undertaken in a reduced water area as shore structures have been built in areas reclaimed by the unexpected siltation. The almost ideal layout of the harbor as it now stands, achieved by accident, has entailed considerable additional expenditure. The importance of pre-design study has now been realized by those concerned as an essential ingredient in the economy of coastal engineering structures.

Coral and Sand Mining in the Coastal Zone

This activity although illegal for most areas has been carried out in particular areas for several decades and the consequences of which are now proving to be serious especially in areas with strong tendencies for natural erosion, e.g. the southwest coast of Sri Lanka.

Coral mining (providing lime for the building industry) has been concentrated within a coastal area about 22 miles north of Galle on the west coast. Coral is obtained by breaking the reef with sharp instruments and by digging in the nearshore and low-lying coastal areas. The excavated material is then burnt in neighborhood kilns and the extracted lime (calcium oxide) is supplied by the producer to the building industry usually through middlemen. It has been estimated that the quantity of coral removed from this area exceeds 75,000 tons per year. This in turn represents a retreat inland of the affected 6-mile stretch of shoreline of about 6 ft per year, only taking into account the sand required to fill in the gaps, while the effect of weakening the protective function of the coral reef and the removal of coral from the littoral drift will be additional in the occurrence of erosion. It has been further estimated that about 20,000 people in this area are dependent on this illegal activity for their livelihood. While existing legislation is weak and new legislation has been prepared, solution of the socio-economic problem is primary in eliminating this destructive activity. As a large percentage of lime for the building industry is supplied from this area, alternative sources of this material have been proposed to meet the demand when coral mining activity in the coastal zone is terminated.

Sand mining, mostly illegal, is also carried out extensively in the coastal zone, especially at the Kelani river outfall, the Kalutara inlet, and south of the Panadura outfall on the west coast. The total quantity mined from these areas would exceed 325,000 cubic yards per year, while legal mining at Pulmoddai on the northeast coast by the State Mineral Sands Corporation for extraction of ilmenite, rutile and zircon, accounts for about 200,000 cubic yards per year in a three mile stretch of foreshore and backshore areas. The consequences of the latter operation will need to be considered in the economic evaluation of the mineral extraction project. The new legislation provides for the control of sand mining in the coastal zone and as before alternative sources have been proposed to meet the commercial demand for sand.

POTENTIAL OF SRI LANKA BEACHES FOR RECREATION

Sri Lanka possesses a number of beautiful beaches and an attractive climate for vacationing. The temperature of the water of the ocean varies between narrow boundaries and is therefore attractive for swimming. Calm sea conditions and gently sloping beaches are present on the west coast during the northeast monsoon and similarly on the east coast during the southwest monsoon. Beach-oriented resort development has taken place in Bentota and Negombo on the west coast, and Kalkudah and just north of Trincomalee on the east coast. The better beaches are found on the east coast where many of them are yet unspoiled by man in the sparsely populated areas where access is hindered by low-key communication development. Arugam Bay on the east coast and the region between Galle and Matara on the southwest coast are other beach recreational areas gaining in popularity in recent years.

Resort developers have sought the assistance of the Coast Conservation Division for the provision of safe bathing areas during the monsoonal period of such areas and for neighborhood beach development. In many such cases, studies are to be undertaken for optimum solutions to be determined, while the topography of some areas have lent themselves to evolving solutions both economical and unusual. An example of the latter is the building of a "sea-pool", where only a narrow beach exists at present on a sandstone reef which drops sharply into the sea making any attempt at swimming a hazardous exercise. A bathing enclosure was therefore excavated by blasting an area 150 x 50 ft out of the sandstone ledge (leaving adequate seaside cover for coast protection) and removing a 6-8 ft layer of sandstone down to the sand base below, which provides bathing depths up to about 8 ft. Sea water enters the pool through a natural inlet at one end and wave attack (when present), is controlled by artificially placed boulder protection on the seaside edge of the sandstone ledge.

PLANNING GUIDELINES PROPOSED

Interest shown by those concerned in the conservation of the country's coast led to the development of a United Nations project in 1974 for the solution of Sri Lanka's coastal problems. The expert's recommendations include the establishment of a Coastal Engineering Research Center to be located within a separate administrative organization for Coast Conservation, along with training of local personnel and curricula development in Coastal Engineering at the University of Ceylong, as the main features of the Program. Complementarily, new legislation titled "Coast Conservation" was prepared and is now awaiting debate in the country's legislature.

The main provisions of this law are:

1. The appointment of a Director of Coast Conservation to be statutorily responsible for the control and management of the coastal zone and the permitting of all schemes of work therein.

2. The creation of a Coastal Advisory Council to advise the Minister in charge of the subject on matters concerning coast conservation.

3. The control of excavation of material within the coastal zone.

Major uses in the Coastal Zone of Sri Lanka that would need to be considered to define shore objectives are: recreation and aesthetic aspects; resource extraction; waste disposal; transportation; residential, commercial, and industrial development; and ecological aspects. After examining techniques for achieving the objectives, a coastal area management plan would be formulated for the purpose of implementation. Some of the studies considered immediately necessary for this Plan are:

1. Physical information of the coast to include an inventory of all maritime structures in Sri Lanka.

2. An estimate of annual mining of coral and sand and the corresponding demand of the building industry.

3. Alternative sources of sand and lime for the building industry.

4. A census of those engaged in illegal mining of coral and sand and the provision of alternative sources of employment.

5. A benefit/cost evaluation of maritime structures built for coast protection in Sri Lanka.

CONCLUSIONS AND RECOMMENDATIONS

1. The coastal zone is of increasing importance for Sri Lanka as a natural resource and deserves careful management and protection.

2. Coastal erosion is a serious threat to the beaches of the State, and particularly to the southwest coast, which is the area of highest population density. Three causes of erosion may be distinguished: natural erosion; man-made erosion; and erosion due to biological activity.

3. Among the adverse effects of the actions by men, most significant are the construction of ill-designed harbors and coastal protection works (seawalls and groins) and the mining of sand and coral from various coastal areas.

4. Solution of the various problems can only be found after a thorough understanding of the coastal processes is obtained. Such understanding may vary between the realization of possible adverse effects of a groin or groin system on the adjacent beaches and the complexities of the sediment transport mechanism in natural inlets or constructed outfalls.

5. The construction of seawalls too close to the waterline as a measure of coastal protection is usually ineffective; it possibly induces increased erosion. Measures to cope with bluff erosion should be tied in with a scheme to stabilize the beach.

6. The mining of sand or coral from eroding areas should be prohibited.

7. Schemes of new fishery harbors on the southwest coast should be based on the results of careful analysis of the sediment transport of the coastal regime. This will usually require both field and model studies prior to the design and construction.

8. For the study and planning of coastal measures the organization of a Coastal Engineering Research Center is recommended. Such a center will be charged with the field and model studies and will give guidance to the branches engaged in engineering design.

9. To solve the problems associated with the conflicting demands on the coastal zone the establishment of a Department of Coast Conservation is recommended under the Ministry of Shipping and Tourism with the power to define priorities and prepare new legislation.

10. For the staffing on the new research center it will be necessary to establish educational programs in coastal engineering at the various campuses of the University of Sri Lanka. The educational aspects will also include training of coastal engineers abroad.

PHOTO 1 SEVERE EROSION ON SOUTHWEST COAST DUE TO COMBINED EFFECTS OF NATURAL CAUSES AND CORAL MINING. NOTE THE REMOVAL OF EXPOSED CORAL.

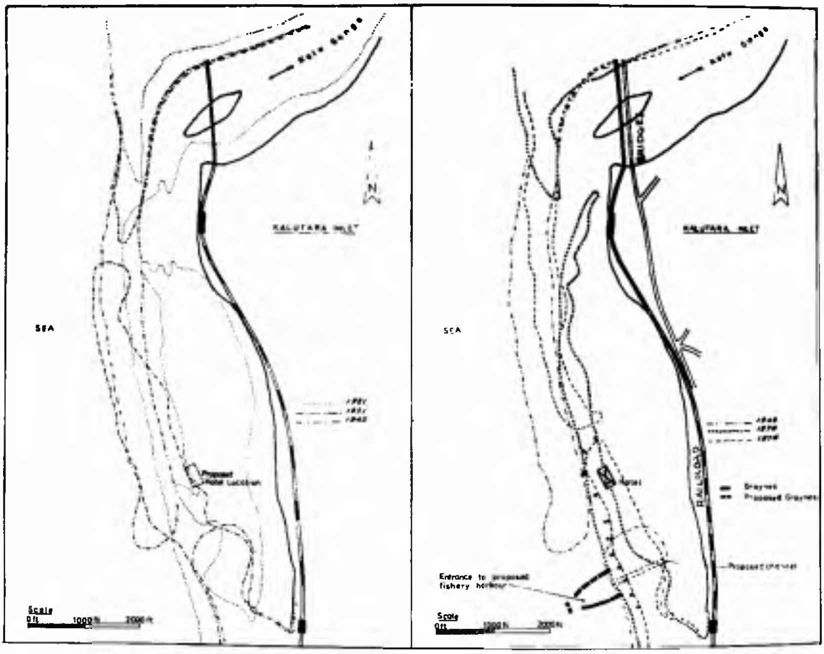

FIG. 5 MIGRATION OF UNIMPROVED INLET AT KALUTARA

PHOTO 2 KALUTARA INLET

PHOTO 3 PANADURA INLET

PHOTO 4 TANGALLE FISHERY HARBOR

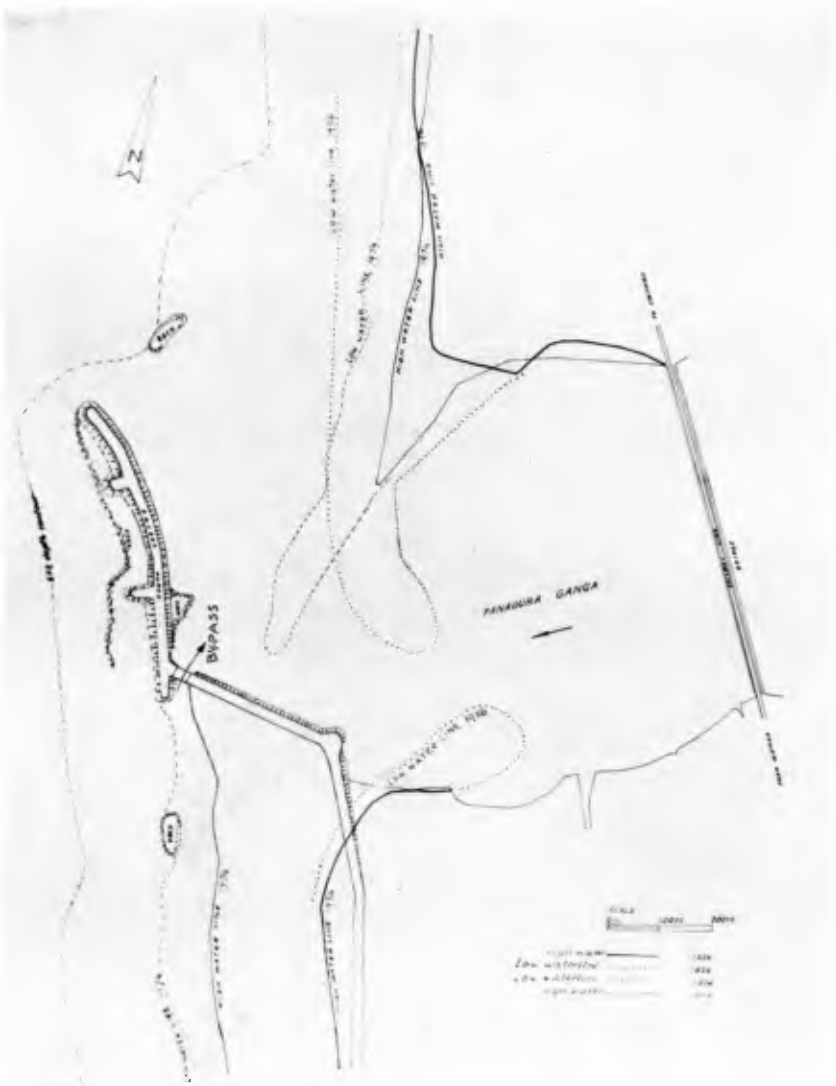

FIG. 6 PANADURA INLET SHORELINE CHANGES CONSEQUENT TO INLET TRAINING WORKS TO AVOID CLOSURE OF RIVER MOUTH FOR UPSTREAM FLOOD PROTECTION PURPOSES.

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