02 Coastal Erosion

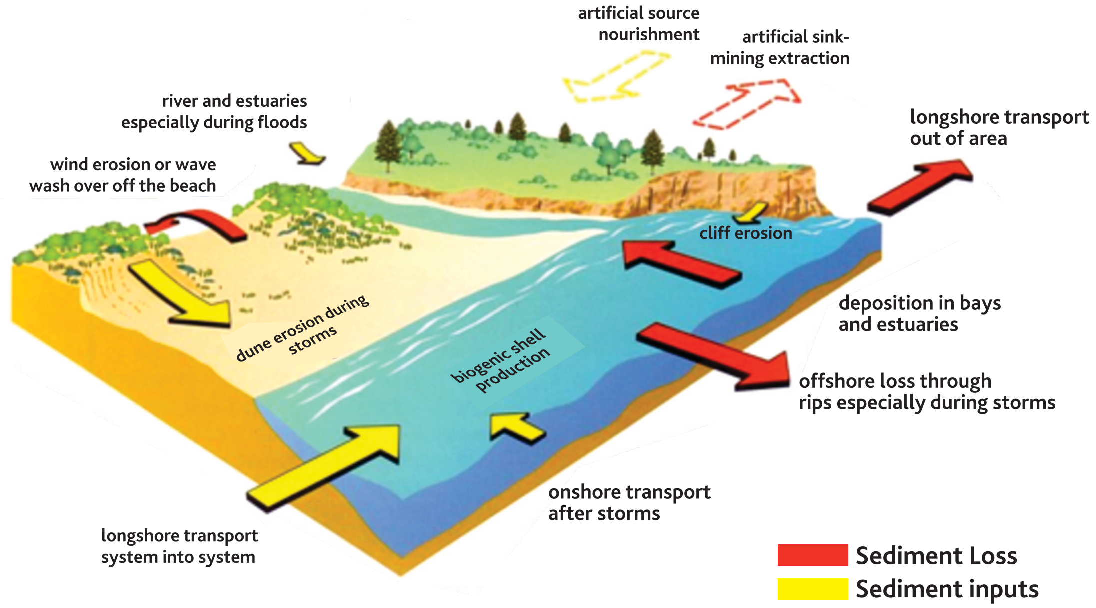
2.0 Coastal Erosion

2.1 Background

Coastal regions of Sri Lanka are greatly influenced by the island's location in the Indian Ocean. The island is surrounded by complex land-ocean systems, with interactive elements having dynamic relationships which determine the behavior of the coastal nature. Coastal forms and shapes are governed by the natural phenomena, which correlate the ocean systems as well as vigorous sediment supplies from land, particularly in the form of river alluvial.

2.1.1 Coastal Hydrodynamics

The ocean systems are featured with frequencies and seasons of hydrodynamics, varying from seconds, to hours, to months to years. Hence the temporal variability of coastal dynamics is mainly governed by the temporal distribution of the coastal hydrodynamics. In the tropics, monsoon seasons are active with the influences of Indian Ocean Dipole. The two monsoons namely Southwest & Northeast cause generation of ocean waves, resulting dynamic behaviors in the coastal areas around the Island. Due to the high energies prevailed in the southwest monsoonal waves, than the northeast, severe dynamics are observed in the coastal regions of southern, south-western and western. The waves act over the sea water level



Coastal Sediment (Sand)

Fig 2.1 Coastal Sediment Inputs and Losses Newman, Steven. "Ecosystems at Risk", http://www.mrstevennewman.com/geo/Stockton/Biophysical_Interactions/Main.htm

oscillations are due to tides, which are Cycles of cycles in nature. There are many local, regional and global, reasons for the dynamics of Indian Oceanic hydrology.

2.1.2 Coastal Sediment Balance

The shoreline stability is determined by the sediment budget of the coastal area. Positive net sediment balance always results stable accreting beaches, and negative net sediment balance results erosion. The sediment budget is balanced with sediment supplies and losses in natural and anthropogenic means. The basic means of sediment supplies and losses are illustrated in Fig 2.1. In Sri Lanka almost all the coastal areas are fed by river supplies. The supplied sediment is distributed, and coastal shapes are formed by the local hydrodynamics. Since the hydrodynamics in the coastal areas are with variable frequencies and intensities, sediment balance at the extreme dynamic conditions establishes the coastal stability. The shoreline instabilities create momentous impacts on physical, social-economic and environmental features in the coastal zone. Diagram of sediment budget is shown in Fig 2.2.

2.1.3 Coastal Geography & Units

Coastal areas are characterized with geomorphologic features, and are differentiated to local units. The natural coastal unit boundaries are generally

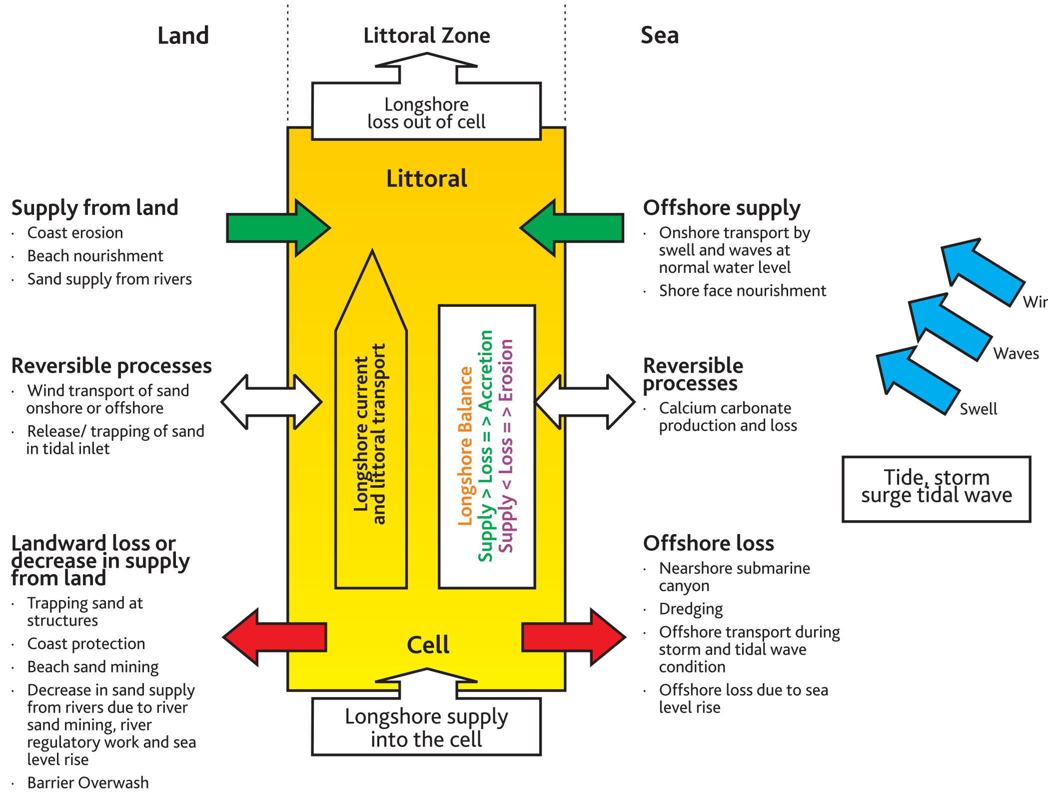


Fig 2.2 Diagram of Coastal Sediment Budget Coastalwiki

featured with rocky outcrops, or river or lagoon outlets. However there are few instances, where the unit boundaries are defined by human actions such as Ports & Habours projected to sea. Even though the coastal units are physically enclosed, some of the long-term coastal processes are continued along the shores.

The higher the degree of continuity exists within the subunits, where the major units are subset to minor units by minor features. The forms and shapes of the units are derived by the driving forces, such as energies and directions of waves, temporal variations of sediment budgets and geographical characteristics of units.

2.1.4 Significance of Coastal Regions

As an island nation the coastal regions play a vital role in the country's economy. As per the Analysis of Economic Significance of Coastal Regions (AESCR) done in 2006 by the Coast Conservation Department (CCD), Sri Lanka, it has found that more than 44% of the National Gross Domestic Production (GDP) has been generated in the coastal regions. Fisheries & coastal tourism have become the dominant economic activities widely spread along the coastal belt, but the tourism activities are more clustered into the favourable areas. Further it is estimated that about 25% of the

population of the country is settled on coastal lands, indicating significance of the coastal area. The inhabitants, in particular who live in rural areas, have social, cultural and livelihood values specifically linked to the coastal features.

The Vision of the Government of Sri Lanka (GOSL) has focused more towards the development activities based on Ocean and Coastal areas where admiring resources are available as an island nation. In the context of Coastal Resources Enhancement towards the increased contribution to national economy, the stabilities of shoreline has become utmost important. The major goals of Government in the coastal sector are the mitigation of the coastal erosion vulnerabilities, enhance the status of the coastal environment and biodiversity, creating opportunities with added values for coastal resources, promoting & facilitating coast specific investments and improving the livelihood of the local people in coastal areas.

2.1.5 Causative Factors Coastal Erosion & Accretion

The erosion and accretion are resultant of natural coastal processes, which take place over the time scale. The coastal erosions are generally varied from catastrophic events to chronic events. Erosions due to the regular waves of monsoons are much likely to cause the chronic (long-term) hazard. There are catastrophic (short-term) erosion incidents, which are due to the storms and tsunamis etc. Macro-scale events are also active with the glaciations cycles that may significantly alter sea levels, and also tectonic activities that cause coastal land subsidence.

Human-induced erosions occur due to extraction of sand and corals from the coastal areas and improperly cited maritime structures. The erosion shall become worse whenever the ill-planned countermeasures are applied. If the entire sediment unit is not considered in the solution, the erosion will transfer to the adjacent shores.

Coastal areas are accreted in places, where adequate sand supplies exist with accretion supported hydrodynamic conditions. Coastal areas with natural or artificial geomorphologic conditions, which provide enough shelter, breaking the high wave energies, are favourable for accretions. Even though the accretion provide land for the Island, it would create erosion in the down-shore due to insufficient sand supplies for the alongshore transport. Rapid accretions will definitely result erosion in the down-shore. In stabilizing the shorelines, coastal structures are constructed accumulating sediment within the scheme to the required level. But generally the schemes are nourished with important sand at the initial stage to overcome the down-shore erosion.

2.2 Scope of the Study

The Coastal Erosion Hazard Assessment & Mapping have explored the spatial and temporal distributions of the erosion hazard around the entire country. The erosions due to catastrophic event such as tsunamis and cyclone induced storms have not been considered in the assessment. Considering the uncertainties of the sediment dynamics, the assessment was based on logical approach, which the results are essentially qualitative rather than quantitative. The degree of erosion is ranked in to three categories of Low, Medium and High. The erosion hazard levels determined are on reference scale and not the absolute.

The erosion hazard profile is detailed with the Coastal Erosion Status in timescale of known history to the forecasts of susceptibility. The degree of hazard has been displayed linearly on maps of scale 1: 50,000 on the standard map tiles of Survey Department. The island coastline is covered by 52 Numbers of map tiles. These maps will be published in DMC web site (www.dmc.gov.lk).

2.3 Methodology

In the absence of a developed state-of-art-model for erosion hazard assessment, tailored methodology has been developed with the fuzzy logical approach. There are high end tools that could be used in the assessment, but due to the lack of long-term data collected for the past period, the alternative approach was adopted. The Subject of Coastal Engineering is being practiced in Sri Lanka for last 30 years for the mitigation of coastal erosion and stabilization of the shorelines. The local expertise developed since then was an advantage for the erosion assessment and the experts' judgments were highly accommodated within the model. However the major parameters were implicitly deemed into the model.

2.3.1 Coastal Sediment Cells

In Sri Lanka, the majority of coastal sediments are fed by the rivers. The command shores of each river are clearly identified by long-term observations. With the existence of coastal geophysical characters such as rocky headlands and river outlets etc, the shorelines have been featured into sediment cells (Fig 2.3), where the seasonal sediment stability is reasonably autonomous. However it does not mean that the inter cells sediment movements are discontinued. The long-term sediment stabilities are uncertain too. Considering the degree of inter cells sediment movement array, sediment cells are categorized into major and minor cells.

The identifications of the cells were done by the frozen geographic characters along the shoreline. The major cell boundaries have been identified by the frozen visible projections on 1: 250,000 maps, and the minor cell on 1: 25,000 maps. The assessments were made locally on the sediment cell approach.

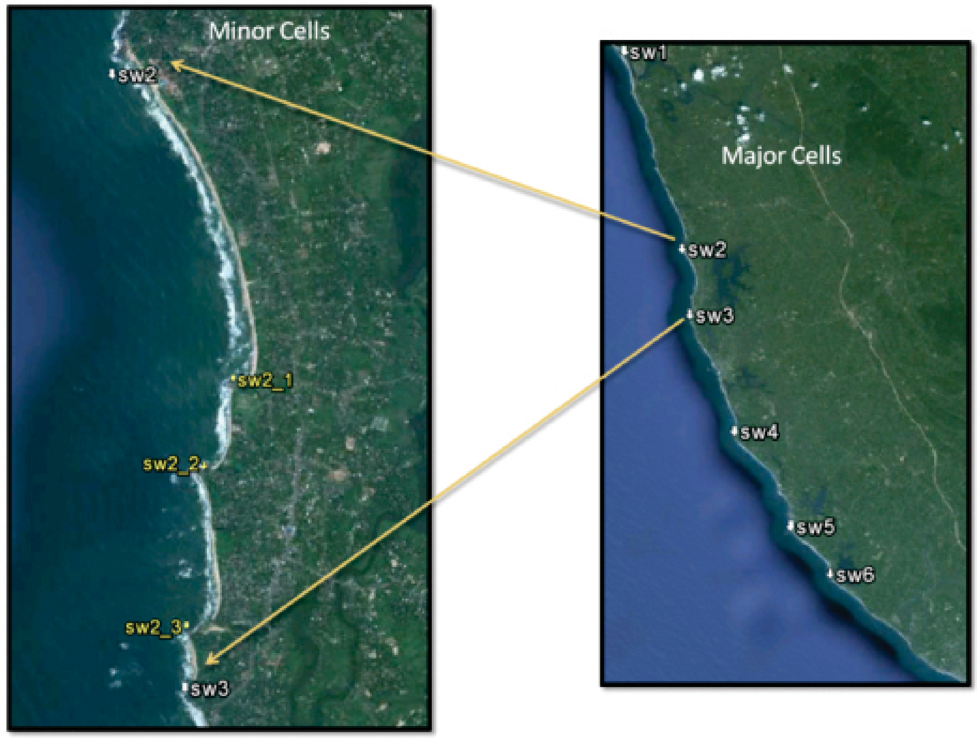


Fig 2.3 Coastal Sediment Cells (Major and Minor) in Southwest Coastal Region

Fig 2.4 Wave Incident Angle

2.3.2 Driver Analysis

There are many factors to be considered in the erosion hazard assessment. Hydrodynamic features such as waves, tides and currents; geomorphologic features such as bathymetry, shore alignments, beach profiles etc; anthropogenic stresses such as near-shore marine structures, sand mining, coral mining, maintenance dredging of navigation channel etc, etc are some of the factors for erosion. However for avoiding the complexity of the erosion assessment model, only three drivers of wave incident namely; the angle, sediment balance and shoreline geometry were considered.

Wave Incident Angle

The shorelines are aligned to diverse directions depending on the locality. The directions shall be measured as the bearing of the shoreline, i.e. the angle of the shoreline to the true north. In nature, the wave directions are also varied in 360°. The wave incident angle is defined as the angle between the wave direction and shore normal at the shore, as shown in the Fig 2.4. Fig 2.5 Incident Angle vs Sediment Transport Rate (Source: Fittschen, et al 1992, Sediment Transport Study for the Sothwest Coast of Sri Lanka) For both wind and swell waves, the predominant wave directions were identified for each wave zones. Varying with the cell geometry, the bearing of the shore and then the wave incident angles were determined (Fig 2.5). When the waves hit the finite shore elements, directional variations of incident angle are limited to 180°. Since the alongshore sediment movement is a function of incident angle, degree of sediment transport rate is indicated by the incident angle. Fig 2.5 shows the distribution of sediment transport rate vs. the incident angles, computed using different formulas. Higher the rates are in the middle angles.

Sediment Balance

As detailed in the background, the sediment balance is a critical driver for

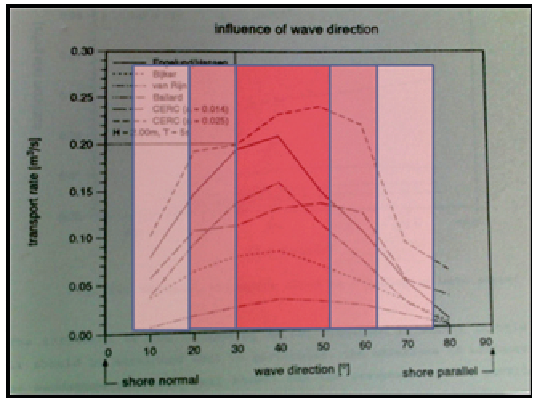


Fig 2.5 Incident Angle vs Sediment Transport Rate (Source: Fittschen, et al 1992, Sediment Transport Study for the Sothwest Coast of Sri Lanka)

coastal erosion. The sediment balance shall be assessed in short and long term. The short-term sediment balances depend on the seasonal dynamics, and the long-term balances are due to the trends of sediment sources and losses. Since the majority of the sediments are supplied by rivers, the long-term sediment trends depend on the upstream catchment activities.

Hence the major sediment trends in the coastal cells are directly or indirectly human induced. Further the onshore sediment movements are naturally governed by the hydrodynamics of the area, but the near-shore manned developments alter the natural coastal processes and patterns altering the long-term sediment balance. Hence in order to consider the long-term sediment trends any natural and most of the anthropogenic factors were included.

Trends of onshore sediment volumes were analyzed using aerial photographs captured in 1956 and satellite images in

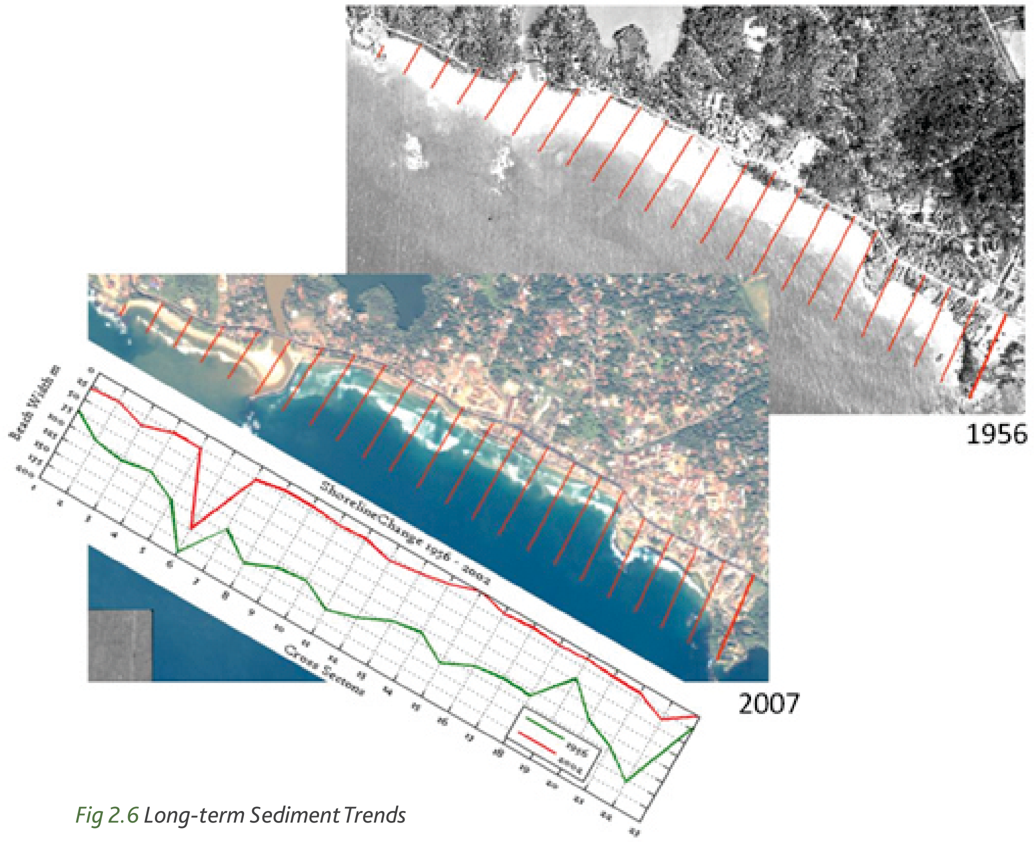


Fig 2.6 Long-term Sediment Trends

2007 (Fig 2.6). Since the seasonal wave climates remain in the similar patterns, resulting unchanged mean slopes of the shores, it was reasonably assumed that the beach volumes are more or less proportionate to the beach areas. Therefore the beach areas shown on the images were extracted and analyzed. The 50 years trend and the rates of change of sediment balance were determined. The trends were forecasted estimating the degree of shoreline stability confined to the time spans.

Shoreline Geometry

The shoreline geometry of sediment cells are characterized by the local hydrodynamics, geomorphology and sediment budget. The fixed boundaries of the sediment cell will determine the alongshore length of the cell, while the offset shape is governed by the hydrodynamics and sediment balance (Fig 2.7). If the natural shapes are allowed, the shoreline might take the stable shape in medium term, but with seasonal changes. Until shape arrives at stable state, erosion shall be taken place, deepening the offset. In general the maximum offset will be a function of the length of the cell. In the erosion assessment, the shape is simply analyzed considering only the length of cell.

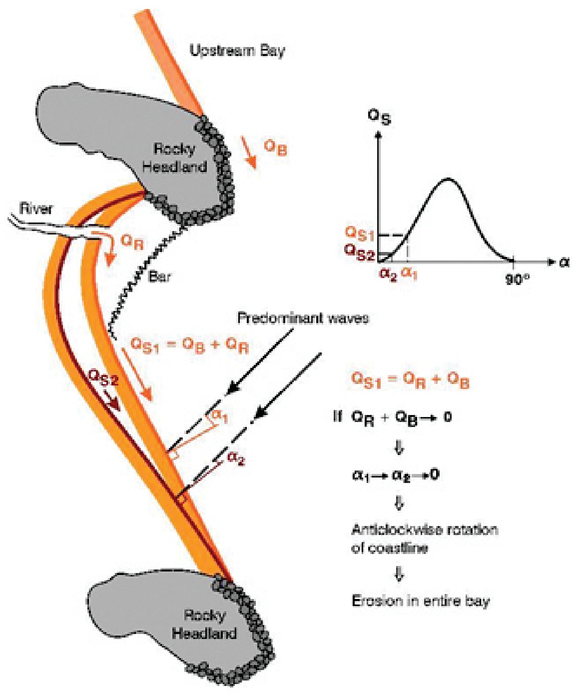


Fig 2.7 Shoreline Geometry Coastalwiki

Fig 2.8 Distribution of Erosion Control Structure in Southwest Coastal cells

2.3.3 Coping Capacity

For the last few decades, many coast protection schemes have been implemented for the control of coastal erosion. All of the schemes are of hard structures, which stand for longer lifespan. These coastal defense structures have reduced the susceptibility of the erosion hazard by increasing the coping capacities. Hence the distribution of coast protection structures (Fig 2.8) was considered in the erosion hazard assessment. The coverage of cells by structures is varied. Some cells are entirely covered, while some others are untouched. The degrees of cell coverage by the structures were used in the assessment.

2.3.4 Significance of Drivers

The three drivers, considered in the hazard assessment, shall have differentiated significances on the coastal erosion, due to the integrity and temporal & spatial resolutions of data, uncertainties and assumptions made etc.

In evaluation of those factors, with experts' judgments, driver weightings were assigned for normalizing the different significances. In determining the comparative significances of sediment cells, the cumulative normalized significances of drivers were evaluated.

Since the coping capacities reduce the susceptibility of erosion, the cumulative normalized significances were divided by the degree of coping capacities in each cell. The degree of hazard, on the Island's reference scale, were then determined.

2.3.5 Verification of the Results

In validation of the model, the results were verified by following three indicators. The verifications were done with the degrees of individual drivers and also with the cumulative normalized significances.

1. Degree of past erosion incidents

In the absence of erosion incident inventory, indirect mode of indicator was used in determining the erosion incidents. As per the past practice in the country, the coast protections were done as a post action against erosion. Hence each and every structure represents an erosion incident occurred in the past.

2. Length averaged annual rate of erosion or accretion

The change of the coastline is considered as the coastal erosion. In most of the cases, the erosions are controlled at the inception by means of temporary measures followed by permanent solutions. However it can be observed that there are coastline changes for the past period.

3. Rate of length averaged normalised percentage of sediment loss or gain

Even though the coastal erosion is commonly known as coastline erosion, theoretically the beach erosion is considered as the setting up of erosion. It shall be measured by means of the permanent loss of sediment from the system.

All the above indicative measures were applied in coastal sediment cell approach.

2.4 Erosion Hazard Profile

The coastal erosion is one of the major chronic hazards prevailing in the country, mainly due to the human induced acceleration. Many erosion hotspots are in the western, south-western and southern coasts, but few cases are even in the eastern, north-eastern and northern coasts. As a result annually a large number of public and private properties have been damaged or under threat. Fishing, tourism and critical services have been disrupted. In addition large number of dwellers was displaced. Annually, millions of Rupees have been spent for the coastal protections. Approximately SL Rs. 1,520 millions have been spent on erosion control within the period of 1985 to 1999. More than SLRs 4 billion has been spent for the period of 2000 – 2006. In 2012 nearly SLRs one billion worth of projects have been planned.

CHAPTER 02

Though the coastal erosion dates back to many centuries, only a few literature have been found on the status of the coastal erosion. In the past, a study on the coastal geomorphology of the country has been done by Bernard Swan (1983). Status of segments of coastlines around the entire country was evaluated and reported as "An Introduction to the Coastal Geomorphology of Sri Lanka".

2.4.1 Master Plan for Coastal Erosion Management 1986

In 1986 the first coastal erosion assessment has been done by the Coast Conservation Department and reported as the "Master Plan for Coastal Erosion Management" (MPCEM). As per the MPCEM, 15 key areas and 11 singular sites have identified as localized areas with erosion threat (Fig 2.9). Out of them 12 key areas and 7 singular sites are in the western, south-western and southern coastal stretches where erosions were most severe.

Other sites are distributed in northern, north-eastern and eastern coasts. Although erosion was not a major problem in the northern and eastern coastal areas, certain coastal pockets had been identified with observed significant impacts. The distributions of those sites in districts are as follows.

- Trincomalee District – Sirimapura, Salpearu and Mutur
- Batticaloa (including Ampara) District – Kalmunai, Palaimeenmadu, and Oluvil
- Mannar District – Vankalai and Arippu
- Jaffna District – Wadamarachchi and Munnai

Further in the MPCEM, the erosion and accretion rates at local coastal segments have been estimated through experts' judgments, and replies to inquires made for general public. The Fig 2.10 shows erosion rate distribution around the country for 25 years from 1961-1986.

As a follow up coast protection and stabilization measures have been implemented with the Danish International Development Agency (DANIDA) project in 1986 – 1989. Most of the identified areas in the MPCEM have been protected by the DANIDA project, but mostly with hard solutions. The first sand nourishment project of the country has been done under the DANIDA project in Entomb.

With the completion of DANIDA project, Coastal Resource Management Project (CRMP) with the coastal stabilization component for SLRs 4 billion has been completed in year from 2000 – 2006 with the major funding component from Asian Development Bank (ADB). Under the project seven critical coastal stretches in southwest and west coast given in Table 2.1 have been stabilized As per the project appraisal, it has been reported that the highest erosion rates of 12 m/yr have been observed in Maha Oya –

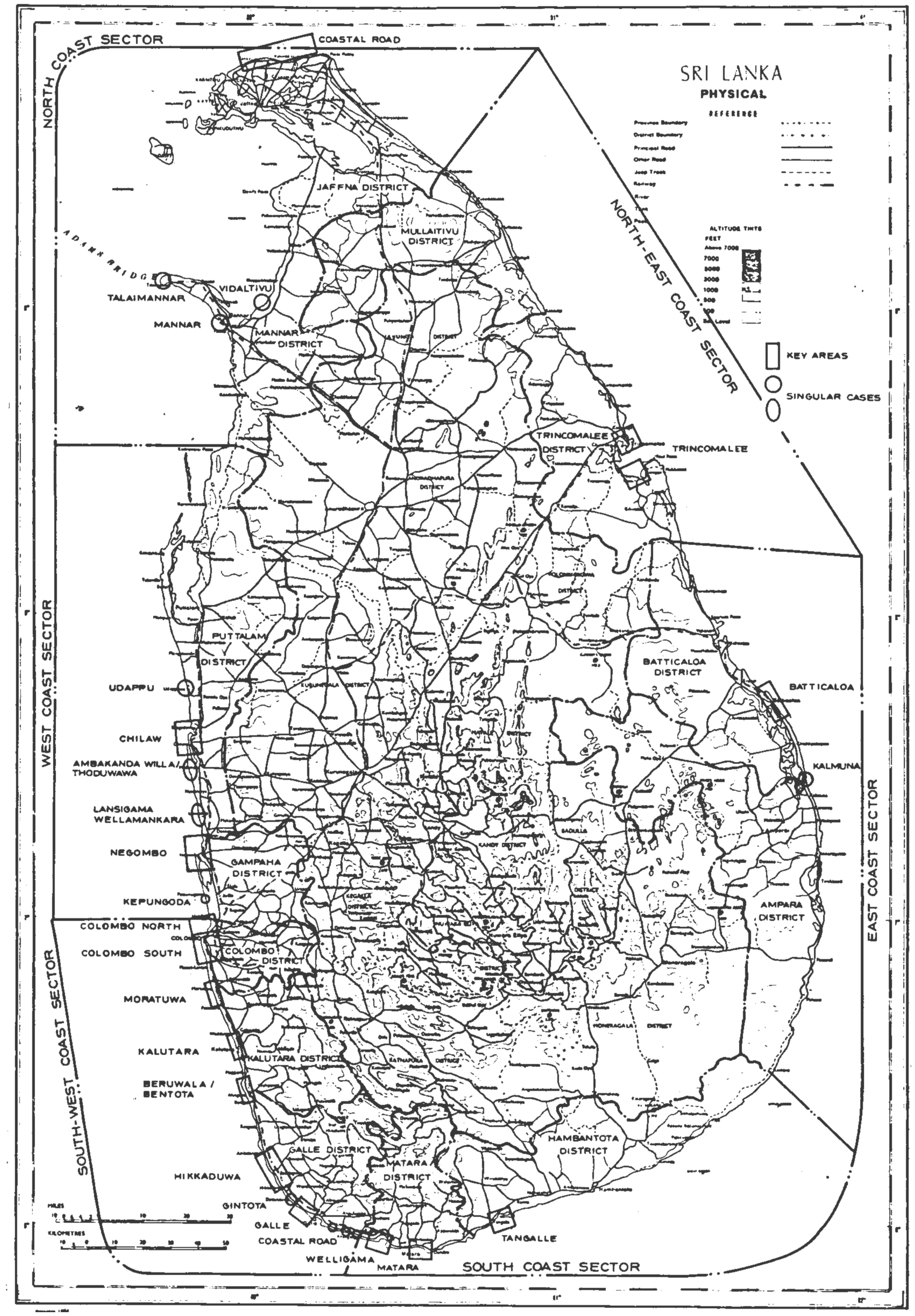


Fig 2.9 Distribution of Key Areas & Singular Cases in 1986
(Source: Coast Conservation Department, 1986, Master Plan for Coastal Erosion Management)

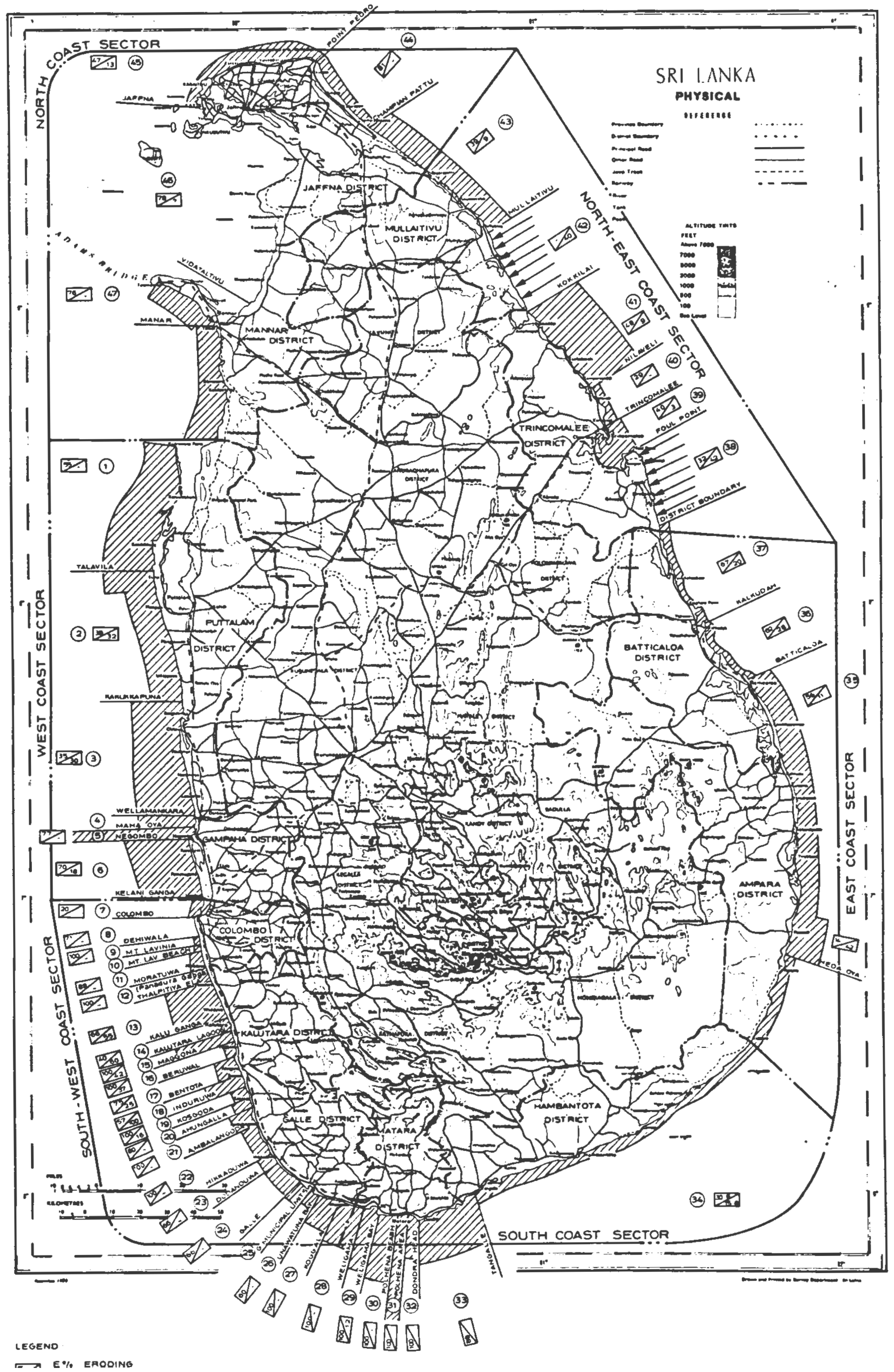


Fig 2.10 Coastal Changes in Around the Country for 1961 – 1986 Coast Conservation Department, 1986, Master Plan for Coastal Erosion Management

Table 2.1 Critical Coastal Stretches Stabilized under CRMP

Coastal Cell	Project Stretch	Length of Project/Cell	% Length of Cell
Negombo - Chilaw	Maha Oya - Lansigama	13 km / 46 km	28
Colombo Port - Negombo	Colombo North - Dikowita	6 km / 30 km	20
Beruwala – Colombo Port	Wadduwa	14 km / 55 km	
Beruwala – Colombo Port	Kalu Ganga - Maggona	8 km / 55 km	44
Beruwala – Colombo Port	Maratuwa - Koralawella	2 km / 55 km	
Beruwala – Kahawa	Beruwala - Bentota	km / 31 km	-
Kahawa – Galle Fort	Hikkaduwa	km / 26 km	-

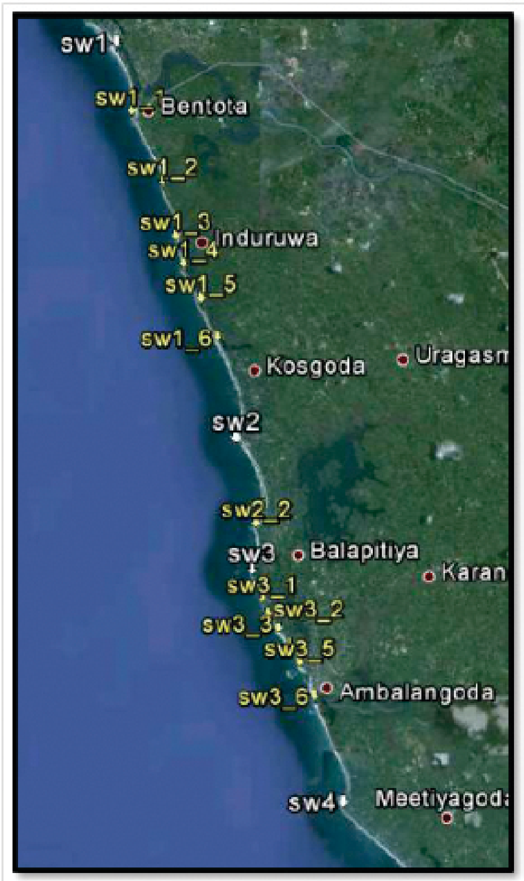


Fig 2.11.1 Major and Minor Sediment Cell Distribution in the southwest Coastal Region (Google earth)

Lansigama coastal stretch. As per MPCEM, of the 685 km of coastline in south, southwest and west coastal regions 45% has been identified as being subjected to erosion. The estimated land area loss is 200,000 – 300,000 m^2 /yr. in the other three coastal regions with 900 km of coastline, 35% has been subjected to erosion with the annual rate of land loss of about 150,000 - 200,000 m^2.

2.4.2 Coastal Erosion Assessment-2012

The coastal erosion hazard assessment is based on erosive driver analysis approach. The degrees of drivers were categorised in to four ranks. The ranks were assigned as per the severity and highest as assigned to the most severe category. The final ranks are High, Medium, Low and no erosion Since the coastal erosion incidents are now well controlled with emergency measures followed by permanent solutions, the coastal erosion rates are not much valid to describe in the erosion hazard assessment.

Through the current assessment, erosive forces prevailed on the shorelines were assessed. Degrees of erosive forces indicate the susceptibility to the erosion, meaning that if the corrective measures are not applied, there shall be erosion incidents as per the severity of rank.

Figure 2.11.2 Major and Minor Sediment Cell Distribution in the southwest Coastal Region (Google earth)

For the illustration of the assessment, erosive forces analysis in the southwest coastal region is described. The major and minor coastal sediment cell distribution is shown in Fig 2.11. The major sediment cells are the group of continued minor cells, which have the similar shoreline orientation (Bearing). Each cell is pocketed by rocky headlands on either side. The shapes and orientations of major and minor cells are clearly visible at two distinctive scales of maps. The major cells were determined at the scale of 1: 250,000 and minor cells at 1: 25,000. The coastal cell lengths are varied form 0.5 km – 6.5 km while the bearings of the cells are varied from 2500 – 3600.

The predominant wave characteristics of southwest coastal region are given for both swell and sea waves.

Significant wave heights
Swell 1.17 m
Sea 1.58 m (May - September)
0.76 m (October – April)

Wave Directions
Swell 1870 Variance 130
Sea 2490 Variance 230 (May – Sept)
(Source; Scheffer, & Fernando, 1994)

Left - Driver Analysis & Right – Indicators for Verification

The Table 2.2 illustrates the analysis of the degrees of sensitivities of erosive drivers at the coastal sediment cells. The drivers of incident angle for swell and wind (Sea) waves, sediment trends and length of shoreline are ranked from 1 to 4 as per the significance. Depending on the reliability of data the drivers, the results shall be induced out of the equilibrium of the assessment. Hence the drivers are weighted considering their data reliability and also accommodating the experts' judgments.

Incident wave angle (weight factor 2)

– In determining the incident angles 5 years wave data have been analyzed.

Sediment Balance (weight factor 1)

– Only two images were used in extracting the sediment volumes.

Shoreline Length (weight factor 1.5)

– the exact geographic shape is only a function of the shoreline length.

Given the weightings, for normalizing the driver significances, cumulative normalized significances were determined. By proportionate reduction of the cumulative normalized significances for adopting the coping capacities in the assessment, final ranks of erosion hazard were derived.

For the graphical presentation of the degree of erosion hazard, map layer was prepared with geographical references. The degrees of hazards were shown with differentiated colour scheme as linear feature. Since the hazard assessments are

Table 2.2 Erosion Analytical Table Left - Driver Analysis & Right – Indicators for Verification

Analysis of Degrees of Driver Sesitivities										Verification Indicators				
Head Land		Incident Angle		Sedim ent	Shore Length	Cumul ative	Capaci ty	Final Rank		Beach Area		Coastline		Existing Protection
Node#1	Node#2	Wind	Swell							Decreased	Increased	Accretion	Erosion	
sw_1	sw_1.1	1	2	1	4	13	4	3	Low	5	0	0.85	0.00	1
sw_1.1	sw_1.2	1	3	1	3	14	4	3	Low	18	0	1.09	0.00	1
sw_1.2	sw_1.3	1	2	1	3	12	4	3	Low	8	0	0.60	0.00	1
sw_1.3	sw_1.4	1	3	1	2	12	4	3	Low	0	2	0.00	0.00	1
sw_1.4	sw_1.5	2	3	1	3	16	4	4	Low	13	0	0.00	0.00	1
sw_1.5	sw_1.6	1	3	3	3	16	4	4	Low	37	0	0.00	0.00	1
sw_1.6	sw_2	1	2	3	4	15	1	15	High	43	0	0.00	0.28	2
sw_2	sw_2.1	1	3	1	4	15	4	4	Low	35	0	0.32	0.00	1
sw_2.1	sw_2.2	2	1	1	2	10	4	3	No	4	0	0.00	0.00	1
sw_2.2	sw_2.3	2	1	1	3	12	4	3	Low	8	0	0.00	0.00	1
sw_2.3	sw_3	2	1	1	1	9	4	2	No	0	29	0.17	0.00	2
sw_3	sw_3.1	2	3	1	2	14	1	14	High	10	0	0.00	0.17	1
sw_3.1	sw_3.2	2	3	3	2	16	4	4	Low	0	5	0.00	0.00	1
sw_3.2	sw_3.3	2	4	1	2	16	4	4	Low	12	0	0.00	0.00	1
sw_3.3	sw_3.4	2	4	1	1	15	4	4	Low	7	0	0.00	0.00	1
sw_3.4	sw_3.5	2	3	1	2	14	4	4	Low	9	0	0.00	0.00	1
sw_3.5	sw_3.6	3	4	4	3	23	3	8	Medium	88	0	0.16	0.00	2
sw_3.6	sw_4	1	3	3	4	17	3	6	Low	48	0	0.01	0.00	4
sw_4	sw_4.1	3	4	1	4	21	3	7	Medium	11	0	0.00	0.19	4
sw_4.1	sw_5	1	2	4	4	16	2	8	Medium	57	0	0.00	0.28	4
sw_5	sw_6	4	4	1	4	23	3	8	Medium	18	0	0.17	0.00	4
sw_6	sw_6.1	4	3	4	4	24	4	6	Low	66	0	0.25	0.00	1
sw_6.1	sw_6.2	4	3	4	4	24	3	8	Medium	57	0	0.00	0.21	4
sw_6.2	sw_6.3	4	4	3	4	25	3	8	Medium	33	0	0.11	0.00	4
sw_6.3	sw_7	4	3	4	4	24	2	12	Medium	97	0	0.02	0.00	4
sw_7	sw_7.1	1	4	4	4	20	3	7	Medium	100	0	0.25	0.00	4
sw_7.1	sw_7.2	4	3	4	4	24	1	24	High	81	0	0.00	0.07	3
sw_7.2	sw_8	2	4	4	3	21	4	5	Low	0	0	0.00	0.00	1
sw_8	sw_8.1	1	3	2	3	15	3	5	Low	0	57	0.00	0.00	2
sw_8.1	sw_8.2	4	4	1	2	20	1	20	High	0	30	0.00	0.31	3
sw_8.2	sw_8.3	3	1	4	4	18	1	18	High	20	0	0.00	0.32	3
sw_8.3	sw_8.4	3	1	1	4	15	1	15	High	22	0	0.00	0.14	3
sw_8.4	sw_9	4	2	4	4	22	1	22	High	50	0	0.00	0.09	3

CHAPTER 02

coupled to multi hazard profile, the uniformity of the layer have been maintained.

The layer was overlaid on the topographic map of Survey Department of Sri Lanka at the scale of 1: 50,000. The coastal erosion hazard profile consists of 52 map tiles prepared for the entire country (Fig 2.12).

2.5 Conclusion & Recommendations

With the accelerated development in the coastal areas, the socio-economic activities should be secured from coastal erosion. Knowing the vulnerabilities for coastal erosion, appropriate remedial measures shall be adopted for the safety. The coastal erosion hazard assessment shall be used for many applications of erosion hazard management through adaptation to mitigation. The assessment shall be the base for preparing the coastal erosion risk profile. The coastal cells are very specific natural units which behave with both intra and inter dynamic relationships. Alternation of any element of the system within the cell would impact on the entire system within the cell, and with extended impacts to the adjacent cells too. Hence all activities shall be done on the coastal cell approach. The degree of erosion hazard in cells would be then much appropriate.

Given the illustrations in Table 2.2, it is clearly evidenced that the drivers used are much expressive of the erosion situations except the swell wave's incident angles. By comparing the erosion status expressed in the indicators, not only the independent driver ranks, but also the cumulative normalized erosion hazards rank, the situation which is much explored.

The maps shall be further improved by adopting quantitative figure into the model rather than qualitative inputs. Increasing the reliability of wave data, calibrations shall be done for the existing wave data accessing the available measurements around the country. However it is strongly recommended to establish a wave data measurement network around the country appropriately.

The sediment balances shall be estimated as a much accurate figure through site investigations and also using frequent aerial and space observations. Since the cell boundaries are fixed with geological features, the cell shapes are mainly governed by the sediment balance and local hydrodynamics. Even the hydrodynamics are with known seasonal cycles, the cell stabilities are purely tailored by the sediment balance. Hence the assessments of sediment balances shall be continually monitored. The coastal erosion hazard profile shall be used by policy makers, developers, administrators and coastal engineers for varying purposes. The setback system in the coastal zone shall be updated with the degree of erosion hazard.

CHAPTER 02

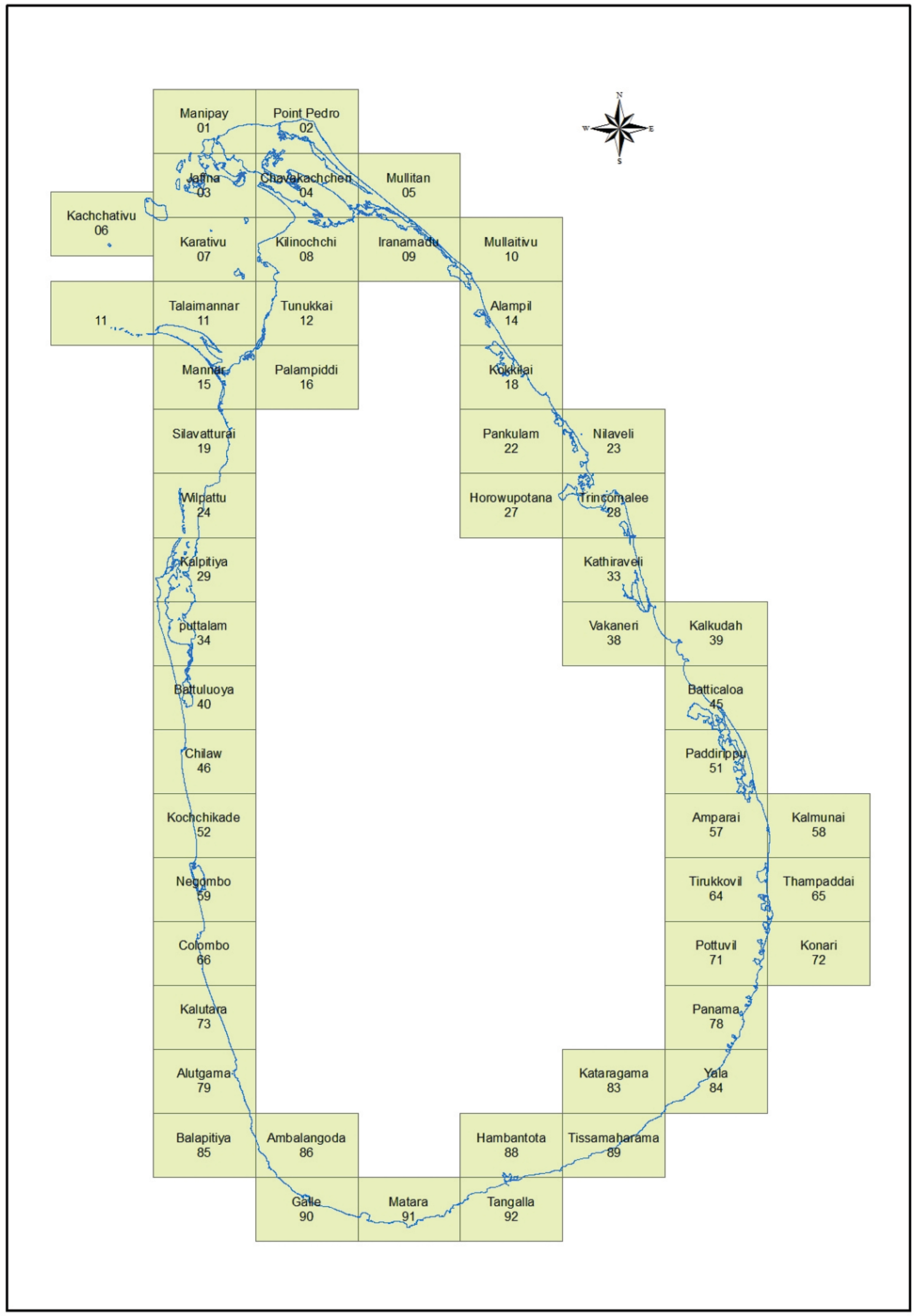


Fig 2.12- 52 Map Tiles along the coast line

2.6 Limitations

There are few issues on the accuracy of the assessment. It is a fact that the beach sediment volumes are seasonally varied. Since aerial and satellite images are used for extracting the shorelines, there might be a seasonal effect if the images are captured in different seasons.

But as per the capturing dates of the two images used in the assessment, both sets are captured within January to March. Hence the seasonal effects of the images are resolved.

Even the images are captured within the similar season; there might be an error due to the apparent erosion visible on the images by the tidal water level variations. As per the estimate, the error would be a maximum of 22%. Since the assessment done on qualitative approaches such errors shall be accommodated. Further in general the images shall be orthorectified for the altitude corrections. In the assessment, it is assumed that the error would be minimal due the the flat nature of the most of the coastal areas.

2.7 References

Coast Conservation Department, DANIDA-Danish Hydraulic Institute, (1986): Master Plan

Coastal Erosion Management, Volume 1, The Plan

Coast Conservation Department, (2004): Coastal Zone Management Plan Coastal Wiki [Internet], Available at: http://www.coastalwiki.org/

Fittschen, T., Perera, J.A.S.C., Scheffer, H.J., (1992): Sediment Transport Study for the South Coast of Sri Lanka: CCD-GTZ Coast Conservation Project

Newman, Steven. "Ecosystems at Risk", *Internet+ Available from: http://www.mrstevennewman.com/geo/Stockton/Biophysical_Interactions/Main.htm

Scheffer, H.J., Fernando, K.R.M.D., (1994): Directional Wave Climate Study for the Southwest Coast of Sri Lanka, CCD-GTZ Coast Conservation Project

Swan, B., (1983): An Introduction to the Coastal Geomorphology of Sri Lanka: A Publication of the National Museums of Sri Lanka