International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 8|| August 2017 || PP. 11-25

Natural Coastal Processes And Its Geo-Environmental Impact In The Area Between Chennai And Nagapattinam Coast Of Tamilnadu And Pondicherry

R. Srinivasan[1], V. Krishnan[2]R. Jayagopal[3]
[1]8/11, Third circular road, 1st cross,Jawahar Nagar, Chennai -600082(Research scholar PT, Presidency college, Chennai),[2]BharathiDasan colony road, K.K. Nagar, Chennai- 600078(Formerly GSI),[3]6th main road, Jawahar Nagar , Chennai- 600082(Formerly Presidency college, Chennai)

ABSTRACT *: Natural coastal /marine processes affect the coastal areas making significant changes in the morphology and associated ecosystem. Geo-environmental appraisal of Tamil Nadu coast between Chennai in the north and Nagapattinam in the south was made by identifying the areas of impact due to ongoing dynamic changes along the coast. The various thematic data such as geological, geomorphological, landuse, ground water etc. was synthesized and field verified to arrive at regional impact assessment for the study area. Apart from sea erosion and progradation, other geological processes taking place in the study area include submergence, silting of lagoons, and growth of spits across tidal inlets and rivers, flooding, high wind, increased salinity/ iron content in soil and water. The information gathered can be an input in the formulation of remedial measures and effective utilization of coastal area resources.*

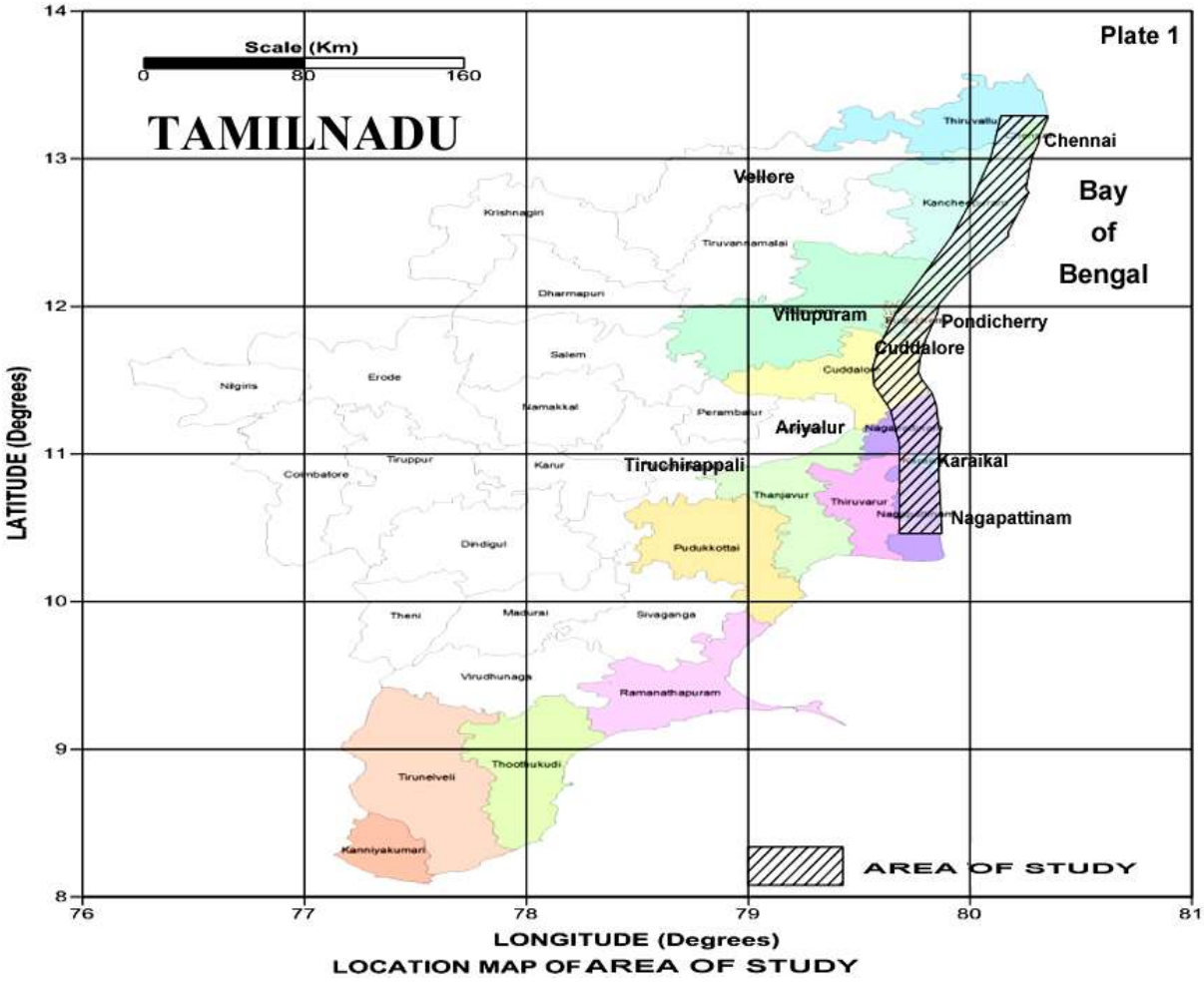
KEYWORDS –*Coastal processes, Geo-environment,Landuse, Mitigation,Natural hazard,*

I. Introduction

Tamil Nadu coast extends for about 1000 Km from the Pulicat lake near Chennai in the north to Kollencode, beyond Kanyakumari in the southern part of Tamil Nadu (including parts of Pondicherry coast). Analysis of only natural coastal processes and the associated Geo-environmental impact was studied along the part of Tamil Nadu and Pondicherry coast between the area from Chennai (Tiruvanmiyur-south of Chennai) in the north and Nagapattinam in the south bounded by latitudes 10° 45' 00" and 13° 00' 00" and longitudes 79° 45' 00" and 80° 16' 30" (Plate 1). This coastal sector has been studied by Krishnan etal (1998, GSI, FS: 93-94) incorporating Anthropological and natural causes for environmental degradation.Further,Geo-environmental appraisal of Pondicherry urban area and its environ was made by Nagarajan (1995, GSI, FS: 95-96) and brought out the specific impacts in and around Pondicherry town.Natural disasters strike this coast frequently by cyclones and storm surges, occasionally by earthquakes and rarely by Tsunami. After the Dec2004 tsunami invasion, Srinivasan and Nagarajan(2007) studied the impacts and reasoning of affected areas along this coastal segment.

The study area has been experiencing rapid developments and diversified landuse practices are being adopted such as ports and harbors, highway laying, tourism, urbanization, Power projects, aquaculture, industrialization etc. Thechanges and effects on ecosystem by these activities are also varying and may be difficult to bring under a single study.Whereas the slow changes due to natural coastal processes are interrelated and a regional study can bring out the various processes and sites of operation so that any landuse planning is done judiciously considering its long range impacts. Henceall the human induced problems along the Chennai-Nagapattinam coastal segment are excluded in this study as it needs a detailed separate approach and only the ongoing geological processes are taken up in this study.

The width of the area studied varies from place to place, depending on the farthest place on land upto which evidences of marine activity are observed and in general, it is of 10 to 20 Km. With the help of different thematic information collected all along the study area and synthesis made later an attempt was made to identify the ongoing geological processes and tolocate areas of natural environmental degradation. Unlike the commonly practiced site specific and theme specific environmental studies carried over limited areas, the present study takes into account the regional characteristics, compare and correlate the features in different areas to understand and identify the issues. In the following paragraphs the various thematic information and the ongoing natural coastal processes are discussed to highlight the impact on the fragile/sensitive coastal environment.



LOCATION MAP OF AREA OF STUDY

II. Geology:

Geologically, the linear coastal study area can be broadly divided into i) hard rock areas in the northern part, ii) Tertiary sediments including the Coromandal Formation, in the central part and iii) Quaternary sediments of fluvial and fluvio-marine origin found in the fluvial and deltaic areas in the southern part. In addition, the unconsolidated beach and sand/clay deposits are prevailing all along the coast.Study area comprises rocks of the Archaean, Permian, Cretaceous, Tertiary and quaternary (including Recent) periods. Detailed surface and subsurface geological studies have been conducted in this area by the GSI, ONGC etc. Based upon detailed geophysical, drilling and palaeontological studies, Sastri et al (1981) had identified two sedimentary basins viz; the Palar basin and the Cauvery basin, to be present in this area. The Palar Basin covers about 4000 sq.km on surface and 2800 sq. km. in off-shore areas. Kumaraguru (1987) by stratigraphic drilling has brought out the sedimentation of fluvial and marine phases during the early cretaceous(Gondwana sediments) as intertonguingfacies in the Palar basin. Very extensive work by the ONGC in the Cauvery basin has brought out clear stratigraphic sequence for the area. Sastri et al (1981) had further proposed that the Cauvery basin is a block faulted, pericratonic basin comprising ahorst-graben basin architecture. It includes several depressions separated from one another by sub-surface ridges trending NE – SW direction.

III. Land forms:

The various landforms present in the area are beaches, dune complex, spits, off-shore bars, tidal inlets, estuaries, lagoons, tidal flats, mangrove swamps, strand lines, older sandy plain with dunal ridges, palaeotidal flats, flood plains, inter distributary basins, river bed with channel bars, point bars, levees, palaeo channels, meander scrolls, pediments, pediplains and inselbergs identified primarily by following the descriptions of Fairbridge, Rhodes.W (1968), the Encyclopaedia of Geomorphology.All the above land forms are not present everywhere. Different segments of the coast are characterised by the presence or absence of some of the landforms as determined by various factors such as lithology, structure, tectonism and wave dynamics along the shore line. Even the same land form occurring in different segments vary in their geometry and disposition. On the basis of the geometry and disposition of land forms the Chennai - Nagapattinam coast is divisible into five sectors such as Chennai -

Palar river sector, Palar river- Pondicherry sector, Pondicherry –Cuddaloresector, Cuddalore - Tirumullaivasal sector, Tirumullaivasal - Nagapattinam sector (Krishnan etal 1998).

3.1 Chennai–Palar river Sector

This sector extends from Tiruvanmiyur, (just south of Chennai city- **Plate 2**) in the north to the confluence of the PalarRiver (debouching in sea) in the south and is characterized by dune complex of lesser height and larger width. The dunes are less than 5 m in height and about 750 to 1500 m in width. Apart from the dunal complex, other land forms present include beaches, tidal flats and palaeo tidal flats. Strand lines can also be recognised. The palaeotidal flat extends from near South of Chennai to Mahapalipuram with width of up to 2.5 km. Its continuity beyond is obscured as it is buried under the Palar alluvium. A few smaller bays viz; Velachery bay, and Manjalmadu are present in this sector, which is bound in the west by the pediplain formed over the charnockite and granite gneisses of Archaean age. PalarRiver has no delta.

3.2. Palar river - Pondicherry Sector

This sector is marked by the presence of 0.4 to 0.8 km wide dunes of varying heights. The dunes in the Palar river area are about 4 to 5 m height and about 400m wide. They gradually increase in height to attain 20 m and width of 800m at Muttukkadu village, located about 4.5 km NNE of Marakkanam(Fig 1), where after they lose their height and width rapidly. Tidal flats are quite wide in this sector attaining a maximum width 4 - 5 km and therefore support the Cheyyur and Marakkanam salt factories. The three lagoons present in this sector are the Cheyyur, Yedayantittukaliveli and Kaliveli lagoons. All of them trend parallel to the coast. The Kaliveli lagoon situated south of Marakkanam is cut off from the sea at present and as such has become a lake. This sector is flanked in the west by the pediplain formed over Archaean rocks uptoChunnambur and south of Chunnambur, by the pediplain formed over the Cuddalore Group of rocks of Tertiary age.

Fig-1 High Dune complex at Muttukadu near Marakkanam

3.3. Pondicherry - Cuddaloresector

This sector consists of dunes of height up to seven meters with width varying between 100m and 200m. However, the width of the dunes is about one kilometer between Ariyankuppam and Gingee rivers and between Pannittittu and Manappattu. This sector is bounded in the west by the pediment consisting of Cuddalore Group of rocks. Low elevation and lack of slope in the Pondicherry - Cuddalore area have contributed to the sluggishness of the rivers flowing in this area, thereby causing poor and irregular development of tidal flats close to the river mouths.

3.4. Cuddalore- Tirumullaivasal Sector

This sector is marked by wider older dunal complex of width up to 9 km with diversely oriented older dunes of height upto 21m. Recent dune complex is only of limited width (100m or less). The Dunal ridges trending N-S, NNE-SSW are preserved up to 9 km west of the present shore line. It appears that the bund of PerumalEri(a big irrigation tank located in the adjoining inland of this coastal sector) could have been an older dune and the PerumalEri itself might have been a palaeo lagoon, now containing only fresh water. Moreover this sector marks the northern limit of the Cauvery delta system. In the southern part of this sector lies the famous Pitchavaram mangrove forest and the shore line in this area shows a broad convexity to the east due to the delta of Koleroon river (part of Cauvery river).This sector is bound on the southern side by a flat submerging coast.

3.5 Tirumullaivasal - Nagapattinam Sector

The Tirumullaivasal - Nagapattinam sector is an anomaly. In the otherwise NNE-SSW to NE-SW trending coast line of Tamil Nadu, the coast in this sector trends N – S, probably a fault as inferred from the bathymetry of offshore areas adjoining this coast. Dunes are virtually absent and beaches are very narrow. The average elevation is about 5m only, upto 12 km west of the shore line. Tidal flats have developed extensively and obliterated by the Cauvery delta. In the entire Tamil Nadu coast, protective embankments, in large measures, are present in this sector only. Older dunal complex with ridges is present between Ambanar and Arasalar rivers and its width varies from 1.5 to 5 km. This entire stretch appears to be a coast of submergence.

IV. Land cover and land use

Table below lists the land cover and land use in each of the land forms present in the study area.

Landform	Land Cover	Landuse
Beach with recent Dunal complex	Partly barren and partly with spartina grass, bushes and shrubs	a) Casuarina and coconut plantations, b) Farms, beach resorts and housingc) East Coast road, d)Desalination plant e)Housing and Farm houses, f) Nuclear power plants. g) Ports and harbors g)Archaeological sites and monumentsh) Rip raps for protection against sea erosion.
Tidal Flat	Partly barren and partly with salt tolerant shrubs and plants	a) Salt pans and associated activities,b) Partly reclaimed as agricultural landc) Aquaculture ponds
Tidal inlets, Estuarines and Lagoons	Covered with saline water some areas with mangrove vegetation, salt tolerant plants	a) Dry lagoonal areas used for Agricultural, Aquaculture, Salt panningb) Fishing, c) Disposal site for Industrial and Urban waste
Lagoonal Salt Marsh	Partly barren and partly with salt tolerant plants	Potential Aquaculture sites and Salt Panning
Mangrove swamp	Mangrove forest	a) Some Fringe areas are converted into aquaculture ponds,b) preservation of mangrove at specific areas and nurseries of mangrove plants in some areas
Spits, offshore bars	Mostly barren, Natural vegetation in some areas	-
Paleo tidal flat	Partly barren and partly natural vegetation in some areas	a) Reclaimed for Agriculture,b) Pasture land,c) Housing
Older sand dune complex with dunal ridges	Partly barren and partly with natural vegetation, palmyrah trees	a) Reclaimed agricultural lands,b) Major industrial belts and urban dwellings c) Casuarina and coconut plantations, d) Sand quarrying, e) Archaeological sites, f) East coast road
Sandy plain	Dense mixed natural vegetation	a) Mixed plantations b) Irrigation tanks and Farm lands c) Silica sand quarrying d) Archaeological sites e) East coast road
Flood basin (Alluvial plain)	Natural vegetation and plantation	a) Predominantly agricultural lands b) Oil and gas wells and associated industries c) Human settlements (Towns) d) Concentration of irrigation tanks and ponds in some areas e) Irrigation canal system with lining of timber trees in deltaic areas f) Sites of Archaeological importance
River bed with channel bars and point bars	Mostly barren, vegetation near estuaries	a) Sand quarrying b) Agriculture c) Sites of effluent discharge
Levee	-	Agricultural land
Paleochannel	-	Agricultural land with good ground water potential
Pediplain (Sedimentary)	Laterite and ferricrete soils	a) Agricultural, horticultural and plantation land b) Irrigation tanks
Pediplain (Archaean)	Some areas with natural vegetation	a) Predominantly agricultural land withntervening irrigation tanks,b) Casuarina, eucalyptus plantation c) Rocks
Pediment	Some areas with natural vegetation	a) Cashew and mixed plantations, b) Quarrying for road metals and pebbles for bore wells,c) Roads
Inselbergs, residual hills, mounds and rock outcrops	Barren rock with shrubs	Quarrying for road metals

V. Resources

The Madras - Nagapattinam coastal stretch contains abiotic and biotic resources. Abioticresources include gravel, pebbles, building stones, silica sand, pozzolana clay, sedimentary lime stone, salt, hydrocarbons, silty clay, river sand and ground water. The occurrences of Silica sand and beach placers are described here.

5.1. Silica Sand

The dunal complex and sandy plain between Chennai and Pondicherry are reported to contain quartz sand occurring as disconnected patches at many places. The silica sand forms the top of the Coromandal Formation and occurs between the Coramandal Formation below and dunal sand above. The sand is rounded to sub-rounded, grey to white in colour and occurs at Akkarai, Kannathur, Injambakkam, Ottaiyur, Mungalvakkam, MunippillaiChattiram areas of Chengalpattu district and at Mudaliyarkuppam, Agaram area of Villupuram district. They extend over a cumulatiave strike length of about 20 km and their thickness vary from 0.1 -2.5 m and tentative width varying between 25 - 500m.

In addition, impersistent, narrow,, linear stretches of silica sand had been reported to be present along the 8 km long, Pondicherry -Pudukuppam coast. They are 15m wide with an average thickness of 2.5m.Apart from these explored areas, potential areas for silica sands also include the Alappakkam -ChinnaKummatti area - 25 km South of Cuddalore(Srinivasanetal 1999), Tirukkadaiyur area (north of Karaikal) and the sandy plains in Mugaiyur and Komuttichavadi areas, located respectively north and south of Marakkanam.

5.2. Ilmenite and Garnet sand

The Cuddalore – Nagapattinam (southern part of study area) contain concentrations of ilmenite and garnet sand and is primarily noted in the beaches at Kilmuvakkarai, Tarangambadi, Kaveripattanam, Karaikal, Pudukuppam, Mel Vanjiyur, Kodiyampallam and Chinnavaikkal. The heavy minerals occur as small patches and individual layers are 1-2 cm thick only. However, good concentration is observed over an 11 km long stretch between Karaikal and Mel Vanjiyur. In this sector 2004 tsunami has brought in significant amount of heavy sand from offshore and its spread and thickness increased compared to previous years (Srinivasan &Nagarajan -2007).

VI. Ground water

The Madras-Nagapattinam coastal tract can be hydrologically divided into four units, viz.,Korattalaiyar basin, Palar basin, Ponnaiyar basin and Cauvery basin. Ground water conditions in these basins are highly varying and complex due to geological and geomorphological features, disposition of fresh water and saline water bodies, aquifer characteristics etc. They are classified in to aquifers in hard rock area,aquifers in Tertiary Sediments, and shallow Aquifers in Quaternary Sediments. Aquifers in the coastal area are occurring in different systems namely water table, shallow and deep aquifers (CGWB 1983). Quality and quantity of deep aquifers are generally very good. All along the coast a wide variation occurs in the disposition of fresh and saline ground water bodies. These variations are i) saline ground water underlying/overlying fresh water, ii) fresh water laterally grading into saline water and iii) fresh water aquifers alternating with saline water zones. Consequently, the ground water potential also varies from place to place depending upon the geological formation.

VII. Ongoing geological processes and their impacts on coastal environment

A larger part of the Tamil Nadu coast has not shown any remarkable or significant spatial changes over the last 40 - 70 years. This is inferred from toposheets and satellite imageries of different periods thereby implying that the shore line has not experienced large scale changes but remained mostly neutral. Yet, sites of sea erosion and progradation are not uncommon (Krishnan and Srinivasan 1998). In the coastal tract between Chennai and Nagappattinam, progradation is observed at the mouths of Vellar, Coleroon, Uppanar near Tirumullaivasal, Ambanar, Cauvery and Tirumalairajan rivers. Sea erosion is noted at north of Mahabalipuram, Palar river mouth, Pondicherry and the 35 km long stretch between Tirumullaivasal and Karaikal in the south.Apart from sea erosion and progradation, other geolgical processes taking place in the study area include submergence, silting of lagoons, and growth of spits across tidal inlets and river mouths, flooding, high wind, high salinity and high iron content in soil and water etc. Each of these processes and their impacts on coastal environment are detailed below and depicted in the **Plate4**.

7.1. Sea Erosion

Unlike the neutral and prograding coasts, an erosional coast poses many environmental problems and consequently, many littoral states have spent considerable amount to control sea erosion. Environmental impact of sea erosion includes loss of property, landward movement of salt water - fresh water interface, enhanced soil and ground water salinity, and inundation of low lying areas. The individual erosion sites are described below. During 2004 tsunami, as one time erosion, many front line beach ridges were breached and eroded and adjoining areas were flooded.

7.1.1. Mahabalipuram

Sea erosion in Mahabalipuram is confined to the shore temple area. The temple is situated on a promontory - an extension of rock mass of quartzofeldspathic gneiss into the sea. Temporal study of different toposheets shows that the sea had advanced by about 20 m in 50 years, which amounts to an average annual rate of about 40

cm. Erosion at this site is prompted by the promontory which acts as a natural barrier to the wave movement and littoral drift. In order to protect the temple from further erosion, huge boulders have been staked around the temple. This has probably resulted in inducing erosion in the area north of the temple resulting in the formation of a bay. Recently in the Nemeli area, the Govt of Tamil Nadu has established the desalination plant with seawater intake through a pipe placed perpendicular to shore line. This area is experiencing sea erosion in the recent years. Similarly the houses constructed close to shore in the Neelankarai-Akkaraiarea north of Nemeli (South of Chennai as urban agglomeration) also face the prospect of sea erosion particularly in the monsoon storm surge periods.

7.1.2. Palar river mouth area

Palarriver enters the sea at about 7 km south of Sadras, without a fluviomarine delta. Absence of the delta can be attributed to various factors such as sea level rise, neotectonism etc.

At present, sea erosion is observed in the areas immediately north and south of the river mouth over lengths of 3.5 km and 1.5 km respectively. The erosion is intense over these stretches and continues southward uptoKuppam at a reduced intensity. The villages located south of the river, viz; Chinnakuppam, Periyakuppam and Alikuppam experience severe sea erosion. Periyakuppam and Chinnakuppam are the worst affected villages with an average annual rate of about 2.0m (Fig 2). The process continues even today.

Fig 2- Sea Erosion at Periyakuppam, South of Palar river mouth

Erosion in this sector is caused due to the combined action of reduced sediment supply by the Palar river (ephemeral river with only a few days of surface water flow in peak rainy season), growth of a spit across Palar river mouth and possibly also due to neo-tectonic movements. A few Submarine valleys are also interpreted off Palarriver which may be trapping the littoral sediments. The disposition of coastal dune between Palar river mouth and Alamparai tidal inlet shows that the dunes gradually gain height towards south, from 4 m at Palar river mouth to 20 m at Muttukkadu, near Marakkanam. Excepting the height difference, the dunes do not differ in their characteristics. This rise could be due to a slow up warping of the coastal area in this part as a result of which the southern side was raised while the northern side near Palar river mouth was lowered. Consequently, areas around the Palarriver mouth experiences erosion as per the probable inference made in this study.

7.1.3. Pondicherry

The coast line of Pondicherry town has been experiencing sea erosion since recent times and urban part is protected by a boulder sea wall. It is claimed that the problem has been aggravated since the construction of fishing harbour/pier in the southern part of town.Probably the littoral sediment transport is interfered such manmade activities resulting in uneven sedimentation. More studies are needed to ascertain the exact causes and applying remedial measures. Off shore and on shore a few probable faults and weak zones are interpreted around Pondicherry from various studies. A few offshore shoals and mounds are also deciphered. All these features and its relation to coastal processes needs drilling and rigorous ground studies to confirm and ascertain the causes of erosion

7.1.4. Tirumullaivasal - Poombuhar - Tarangambadi - Karaikal Coast

South of Tirumullaivasal, 35 km long stretch from south of Uppanar river uptoKaraikal is an area of intense sea erosion. This is an important coastal stretch from historical, archaeological, geological and tectonic point of view. The ancient port cities of Kaveripoompattinam and Poombuhar and the Danish fort of 'Danesborg' at Tarangambadi fall in this stretch, although the port cities had been washed away in the past.

The study has brought to light that barring the river mouths' area, generally, the entire stretch of 35 km is an erosional coast of varying magnitudes. The approximate magnitudes of sea erosion at various places along this stretch for the last 50 years are given below.

Magnitude of Sea Erosion along the Tirumullaivasal - Karaikal coast.

Sl.No	Location / Reference Point	Approximate/tentative Erosion (m) in the last 50 years	Average rate of erosion (m) per annum(tentative)
1	Kaveripoompattinam	27.00	0.67
2	Kuttiandavar Temple	28.00	0.70
3	Tarangambadi Railway Station	18.00	0.45
4	Tarangambadi south Pillar	13.00	0.32
5	11° 00' :79° 50'	32.00	0.80
6	10° 45' : 79° 50'	25.00	0.62

T. Mageswaranetal (2015) have studied the shore line changes along the Tirumullaivasal - Nagapattinam coast by comparing the satellite imageries for the period from 1978 to 2013, subsequently by taking the field traverses and had arrived at the average rate of erosion as 0.99m to 1.99m per year indicating a low to moderate erosion in this sector.In order to verify the magnitude of erosion at all those places, local enquiries were made and structures on the shore line vis-a-vis their distance to shore line during earlier years were considered. It was found that a fair degree of agreement exists between the values computed from the toposheets and those obtained by ground checks and local enquiries. The local people claimed that the process was continuing all along and there was no reversal of it at any time over the past 40 - 50 years.

Incidence of sea erosion at Tarangambadi for three centuries (17th to 19th) were referred to in various records of the Danish Settlement, East India Company and British India. The Danish Fort- 'Danesborg'- at Tarangambadi (Fig -3) was built in 1626. A battery stood at 300 feet (about 90m) east of the fort wall. In early 1750 a larger part of the fort was washed away. It is mentioned that during the 17-18th century the sea was 400 - 500 feet away from the sea line in 1850. Presently the sea is close to the east wall of the fort. Further evidence for erosion at Tarangambadi comes from the Masilamani temple, built during 10th century. The temple is located about 150 m north of the fort. It had been consistently attacked by the waves. Its tower had fallen due to sea erosion in 1859, and presently, the temple has been brought down by the sea (Fig-4). At Tolamtondi the severity of sea erosion in this area is unquestionable because it is only in this stretch anywhere south of Chennai that protective embankments have been constructed to ward off sea erosion. Even these embankments have been breached at places.

Fig-3 Sea erosion at the Danish Fort- 'Danesborg'- Tarangambadi

i

All the above descriptions clearly indicate that the Tirumullaivasal-Karaikal coast is a zone of intense sea erosion and any developmental activity in this sector should give serious consideration to the problem of sea erosion. The Tamil Nadu state Government has carried out shore protection measures by placing a Boulder wall adjoining the above monuments but the raging waves overriding the boulders and eroding the features. The severity of erosion in this sector might be due to submergence of the coast described in the following paragraphs.

7.2. Submerging Coast

In the Tirumullaivasal - Karaikal sector submergence and neo tectonism appears to be the geological phenomena leading to the lowering of land accompanied by sea erosion. No measurement of submergence has been carried out by any agency so far in this sector. But, submergence can be inferred from geological, historical and archaeological evidences which are described below.

7.2.1. Geological Evidences

Geological evidences in support of submergence of coast include absence of beach dunes, low flat coast, and breached dunes. The 3-4 m high, circular to elliptical, discontinuous dunal mounds from Santirapadi to Kilinjimedu would have been a continuous beach dune in the past. Yet, in course of time, this once continuous body of dunes was breached at a number of places along the 5.5 km stretch. At present, the dunal mounds occupy a length of only 2.0 km and the remaining 3.5 km has been cleared of dunes due to breaching by sea water **(Plate 3).**Protective embankments (Fig-5) were built along the breached sections. Even these embankments were breached at places. Also, the sea water during storms has flowed across these embankments inundating the agricultural field to further west.

Fig-5, Protective embankment –North of Karaikal

7.2.2 Straightness of coast

The Tirumullaivasal - Nagapattinam coast and its continuity upto Point Calimere is a straight coast trending N-S whereas the rest of the Tamil Nadu coast trends NNE-SSW / NE-SW with many bays, incursions etc. The 5 fathoms bathymetric contour runs very close (0.5 - 1.5 km) to the coast implying the presence of a flat shallow broad shelf. This could be attributed to a N-S trending fault extending between Vellar and Vettar rivers. It is quite likely that this fault hasinduced the submergence of this coast.

7.2.3. Historical Evidence

Poombuhar was the capital and port city of the Early Cholas (2 century,B.C - 2 century,A.D) and was the most celebrated port among all the ancient ports of Tamil Nadu. It was the most active port of that time and vessels from Rome, Greece, SriLanka, Savakam(Thailand and Campuchea) Kadaram (Myanmar) and other countries were frequently calling at this port. The various merchandise brought into and carried away from this port as well as the people who manned those vessels are frequently referred to in the Classics such as Chilappadikaram and Manimekalai and the Sangam Literatures like Pattinappalai, Purananooru, Agananooru and Nartrinai.

During the Post - Sangam period the city lost its glory as it was submerged under the sea and Nagappattinam port gained eminence during the period of Imperial Cholas (9 Century,A.D - 12 Century,A.D). Although direct evidences for submergence are not available, no literatures of the later period mention anything about this city. This only probably indicates that the city did then not exist.

7.2.4. Archaeological Evidences

Marine Archaeological Surveys in the Tarangambadi - Poombahar area was recently conducted by the Archaeology Department of Tamil Nadu and the National Institute of Oceanography (NIO), Goa. The survey had traced the existence of manmade structures at 6-7m and 11-14m water depth off the coast of Chinnangudi and Chinnamedu. The sonographs and echograms had registered the extension of the submerged valleys of Nandalar and Uppanar rivers upto 6m water depth. They had also registered the presence of circular, cairn-like features at that depth off the coast of Tarangambadi. These features are believed to be the burial grounds of the ancient people. All these evidences suggest that submergence was continuing from very early period.

From the foregoing paragraphs it is clear that the Tirumullaivasal - Karaikal coast is undergoing submergence for many thousands of years and its surface manifestation include sea erosion, flooding by sea, low flat coast, and extensive tidal flats including the Pitchavaram lagoon.

Any developmental and other construction activities in this sector should therefore take into account submergence and related processes in the planning stage of the projects.

7.2.5 Remedial Measures

Suitable remedial measures to counter sea erosion depend on the ground conditions. Brush fencing will be useful to a greater extent. By this technique a dune of 1 - 1.25m height can be grown in just one year. Planting of mangrove vegetation along the erosional coast at suitable distance from the waterline will also help in checking the erosion. Strict implementation of Coastal Regulation Zone Act (CRZ act 2001,2010) is essential. It is not possible to counter submergence. Construction of a number of discontinuous groynes made up of two arms of short length at obtuse angle to shore line and placed in two or three rows, as need be, will speed up dune formation.

7.3. **Progradation**

Progradation or accretion - advance of land into the sea over some limited areas - has resulted in continuous sedimentation at the sea in front of the mouths of Cauvery, Arasalar, Vettar, Coleroon and Vellar rivers. As all these rivers are located in the Cauvery delta region, sufficient quantity of sediment supply is assured. Progradation in front of other rivers located outside the Cauvery delta is very minimal and as such is insignificant. Tentative rate of progradation in these areas varies from 1 to 2 m /year. Progradation process on the whole is beneficial and the prograded coast can be reclaimed for usage of fishermen, agriculture, Aquaculture etc.But as the sediment supply by the rivers in to ocean have dwindled drastically in the past decades due to poor rainfall, upstream dam construction, and other human activities, delta progradation rate is reduced. More over other than the river based progradation, due to the offshore littoral sediment distribution imbalance the accretion of shore line takes place in nearby areas as counter to erosion and hence the local variations in shoreline needs a multi temporal, annual, repeated studies for understanding the coastal processes and development or utilization of such areas.

7.4. **Silting of Lagoon**

Lagoons sustain various economic activities such as salt panning, fishing, collection of shells etc. and provide gainful employment to the coastal people. In addition, they are sites of mangrove vegetation and scenic beauty and thus promote tourism. All these activities will get curtailed and may even come to a standstill with progressive silting up of lagoons.

Silting of lagoon is in progress in the YedayantittuKalivelilagoon near Marakkanam. Sprawling over an area of 25 sq.km in the past, this lagoon covers only 15 sq.km now. It has lost 10 sq.km area due to silting and also probably due to reduced inflow of sea water. Silting is effected by the sea water and to a greater extent by the Ongurriver which drains into it.Although the volume of sediments entering the lagoon may be less in comparison to the volume active lagoon, one cannot be passive since more areas will be silted up in future leading to reduced salt production and job opportunities.

7.5.**Growth of Spits across Tidal Inlets and Rivers**.

Dimension, geometry and disposition of various spits present across the tidal inlets and rivers in the study area vary from place to place and there are three spits across the tidal inlets and eight across the rivers. The off shore littoral processes and long shoredrift by long shore currents which carry the sediments parallel to shore line in up and down direction in different parts of year dump the sand at the gaps and opening in the shoreline as a natural offshore coastal processes. The formation and growth of spit at a specific place depends on sediment supply, orientation of shore line with respect to long shore current, wind/wave direction etc.The impacts due to the geological process of spit growth on coastal environment are given below spit wise. It is not that all spits cause environmental impacts.

7.5.1. Spits across tidal inlets:

7.5.1.1. Kovalam Spit

At the Kovalam tidal inlet, growth of paired spits is facilitated by poor drainage development and flow in this area and near neutrality of the coast. Strong, oblique waves cause long shore drift to gag the tidal inlet as a result of which only for a period of 4-5months in a year, the inlets remain open. This affects the salt production and job opportunities in the area. The Muttukadu creek here, which is a major picnic spot near Madras with boating facilities, also suffers since the depth of the water column is insufficient for boating. To overcome this, the Tamil Nadu Tourism Development Corporation (TTDC) dredges the creek and the inlet periodically.

7.5.1.2.Alamparai Spit

This spit, which has grown across the 1.5 km wide Alamparai tidal inlet through which sea water flows into YedayantittuKaliveli lagoon, which supports the Marakkanam salt pans is the second largest salt factory between Madras and Vedaranyam. Only one third of the original width of this inlet remains open and with further growth, this spit may close the inlet completely depriving the lagoon of sea water.

The spit growth will reduce the inflow of sea water into the YedatittuKaliveli lagoon as a result of which its area will shrink. This lagoon had already shrunk by 10 sq.km due to silting the consequent reduced inflow of sea water It is causing reduction in salt production and employment opportunities, decay of mangroves and the death of the lagoon.

7.5.1.3. Tengatittu Spit

The creek encircling the Tengatittu Island south of Pondicherry was connected to sea in the early part of this century by a tidal inlet located at about 1.2 km north of Virampattinam. It was closed naturally later and a new inlet located at 600 m north of Virampattinam came into existence and remained active during the seventies. A spit grew across this inlet later and sealed it eventually.

To save the creek and the associated activities as well as to provide a safe anchorage for fishing boats an artificial opening was cut at the site of old inlet and is being maintained.

7.5.2. Spits across River mouths.

Presence of spits is noticed across Palar, Gingee, Malattar, Ponnaiyar, Vellar, Coleroon, Uppanar near Tirumullaivasaland Nandalar rivers as mentioned earlier and it mostly induces sea erosion, water logging and flooding. The spits of major rivers the Palar and cooleron is described below.

7.5.2.1. Spit across Palar River

The Palar river that had no growth of spit across it in 1917 (as per the old maps) was then facilitating free flow of sea water both ways, with the growth of a 2-2.5 km long partly subaerial spit and the presence of a off shore bar across it, width of the river mouth available for exchange of water was reduced. This has resulted in blocking of sea water from entering the river. Consequently, the wave energy was directed to scour the coast on either side of the river mouth leading to heavy sea erosion in Voyalikuppam, Periyakuppam, Chinnakuppam and other villages.

7.5.2.2. Spit across Coleroonriver

The spit that grows across the mouth of Coleroonriver extends south eastward from its northern bank and then veers southwardly. It is likely that it may join the southern bank eventually and seal the mouth. Considering the heavy discharge of the river (part of Cauvery and its sediment load) such a possibility may not take place in the near future. However, it is possible that the process may be accelerated due to poor receipt of water being registered year after year in the past decades on account of Cauvery water dispute. In such an eventuality, the impacts will include, breaching of coast at a new place for discharging water flooding and water logging in the area south and southwest of Pitchavaram R.F.

7.6.**Flooding**

The Coromandal Coast is frequented by cyclones every year during the months of October - December. Most of these cyclones cross the shore along the coast of Andhra Pradesh. Tamil Nadu coast witness the second largest number of crossings. Nagappattinam, Karaikal, Cuddalore, Madras, Rameswaram and Kilakkarai in Ramanathapuram district are certain places where the cyclones had crossed in the recent years.

The storms/cyclones bring heavy amount of rain fall in the Cauvery delta. The delta region generally receives an average annual rain fall of about 1200 mm and 50 to 60% of it is received during October - December. Consequently, all the rivers are in spate and the tail end region is heavily flooded. Simultaneously sea swell causes sea water to flow inland causing large scale inundation. As a result, large areas in the tail end region of the delta remain flooded during this period. Such areas include Tirumullaivasal –Nagappatatinam andChunnambar - Malattar sectors.The flooding of urbanized, low lying, flat coastal towns is a regular phenomenon and it is noteworthy that coastal Chennai metro city flooding during 2015 December was severe and unpredented. The Cuddalore town was also flooded during this period and also during the earlier Thane and Nada cyclones.

Area affected by flooding in a year depends on the intensity of rain fall, catchment area, rate of infiltration, wave height and duration of storms, urbanization etc. Some of the impacts include Contamination of drinking water and Soil erosion. Development of effective drainage channels to conduct storm water quickly can alleviate the problem to some extent.

7.7.**High Winds: Sand Accretion**

Certain areas along this coastal stretch appear to be experiencing strong winds over a larger part of the year. This can be confirmed only by carrying out relevant studies. The areas where such high wind is observed are a)The five kilometre stretch betwen 2 km north of Tirumullaivasal and Kolaiyar and b) Tirumeigyanam - Pillaiperumanallur area east of Tirukkadaiyur . In both these areas, large volume of sand is noted to be disturbed by strong winds. The transported sand covers the agricultural land as a thin veneer. Sand migration is from east west and causes low productivity. However, the process and its impact need to be verified.

Large scale sand accretion had also taken place in Mahabalipuram area in the past as inferred from various sites. Till its restoration in its recent times the Mukundanarayanar temple (nineth century A.D. temple) in the northern part of the town partly remained under 3-4 m thick dunal sand resulted from sand accretion (Fig-6) . Similarly, the five rathas monument also remained partly under 2-3 m dunal sand. The sand accretion had occurred due to high energy winds in the past.

Fig-6 Mukundanayanar Temple at Mahabalipuram and a view of sand accretion

Sand accretion studies assume significance in the present context since more number of buildings, plantations and farms are sprouting all along the coast. The problem will be severe in areas of wind chute.

7.8. **High Iron Content in Water**

In the southern part of area of study, the Tirunagari-Mangaimadam-Nangur-Tiruvengadu area is located between the TirumullaivasalUppanar river and Cauvery river . This area has the problem of heavy soil and ground water salinity. In addition, high iron concentration is noted in the ground water and the river sediments of this area.

All hand pumps installed in this area spout out odorless and colourless water. The hand pumps bore wells are lowered to a maximum depth of 6-8 m only below which the water is highly saline. After 10-15 minutes, the pumped colourless water changes to yellow brown to dark brown colour. On investigation it was found that the water contains excess concentration of ferrous ions. These ions are supplied from a 50 cm thick, iron rich sandy horizon occurring at a depth of 1-1.5 m in the alluvium. The ions remain dissolved in water and on exposure to atmosphere, get oxidised resulting in colour changes. Such high iron concentration in the ground water is noticed in Kudikkadu village, near Cuddalore, also. The iron concentration in Mangaimadam and Kudikkadu areas as analysed earlier is 9.9 and 9.4 ppm respectively against the WHO recommended value of 0.03 ppm.

7.9. **Salinity in Soil and Ground Water**

Soil and ground water salinity levels in an area depends on various factors such as rain fall, temperature, depth to ground water, aquifer geology, behavior of fresh water - salt water interface etc. In the study area, inherent (not induced by Anthropological causes) salinity problem in soil and ground water is met with in many parts of the coastal tracts, especially in the tail end regimes of Cauvery delta

7.9.1 Soil Salinity:

Surface and subsurface salinity in soils in the coastal tracts of the present study area respectively upto a depth of 30 cms to 100 cms.is seen in the areas occurring in the taluks comprising Chidambaram, SirkazhiMayiladuthurai and Nagapattinam (southern part of study area). The causative factors attributed by them for soil salinity include weathering of primary minerals, improper drainage facilities, and poor quality of ground water, high ground water table, presence of marine sediments, salt water intrusion and inundation by sea water. There is every reason for increase in the area affected by soil salinity in recent years since not only the Cauvery delta area has been receiving only less quantity of water from the upper reaches but there has also been a proliferation of aquaculture farms in many areas.

8.9.2 Ground Water Salinity

Both soil and ground water salinity are complimentary to each other. Accordingly the factors mentioned above for soil salinity affect the ground water salinity levels too. All four types of ground water tapping system, viz. open well, shallow and deep tube wells are present in the Tamil Nadu coastal area. Various levels of salinity are met with in these systems. Yet the most affected systems are the open wells which are typical of dunal sands from which domestic and irrigational needs of coastal area are mostly met with.

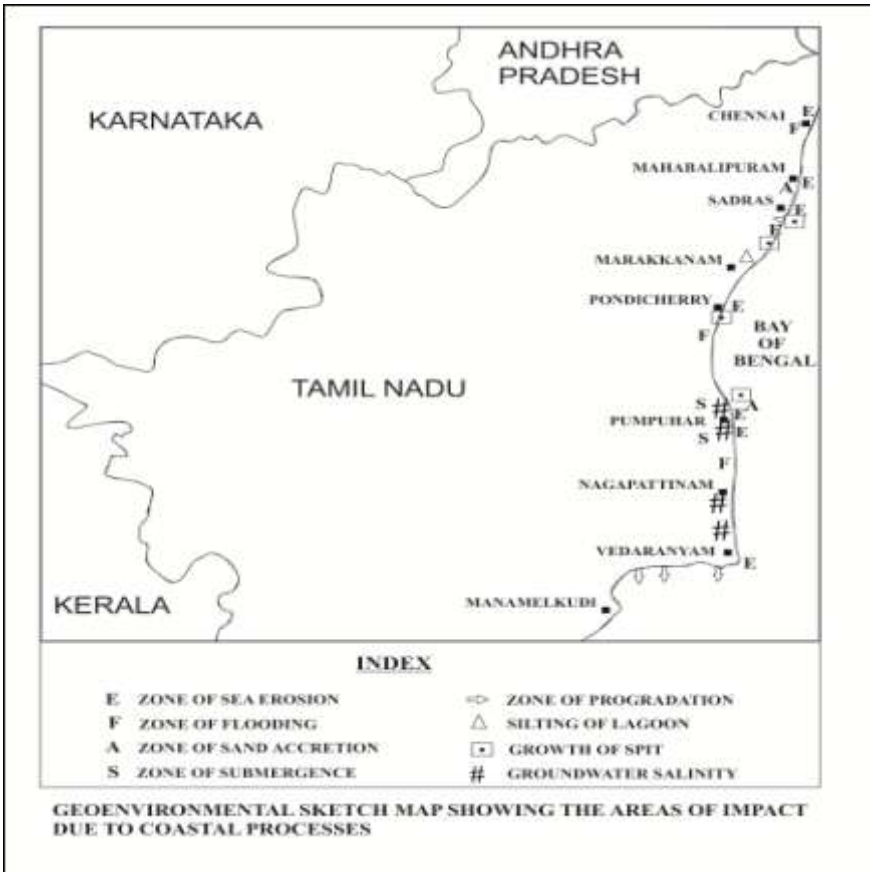
However, ground water salinity problem has become acute in many coastal areas. The entire coastal stretch south of TirumullaivasaluptoNagapattinam has ground water salinity problem in varying degrees. The worst affected area lies in between TirumullaivasalUppanar and Cauvery rivers. In this sector high ground water salinity is observed even upto 6-7 km west of present shore line as shown in the table below (Krishnan and Srinivasan 1997).

TabC Chemical characteristics of Ground Water samples from selected coastal areas, Cuddalore&Tirunagari area

Sl.no	Location	NO3	Cl	Na ppm	Fe ppm	Mn ppm	HCO3	Hardness PPM
1.	Kudikadu, cuddalore	1.5	250	85	9.4	165	215	380
2.	Mangai-Madam	1.5	700	230	9.9	270	150	540
3.	Nangur	40	525	450	0.18	30	900	335
4.	Allimedu	10	1760	710	0.08	910	290	1240
5.	Kuruvallu	5	1510	610	0.17	600	125	810
WHO standard for potable use		40	250	200	0.03	0.05	50-400	500

It is clear from the table above that ground water in all these coastal villages are not potable in nature. Avoidingover drafting, improved canalirrigation and drainage practices and assured water supply for irrigation through canals can be some of the remedial measures.

Plate-4



GEOENVIRONMENTAL SKETCH MAP SHOWING THE AREAS OF IMPACT DUE TO COASTAL PROCESSES

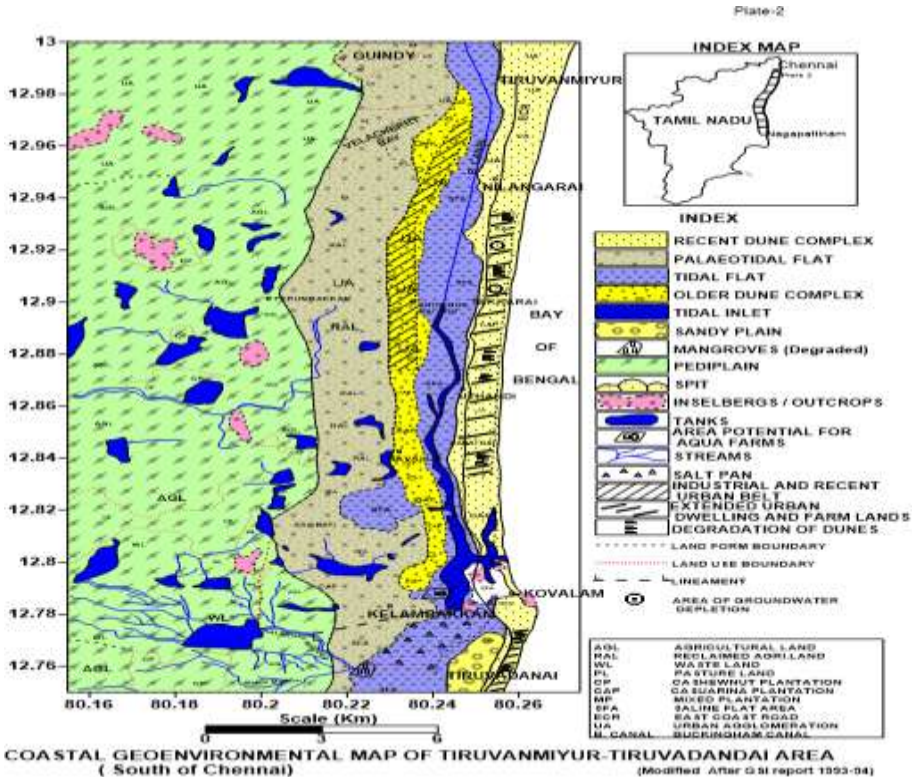
VIII. Discussion and Conclusion

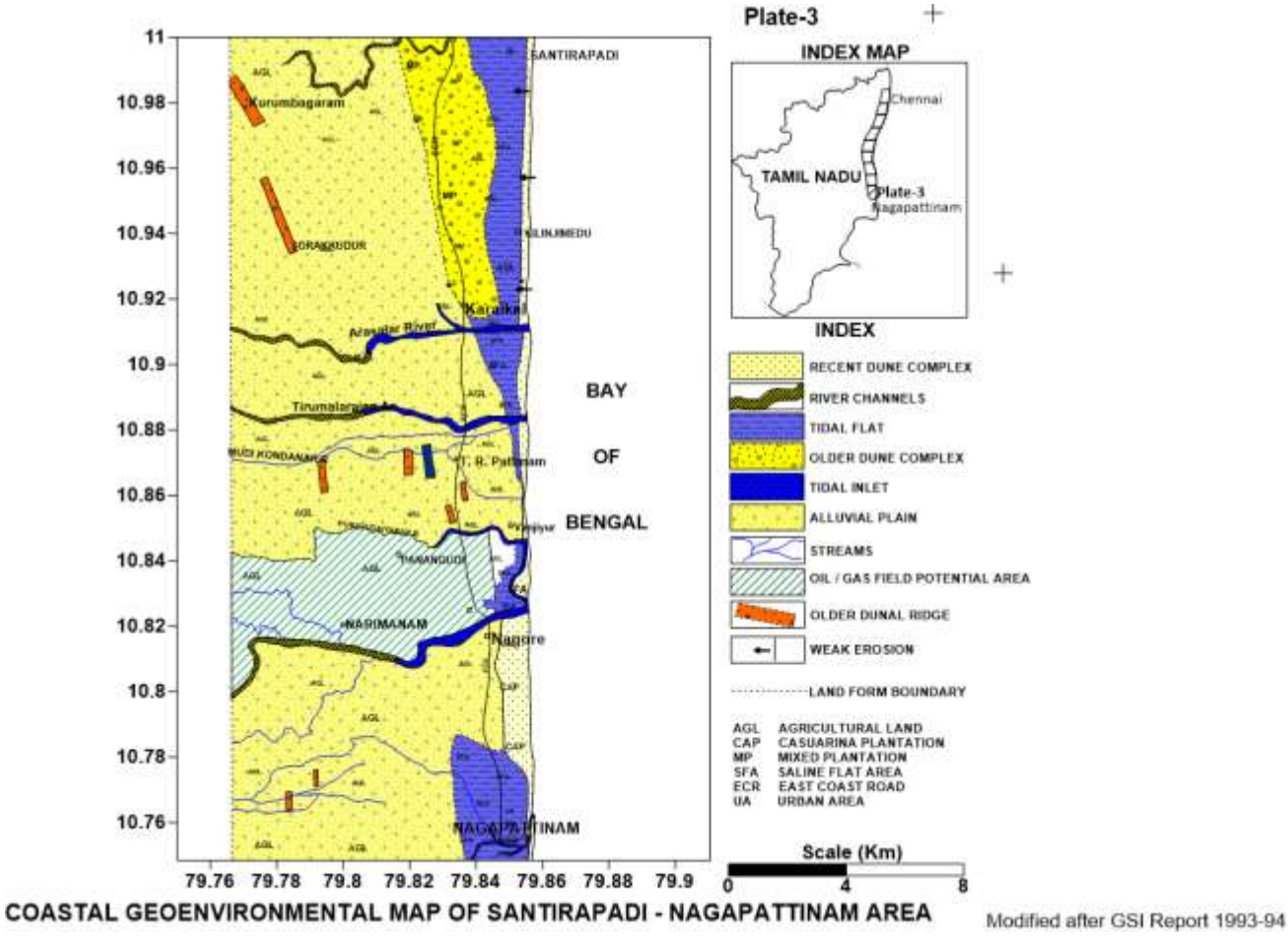
The study was aimed to bring out the regional geo-environmental problems due to natural causes along the part of Tamil Nadu and Pondicherry coast so that the impact on the coastal eco system is understood and suitable remedial measures can be implemented to overcome the ongoing degradation. Other than the natural causes, anthropogenic activities are intense in the well-populated coastal stretch between Chennai and Nagapattinam such as high way laying,aqua culture, industrial activities, establishment of Power projects, urbanization /commercialization, development of ports and harbours etc. These are interfering and altering the natural near shore and offshore process there by aggravating the impact on the geo-environment.

Moreover some special natural circumstances like the occurrence of an under Sea earthquake which generates a tsunami will also have a significant effect on the coastal morphological units and (temporarily/permanently) alters/modifies the ongoing coastal processes. The December 2004 tsunami waves severely affected the study area (Chennai-Nagapattinam coast) resulting in breaching the barrier dunes, opening the river /creek mouth , silting the tidal channels and estuaries, flooding and devastating the low flat coastal areas etc. In the same way frequent storm surges erode the coast redistribute the beach and tidal sediments. The impacts on the ecosystem will be severe with the combination ongoing coastal processes and natural disaster occurrences. The natural disasters threatening this part of east coast of India has to be assessed bymapping the active faults, recognition and mapping of coastal neotectonic features, identification and dating of paleo tsunami deposits,detailed seismic susceptibility studies, etc.

The sustainable coastal zone management of a well-developed coastal segment of TamilNadu, needs the proper understanding of the coastal processes and impacts mentioned in this study by continuous multi temporal monitoring the slow changes taking place all along the coast. One such major and serious problem being the sea erosion caused due to sea level changes by the eustatic climatic changes and tectonic upwarps along the active fault margins.The available offshore data on littoral drift, current directions, bathymetric configurations, offshore morphological and tectonic features (Submarine canyons, deltas) etc should be correlated and studied conjunctively with on shore data for proper understanding the ongoing processes and implementation of remedial measures. The subsiding Poompuhar- Karaikal coast has to be studied with multiple DGPS at different locations to ascertain the crustal movements. The same has to be done at upwarping or emergentlocations such as Marakkanamcoast andCuddalore coast.

The priority has to be accorded to protect the coastal mineral resources and fragile mangrove swamps/wetlands/tidalflats, archeological monuments from the impacts of natural geological processes and this study has highlighted the need for identifying, understanding and solving the geo-environmental issues in the dynamic emergent and submergent coastal sectors of the Chennai-Nagapattinamarea of Tamil Nadu.





COASTAL GEOENVIRONMENTAL MAP OF SANTIRAPADI - NAGAPATTINAM AREA

Modified after GSI Report 1993-94

Acknowledgements

The first and second authors gratefully acknowledge the GSI for the opportunity provided to conduct the study and encouragement given. The Authors are thankful to Shri G. Nagendran and Mrs. VidyaSivadas for the help rendered in plates preparation. The Authors are also thankful to HOD, Geology Department Presidency College Chennai for the discussion, modification and analysis.

.

REFERENCES

[1] V. Krishnan, R. Srinivasan, and R.Sundaram, (1998)*Geological Survey of India unpublished progress report* for FS 1993-94 on Geo-environmetal impact studies along the Tamil Nadu coast between Madras and Nagapattinam.

[2] K.Nagarajan(1997)*Geological Survey of India unpublished progress report*for FS 1995-96Geo-environmental appraisal of Pondicherry urban area and its environs.

[3] R. Srinivasan and K.Nagarajan (2007) Tsunami Survey in the Chennai-Nagapattinam Segment, Tamil Nadu Coast, *GSI Spl.Pub. No.89 Page 183-203.*

[4] V.V, Sastri, , B.S.Venkatachala and V. Narayanan,. (1981) The evolution of the East Coast of India. Jnl. of *Palaeo Geography and Palaeo Ecology, Vol.36, Pp.23 - 54.*

[5] P.Kumaraguru (1987) Stratigraphic drilling in Palarbasin , Tamil Nadu, *Rec.Geol.Surv. Ind., Vol.124, Pt5*

[6]. Rhodes.W.Fairbridge, (1968) *The Encyclopaedia of Geomorphology. Reinbold Book Corporation, London*.

[7] R .Srinivasan, V.R.Sowmi Narayanan, K.Ayyasami, (1999) *Geological Survey of India FS 1996-97 unpublished progress report* on Search and Evaluation of Silica sand resources in the dune complex of Alapakkam-Chinnakummatti area, Cuddalore District, Tamil Nadu

[8] *Central Ground Water Commission (1983)* Hydrogeological and Hydrochemical data of National Hydrograph Network Stations in Southern Region, Part II. Tamil Nadu and Pondicherry.

[9] Min.of Environment and Forests, Govt of India.(2011)*Coastal Regulation Zone (CRZ) Act notification, 2001, 2010*

[10] T Mageswaran,V. Ram Mohan , S ChenthamilSelvan , T Arumugam , Tune Ushaand R.S .Kankara(2015) *International journal of Geomatics and Geosciences* Volume 5, No 4, 2015 Assessment of shoreline changes along Nagapattinam coast using geospatial techniques

* R. Srinivasan " Natural Coastal Processes and Its Geoenvironmental Impact in the Area between Chennai and Nagapattinam Coast of Tamilnadu and Pondicherry " International Journal of Engineering Science Invention (IJESI) 6.8 (2017): 11-25