CHAPTER 6
COASTAL PROCESSES (ENVIRONMENTAL PARAMETERS)

6.1 GENERAL

Human agglomerations in the coastal regions bring about unprecedented changes, the impacts of which are on the rise. A clear picture has emerged recently on the deterioration of the highly fragile and sensitive zone of the coastal ecosystem due to overexploitation of living and non-living resources (Joseph and Balchand, 2000). In the context of land-ocean interaction, coastal zone is defined as extending from the coastal plains to the outer edge of the continental shelves, approximately matching the region that has been alternately flooded and exposed during the sea level fluctuations of the late quaternary period (IGBP, 1993).

Coastal zones all over the world are characterised by abundant water resources and vast expanses of fertile land. Due to these reasons, they have always been thickly populated and are centers of urbanization, industrial growth and intense agricultural activities. The Indian peninsula has a little over 6000 km of coastline. These coastal zones are characterised by a variety of complex environs like bays, beaches, estuaries, dunes and marshes, evolved through process like depositional activities of major rivers, eustatic changes, tidal effects and neotectonic activity. The coastal zones also have their own geomorphological, hydrogeological and hydrochemical characteristics.

Waves are the prime movers for the littoral processes at the shoreline. For the most part, they are generated by the action of the wind over water but also by moving objects such as passing boats and ships. The dynamics and kinematics of water waves are important factors to be addressed in any coastal engineering study. The coastline responds to various mechanisms that provide the energy and momentum to drive the littoral processes. In addition to long-term mechanisms such as sea level rise and equilibrium beach profile, there are short-term forces, including storm, wave, current, tide and wind effects.

Beaches serve as natural buffers between the ocean and the land. The destruction and removal of these buffers, levels the coast exposed to the erosion effects of the waves. Attempts are then made to prevent erosion and property destruction, a job done formerly and much more effectively by the beach. The beach or a shore is one of our finest natural resources. Once destroyed, its repair is difficult if not impossible but very costly.

Coastal areas can be highly dynamic because they receive very high inputs of energy and materials from surrounding terrestrial and marine areas. Sustainable utilization of coastal areas and resources can be adversely influenced by natural hazards such as flooding, erosion, tidal waves and other natural phenomena. Our limited ability to predict such events is often compounded by poor management of human activities in coastal areas and associated upland and marine environments. This can increase the incidence and severity of hazards and in turn increase the risk to people, property, crops and investment. The complex character of the ecosystems, natural resources and human activities found in coastal areas is often matched by complex and often overlapping institutional arrangements governing human activities. Conflicts of interest among different interest groups seeking to utilize coastal areas and resources are common. It is essential that these conflicts are anticipated and addressed in order to secure the livelihoods and well-being of communities who depend directly or indirectly on coastal resources.

The understanding of coastal systems over the years, the so called “Large Scale Coastal Behaviour” has been increasingly recognized as essential in order to both understand and predict future coastal change, including the coastal impact of climate change (Terwindt and Battjes 1991). Traditionally, studies of coastal processes have operated at much smaller scales, leading to dearth of information at the large scale (Short et al 1995). In this study, an attempt has been made to collect short-term data on beach profile and shoreline changes, wave, tide, current, etc., through field measurements on the coastal stretch between EID Parry factory (south of Ennore creek) and bar mouth of Pulicat Lake with available resources and utilized for simulation studies.

6.2 CHENNAI PORT AND ITS IMPACTS

Chennai coast is an open, high-energy coast having no natural harbour. Due to industrialization, an artificial harbour has been created in the year 1875 on the Chennai coast, namely, Chennai port. The initial construction of the harbour for the port of Madras (Chennai), on the southeastern coast of India, was the breakwater extending outward about 1000 metres from the original shoreline took place in 1875, (Vernom-Harcoart 1881; Spring 1919; Johnson 1957; Cornick 1969; Komar 1976). The original coastline at Madras was oriented 15º - 195º. After the construction of harbour due to erosion and accretion problems, it has changed drastically. The coastline in the erosion zone is oriented 20º - 200º, whereas the accretion zone is oriented 35º – 215º. It is estimated that the coastal erosion in the North Chennai is 5 to 10 m per year and accretion is of the order of only 0.5 m in the Marina Beach (Venugopal 1996).

The erosion potential experienced on the north Chennai coast poses a great danger to Ennore Highway, north Chennai rail link, the industrial installations, fishermen and disrupt normal life. It has been reported that an area of 260 hectares of land has been lost during 1893 and 1955 along the coastal region between Royapuram and Ennore. About 30 hectares of land have been destroyed by the sea during 1980 and 1989. Overall loss has been estimated to be of the order of 350 hectares during 1893 to 1989 (IHH Report 2000). The cost of land lost to the sea alone is of the order of Rs 200 crores equivalent to US$ 45 million.

The Chennai fishing harbour was constructed in the year 1975 and the Chennai Port Trust had extended their eastern breakwater and established an outer harbour. Thereafter the erosion in this coast became very pronounced and affected the north Chennai coastline, which necessitated constant attention and protection works in response to the cry of fishermen living along the coastline. About 15 villages were affected due to the coastal erosion (IHH Report 2000). Ever since the Chennai harbour was constructed, the coast north of the harbour has been experiencing erosion at the rate

of about 8 metres per year. It is estimated that 500 metres of beach has been lost during 1876 and 1975 and another 200 metres during 1978 and 1995.

Studies based on shoreline oscillations at selected locations during the period 1978 and 1988, revealed that erosion has taken place at Royapuram at the rate of 6.6 m/yr. Area of land lost is estimated as 215 ha (Kaliasundaram et al 1991). The erosion north of the harbour has resulted in the loss of various fishermen hamlets. The length of the erosion zone is 7.5 km at present and may continue if no proper protective measures are taken. Coastline of north Chennai coast has receded by about 100 m between 1978 and 1995 (Ramaiyan et al 1997).

Net littoral transport on this coast is towards north with the littoral sand trapped in between Chennai port and the southern end of Marina Beach. This results in the choking up of the mouth of Cooum river and blocked the exchange of tidal water and river discharge which is mostly of sewage. It has created a permanent health hazard problem in this area. In 1937, accretion has taken place up to a distance of 3 km from the Chennai harbour on the southern direction. But due to continued developmental activities within the harbour complex, the accretion is now causing menace to the river mouth of Adyar, located 5.5 km south of Chennai port (Kaliasundaram et al 1991).

The first coastal protection work was taken up in north Chennai during the year 1950. The protection work has become necessary since 1980 as the erosion has become vigorous after the construction of fishing harbour at Royapuram. A seawall for a length of 563 m was constructed to protect the Kasimode Bay to begin with as a remedial measure against sea erosion. After the construction, the erosion shifted to the north end of the seawall.

In order to contain the erosion along these stretches, temporary remedial measures such as concrete pipes (previously procured for Veeranam Project to supply water to Chennai city) of 1.2 m diameter, filled with sand, was erected during 1992 to 1996 as a toe mound. The effectiveness of these pipes lasted over a short period only.

Coastal protection works on Royapuram coast are presented in Figure 5.1. At several places along the coast, rock revetments are built to protect private property and the coastal road. These revetments reflect waves more than the original beach and thus contribute to a local increase in wave height with an associated increase in offshore transport. The rock revetments have temporarily protected and stabilized the coast directly behind them but failed in preventing erosion on the downdrift. Erosion experienced at Periakuppam village located south of Ennore on the down drift coast is presented in Figure 5.2. It is seen from the figure that fishing hamlets on the coast are severely affected by erosion year after year. At this location rubble mounds are dumped at present in order to save the remaining houses. At present the erosion has extended almost over the entire 10 km coast between Chennai and Ennore and hardly any sandy beach is visible. The total cost of expenditure spent by the Government agencies (IHH Report 2000) towards the coastal protection works in this eroding coast during last ten years is about 15 Crores of rupees.

Construction of groyne field is considered to be the most effective method of protection on the eroding coast (Nagai 1956). Groyne field cannot function independently and it requires continuous monitoring and periodical nourishment (CERC 1984). A series of short groynes capable of interrupting long shore sediment transport was proposed by the Institute of Hydraulics and Hydrology, Poondi (Sahadevan 1996; IHH Report 2000) with an assumption that it would take less time to fill the compartments between the groynes by natural transport processes. A physical modeling study conducted by Sundar (1999) revealed that the downdrift erosion would be limited as a series of 10 groyne with an overall length of 90 m at an interval of 275 m to protect the Royapuram-Ennore coast. These proposals were evolved prior to the construction of satellite harbour. In order to protect the coastal stretch of fisheries harbour to Ennore creek, construction of 500 m groyne was originally contemplated by Haskoning (1995). This proposal was discussed to comply with the stabilisation and protection of the sea front with beach pockets that existed prior to 1990.

Institute of Hydraulics and Hydrology, Poondi (IHH Report 1984; Sahadevan 1996)) has conducted a study using physical model to determine the performance of 100 m long discontinuous offshore breakwater laid at –3.0 metre contour from fishing harbour to Ennore creek and confirmed the worthiness of construction of offshore discontinuous breakwaters (IHH Report 1989). In the coastal conservation programme, a reclamation scheme is suggested by Mani (2001) wherein a sea wall would be constructed at a distance of about 150 m from the present coastline with 100 m long landing beaches at every one km distance to provide an access to the fishermen.

It can be seen that whichever method is finally adopted, cost involved will be huge and large scale work would also be involved. It would be possible to implement the mitigation methods, only if all the involved agencies act together. The lessons learnt and experiences gained from the earlier cases along the Chennai coast suggests that issues are not resolved completely due to the following reasons:

- In spite of considerable efforts made by the Government of Tamil Nadu (an expenditure of Rs 138 Crores spent so far) to protect the Royapuram coast, the issue is not resolved because the measures are highly localised in nature and the problem is shifted from Royapuram to EID parry (Ennore) over a length of 8 km by construction of seawall.

- The behaviour of coastal processes is not understood completely due to lack of proper monitoring mechanism after the implementation of protection measures. Often the schemes are worked out based on the limited oceanographic information, which is rather expensive to collect and
- The coordination between the agencies operating in the coastal developmental activities is not satisfactory due to their individual mandates and constraints.

In addition to Chennai port, the Ennore satellite port has also started functioning on the north Chennai coast from 2001. In order to fill the gaps which were identified

from the background information of Chennai port, an effort has been made to collect data on environmental parameters such as waves, tides, current, sediment characteristics, bathymetry, etc. In order to identify the impacts beach profile and shoreline surveys have also been conducted. The results are presented and discussed in detail in the following sections.

6.3 FIELD OBSERVATIONS

The field measurements were carried out for the parameters such as (i) tides and waves (ii) Currents (iii) Wave orbital velocities (iv) Beach Profiles (v) Bathymetry and (vi) Sediment Characteristics.

The field program was organised from 13th May to 2nd June 2001 between Ennore and Pulicat lake to study the oceanographic parameters. The overall objective the study is to assess the skill of wave transformation, hydrodynamics in coastal stretch between Ennore and Pulicat through collecting wave, water level, current and bathymetry and other supporting data to quantify the environmental conditions. Details of the parameters and the equipment used are given in Table 6.1. Location of field measurements on the Ennore – Pulicat offshore region is presented in Figure 6.1. Results of the measurements are discussed in the following sections and in the next Chapter.

Table 6.1 Deatails of parameters and equipment deployed

Parameter	Equipment
Waves and Tides (water levels)	Wave and tide gauge (Veleport), 730W
Currents	Self Recording current meter (RCM 9 of Anderra) and Acoustic current meter (Aquadrop, Nortek)
Wave orbital velocities	Acoustic Doppler velocity meter (ADV), Sontek
Beach Profiles	Wave Sled, Eco Sounder and Real time Kinematic GPS, Leica
Bathymetry	Odem Ecosounder interfaced with differential GPS and track position controlled by HYPACK software

6.4 TIDES

The daily rise and fall of the tides is caused by the gravitational attractions of the moon and sun acting on water particles on the surface of the earth. A convenient model of examining the mechanisms of tides is the equilibrium theory of tides proposed by Darwin (1898). In addition to the variation in the tides that are a result of the relative positions of the moon and the sun (the fortnightly equality), there are effects caused by the varying distances between the moon and the earth (the parallactic inequality), which has the period of about 27.55 days and the varying distance between earth and the sun. For the present study Tide & Wave gauge (Valeport) along with current meter was deployed simultaneously for three days in six locations on both sides of the Ennore port and both sides of the Ennore shoals.

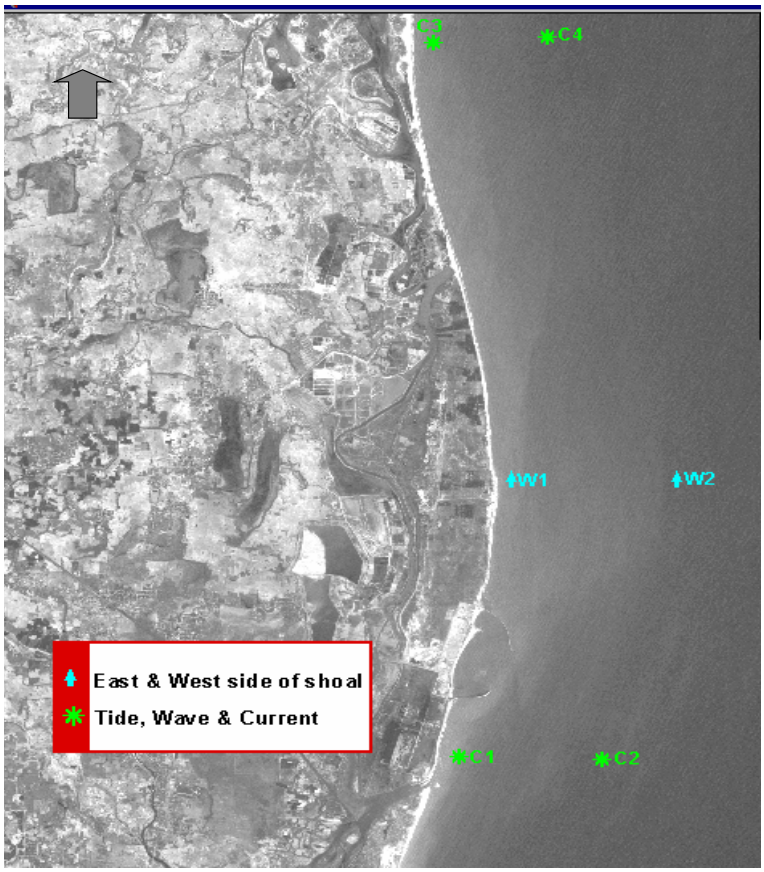


Figure 6.1 Locations of Data Collection on Ennore – Pulicat Offshore Region

Water levels were recorded for every four minutes, the recorded levels were processed and chart datum reduced for further comparison to know the phase lag between the near shore and offshore locations of tide stations. Observed levels were given in the Appendix and the results are depicted in the corresponding Figures 6.2 and 6.3. Phase lag between the stations C2 and C4 observed as 4 minutes.

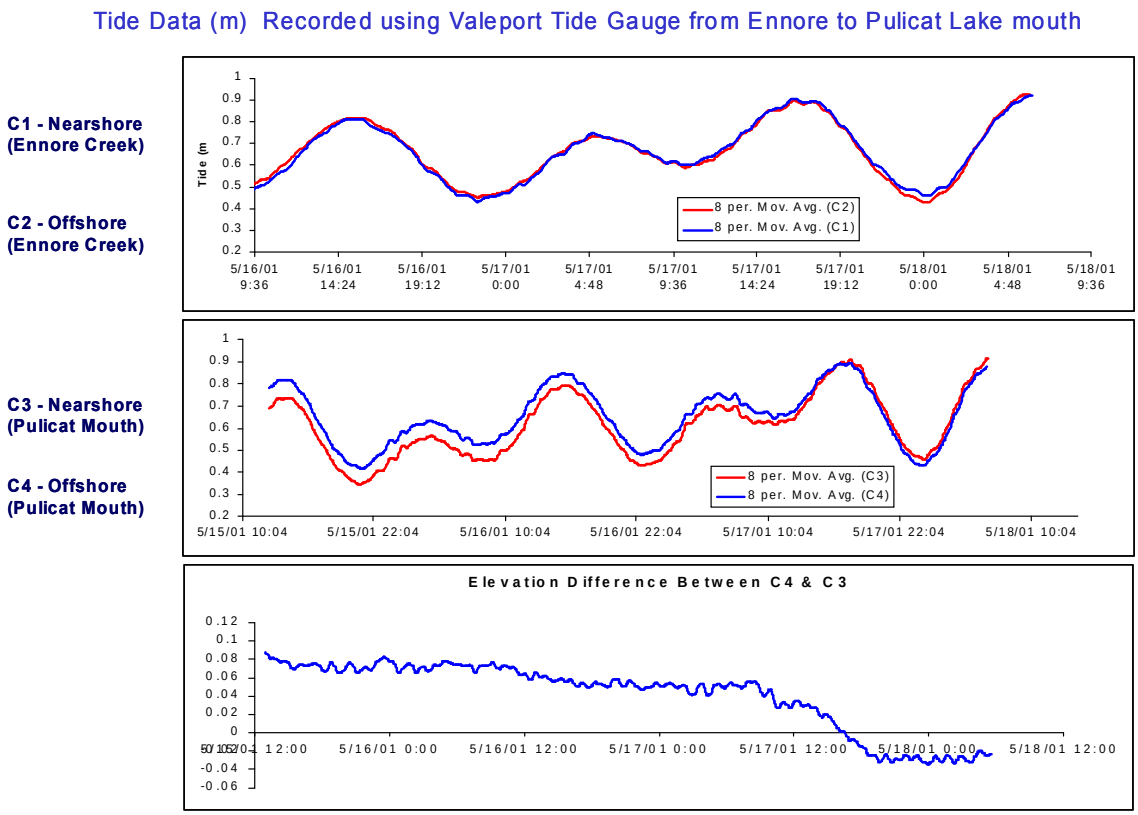


Figure 6.2 Comparison of tidal elevation in nearshore and offshore region of Ennore and Pulicat coast

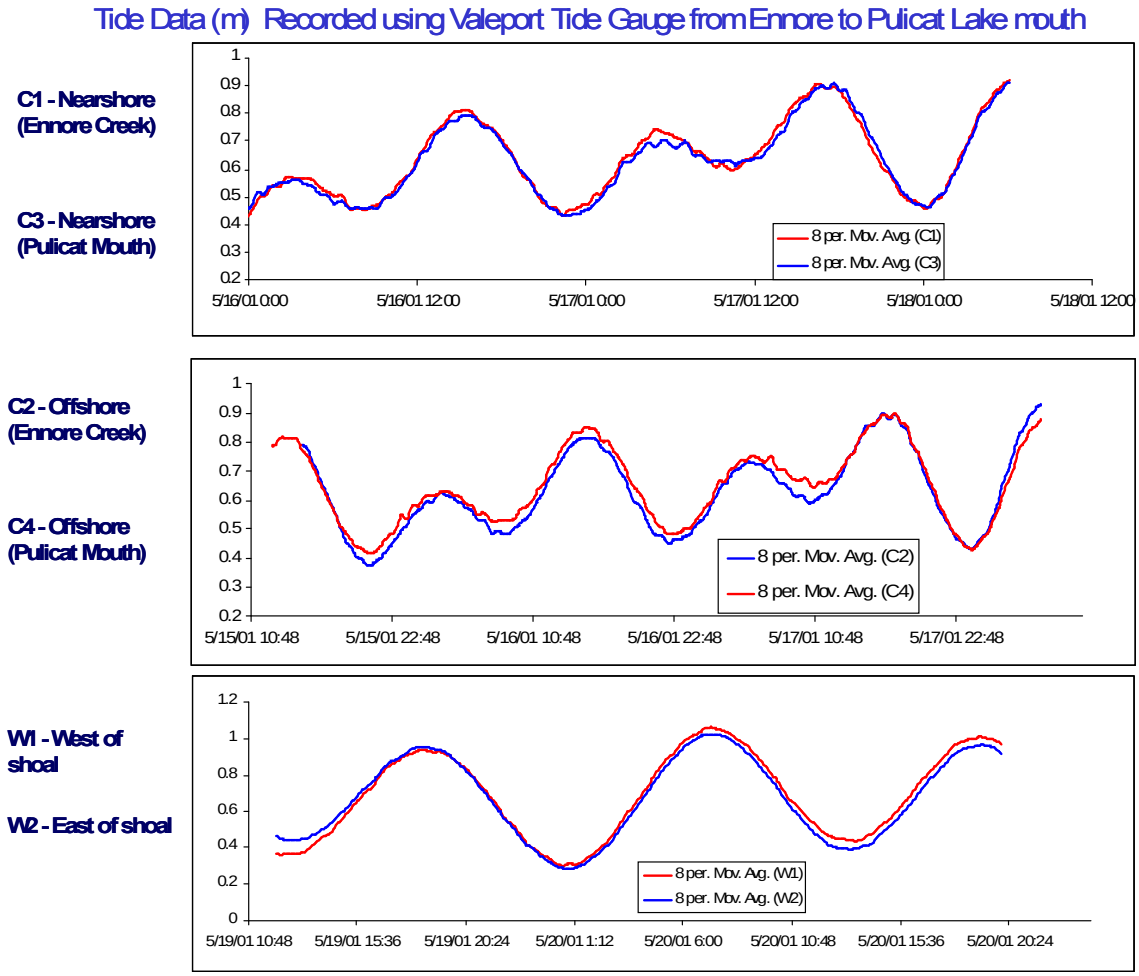


Figure 6.3 Comparison of tidal elevation in nearshore and offshore region of Ennore, Pulicat coast and shoal region

Not much difference is observed between the W1 and W2 locations which are falling on east and western side of the Ennore shoal respectively. The results from these observations are used for the profile corrections and to use in the numerical modeling studies.

6.5 WAVE CHARACTERISTICS

A beach must constantly adjust to wave energy and water levels. It must sacrifice some beach, to provide material for the building of an offshore bar. The beach berm, built by waves to the highest elevation that can be reached by normal storm waves, is another protection barrier, whose value is reduced when its sand is carried offshore.

Major causes of beach erosion are waves, storm surges, near shore currents and tides. The usual response of a beach is sand loss, migration off-shore and berm width decrease. Critical conditions for erosion involves wave steepness, sediment fall velocity and beach bed slope. The supply of beach sediment is affected by an areas coastal geology which determines the initial conditions for littoral processes. Waves can be a primary cause of erosion due to the energy they have stored; they can create various near shore currents and develop specific sand transport patterns.

The width of a breaker zone, an area in which waves of varying heights break at specific depth, depends on beach slope and wave size range. Beach sediments grain size and wave energy level are determinant in over all beach slope. The coarser the steeper the slope as breaking occurs at the foreshore (beach faces) base. Hence the beach profile morphology itself is influenced by wave energy levels as high waves shift sand off-shore, thus eroding the beach berm and re-deposition the material in the breaker zone there by building off shore bars.

For the present study to know the wave climate in the study region the wave gauge (Valeport) was deployed in all six locations C1, C2, C3, C4, W1 and W2. Wave parameters Tp, Ts and Hs were recorded in four minutes interval. The results were given in the Figures 6.4 to 6.9.

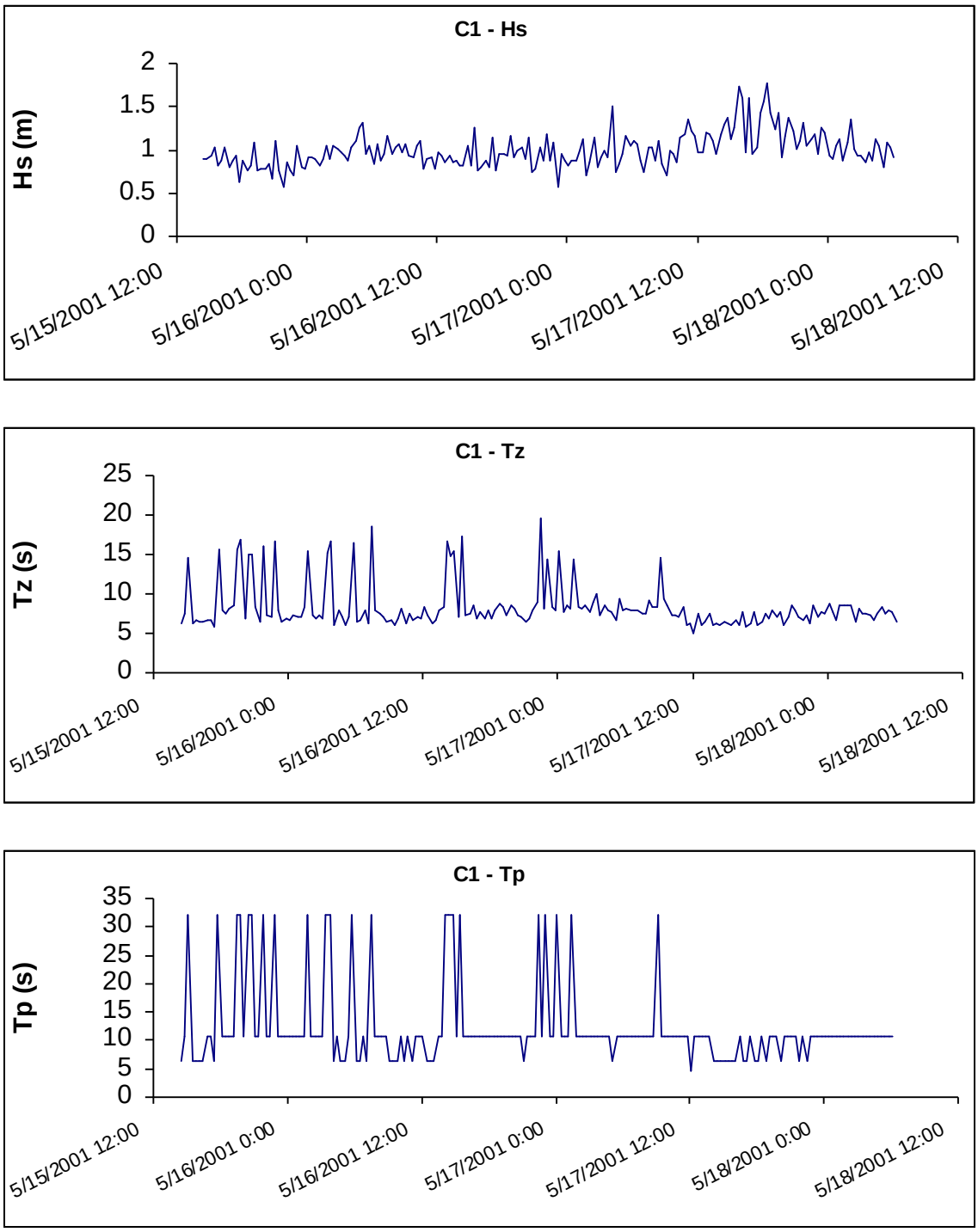


Figure 6.4 Wave Parameters in the Study Area

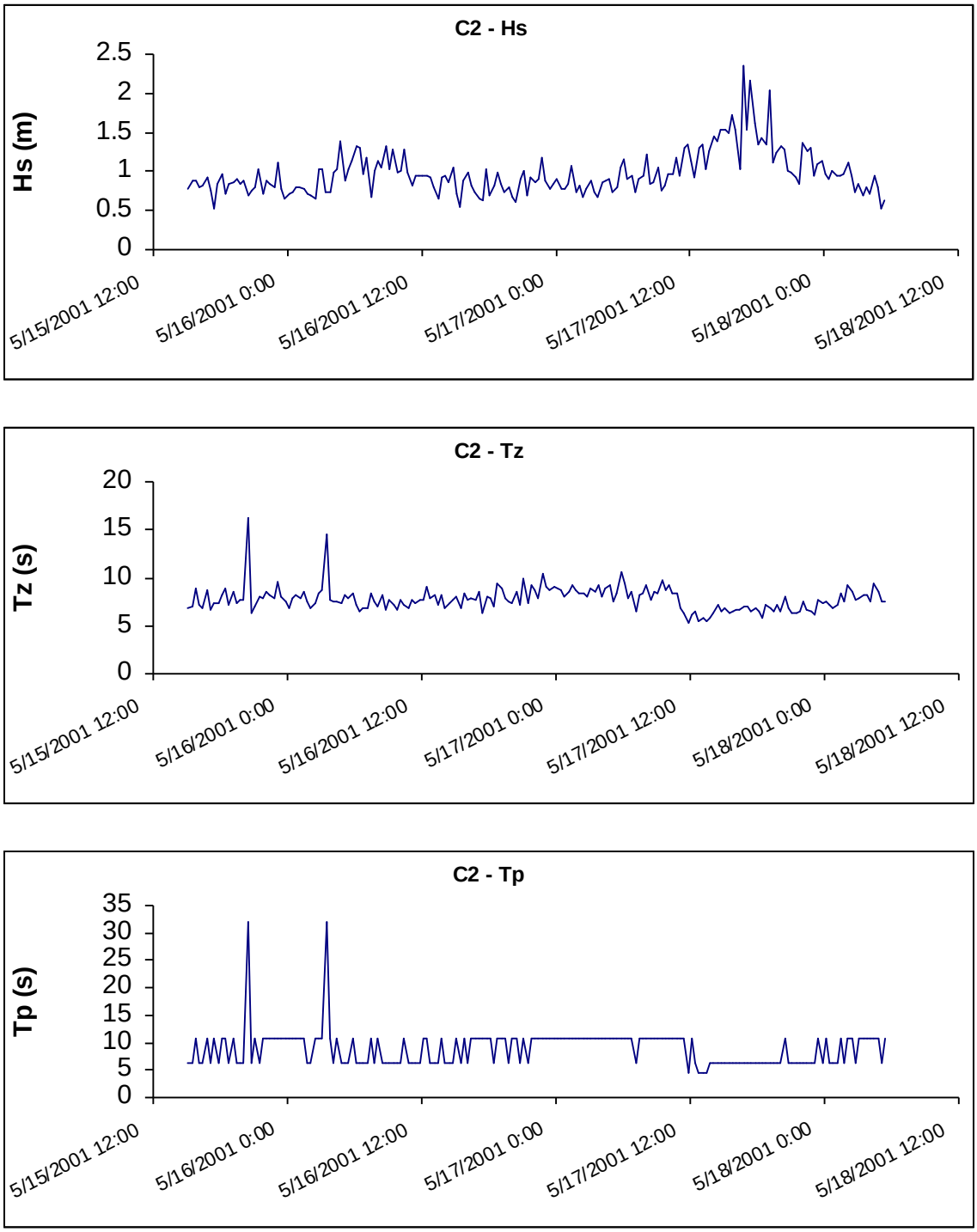


Figure 6.5 Wave Parameters in the Study Area

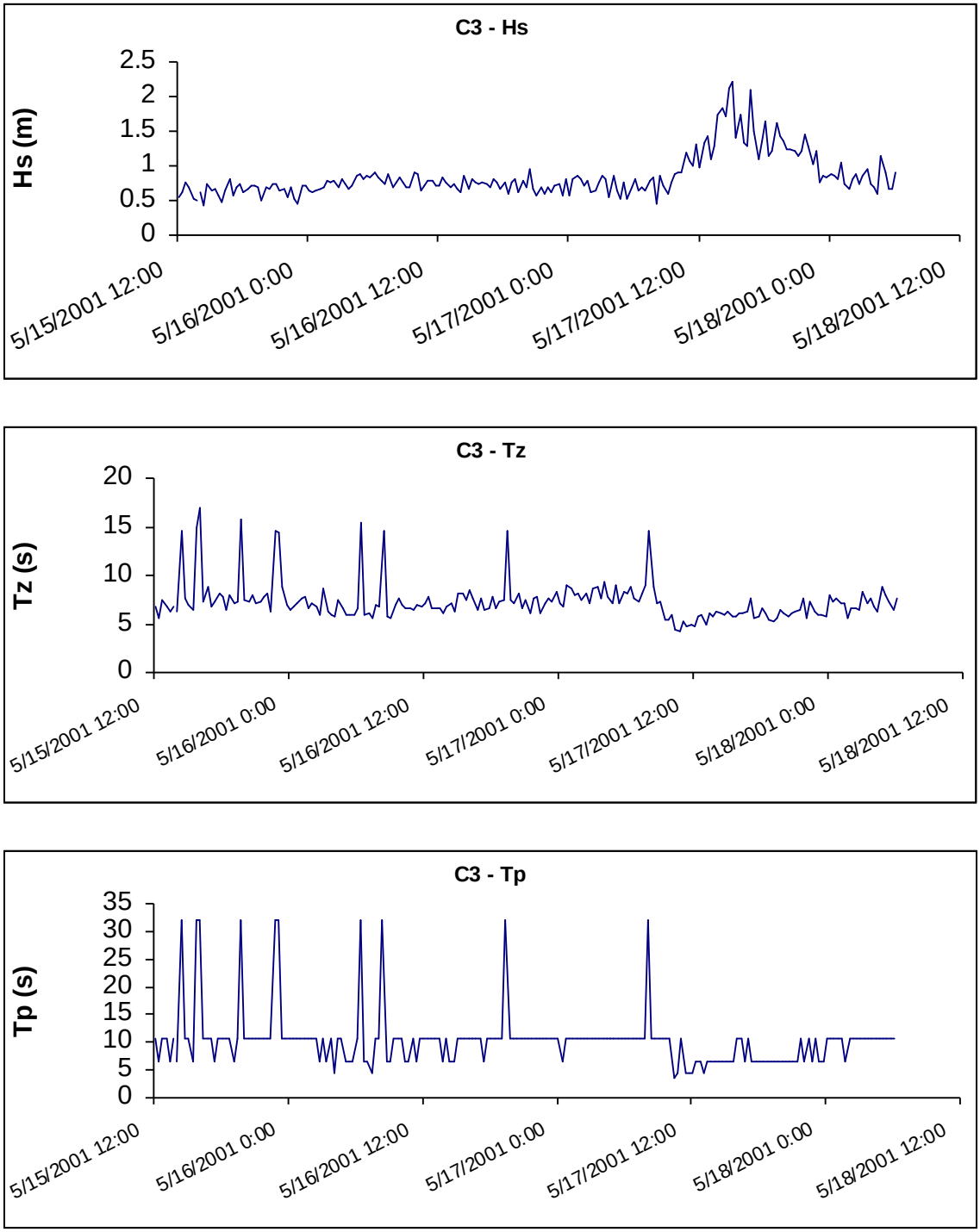
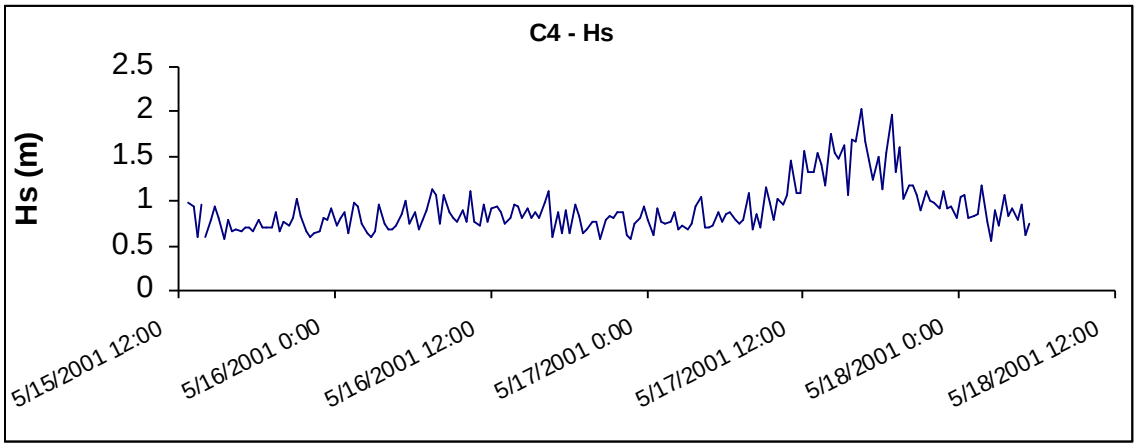
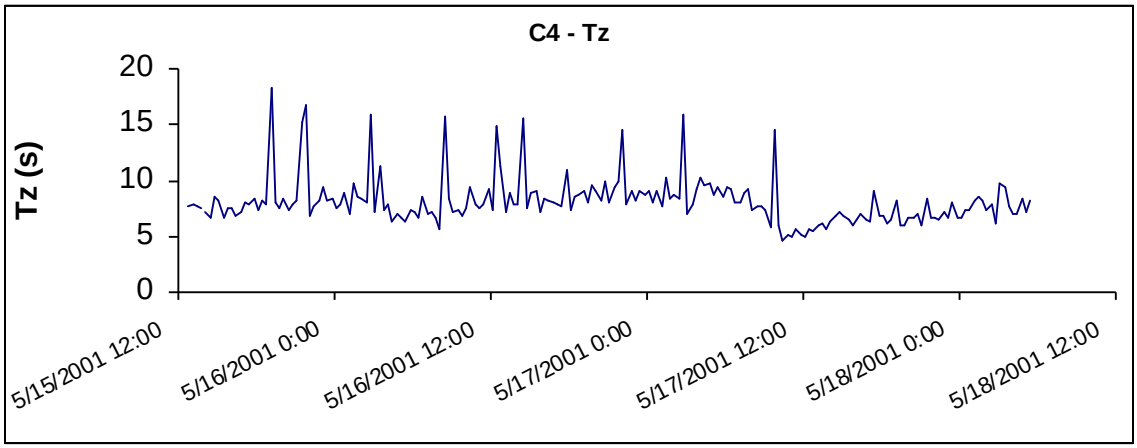


Figure 6.6 Wave Parameters in the Study Area





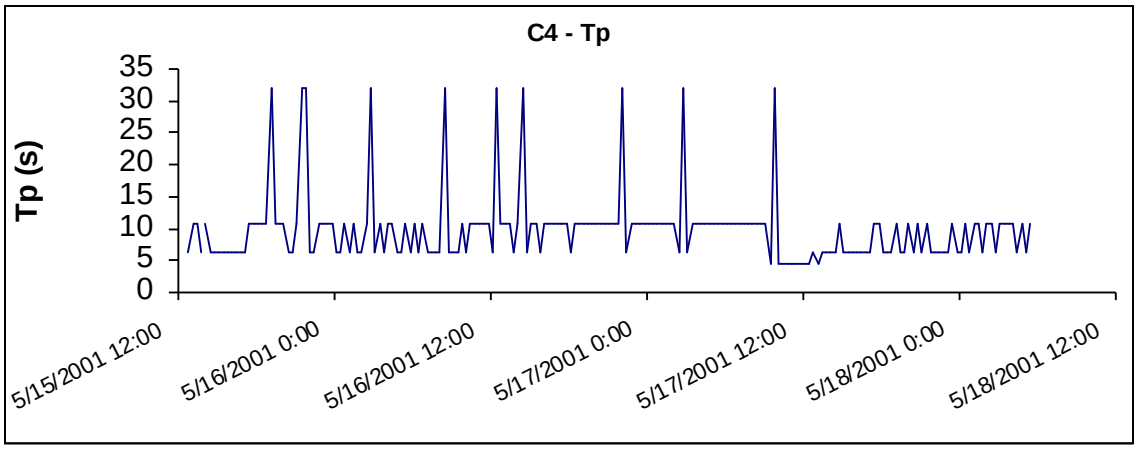


Figure 6.7 Wave Parameters in the Study Area

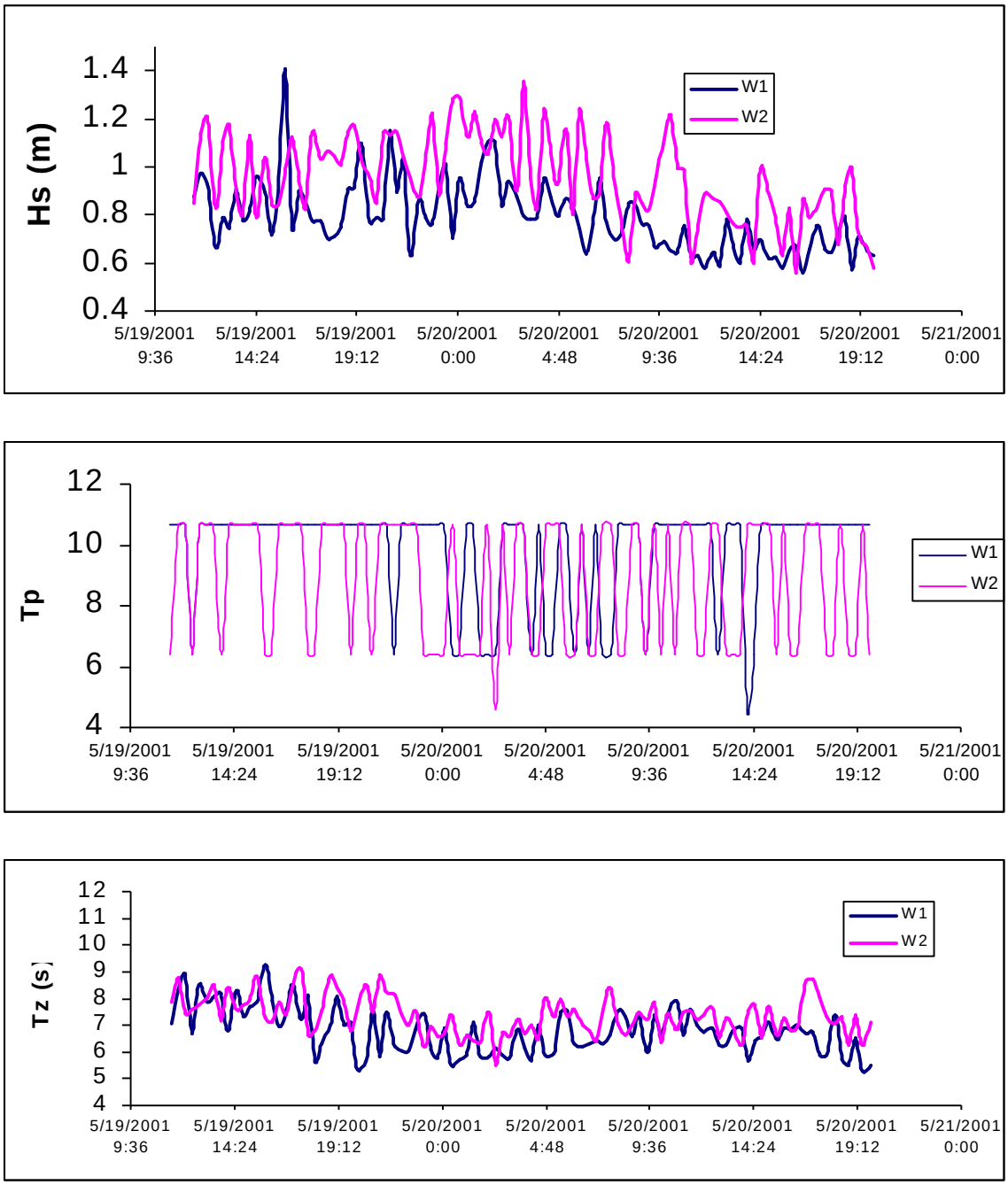


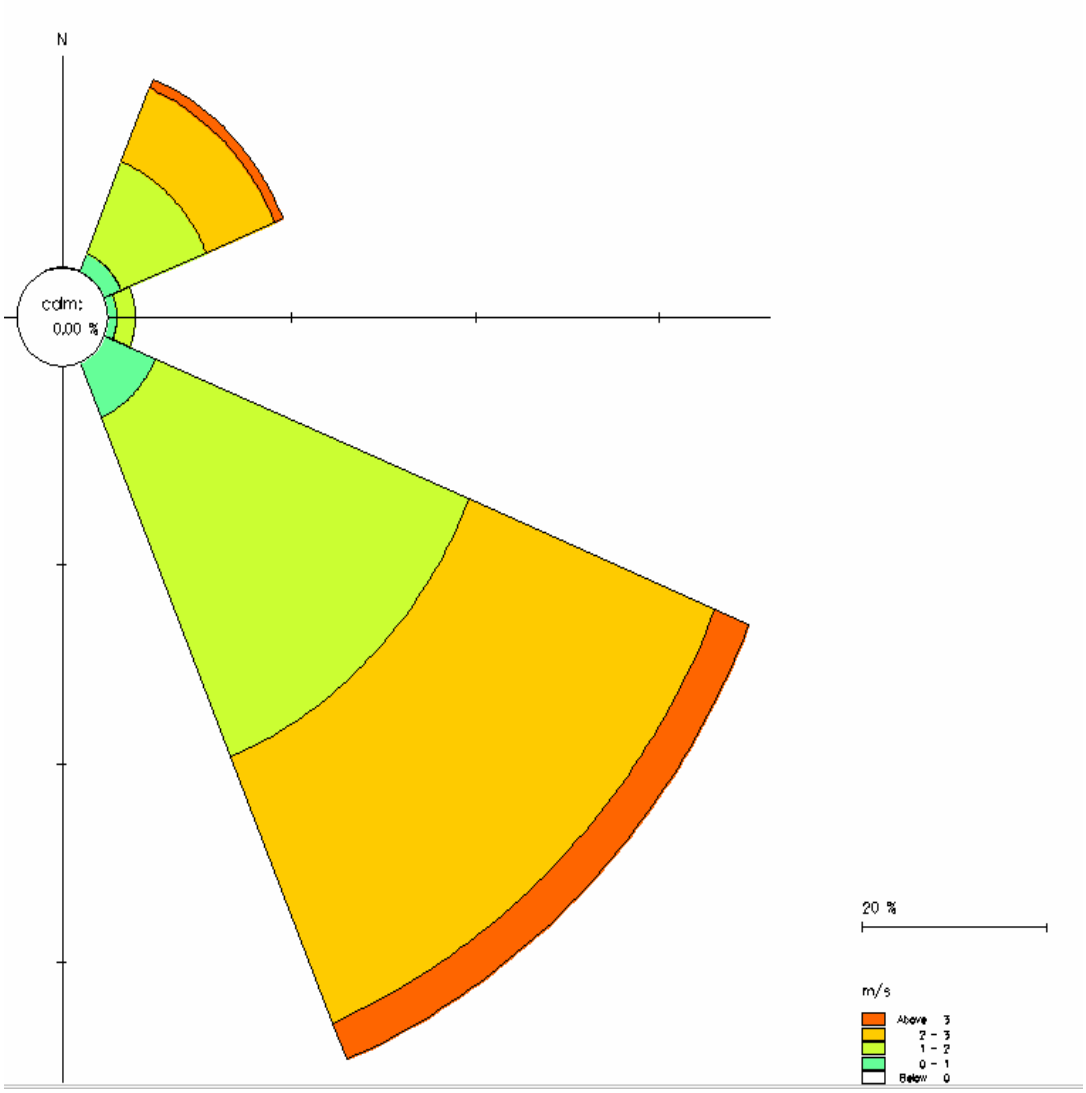
Figure 6.8 Wave Parameters in the Study Area

The results from the study show not much wave height difference between C1 to C4 stations. But W1 and W2 stations show that the eastern sides of the shoal (W2) have Hs of 1.1 m while the W1 is having 0.8 m, reflecting the shoals obstruction on wave

energy. This obstruction reduces the present erosion problems on the northern side of the breakwater. In long run the shoal will get eroded slowly then the problem of erosion will be multiplied. Obtained results are given in the following tables.

Based on the field observations and the historical observation on the wave characteristics of the study region following wave climate is generated from NSW module to use in LITPACK for further simulations on coastline evolution and for remedial solutions.

Figure 6.9 Wave Pattern in the Study Area



6.6 CURRENTS IN THE STUDY REGION

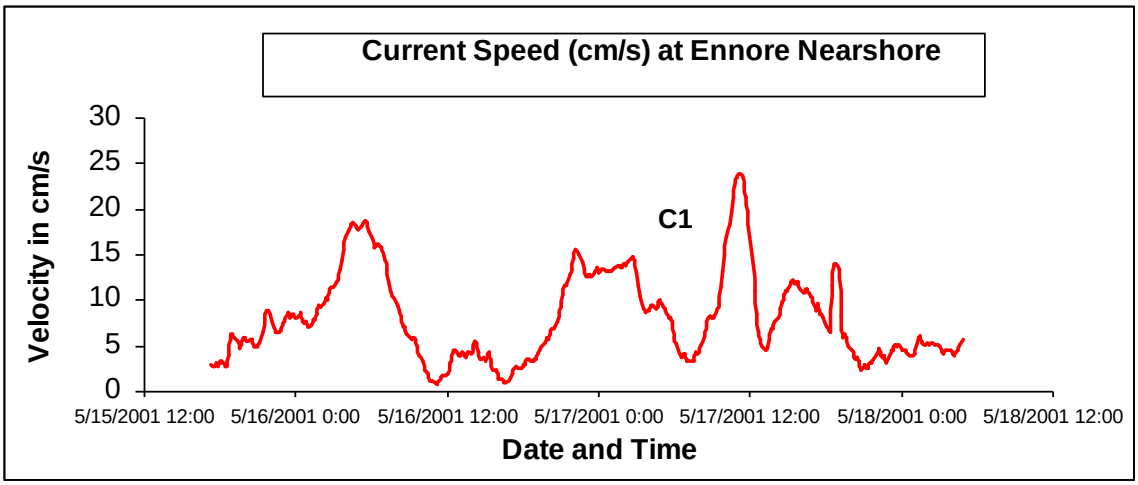
6.6.1 Current pattern in East coast of India

The surface currents in Bay of Bengal are developed by the turning of Southwest Monsoon Current (SMC) around Sri Lanka and flowing towards the bay. The SMC is the extension of the Somali current of Northeast Indian Ocean and the surface current flow east of Sri Lanka is of the order of 40 cm/s. Reports from the direct measurements south of Sri Lanka suggests that the circulation along the coast of Sri Lanka plays an important linking role for the current circulation pattern of east coast of India.

Earlier studies on forcing mechanism for the circulation pattern in Bay of Bengal suggested two important mechanisms that drive the summer monsoon circulation in the interior of Bay of Bengal. The first one is the Ekman pumping by the winds over the Bay of Bengal are southwesterly during summer, and they posses positive (cyclonic) curl in the western part of the Bay of Bengal and negative (anticyclonic) curl in the eastern part. The second one is due to the Rossby wave radiated from the eastern boundary, primarily by the reflection of the eastward spring Wyrtki jet in the equatorial Indian Ocean. During the transition between monsoons (i.e during April – May and October –November) the westerly winds along the equatorial Indian Ocean drive intense eastward jets. Hence the firs mechanism can affect the SMC locally as well as remotely through Rossby waves generated in the eastern part of the ocean; the second mechanism influences the SMC by Rossby wave radiation from the eastern boundary. The background information's on SMC will give an idea for the model simulation for the forcing mechanisms for the environmental parameters (waves, current etc) in the study region for the long-term predictions. It is to be noted that the SMC serves as an open ocean links that connects Arabian Sea and Bay of Bengal and has an important role in the salt balance of the Bay of Bengal.

6.6.2Current Pattern in the Study Area

To study the current pattern in the study area RCM 9 current meter was deployed along Aquadopp. Current speed and direction were recorded for every 10 minutes for the period of three days. Results from the current observation are given in the Figures 6.10 to 6.13. Observed data are presented in Tables 6.2 and 6.3. To have a comparative idea the RCM9 data direction plotted with Aquadopp data for one location and it show almost similar behavior in the direction.



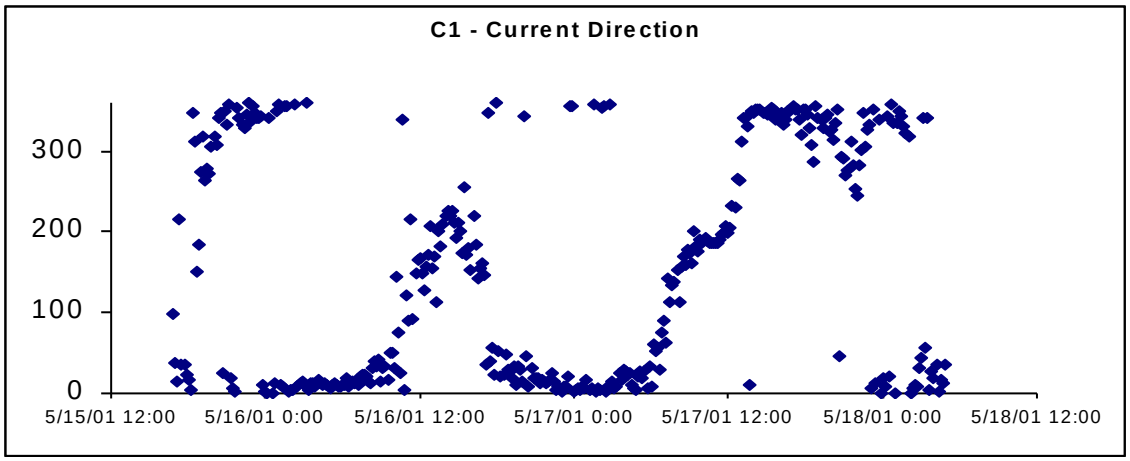
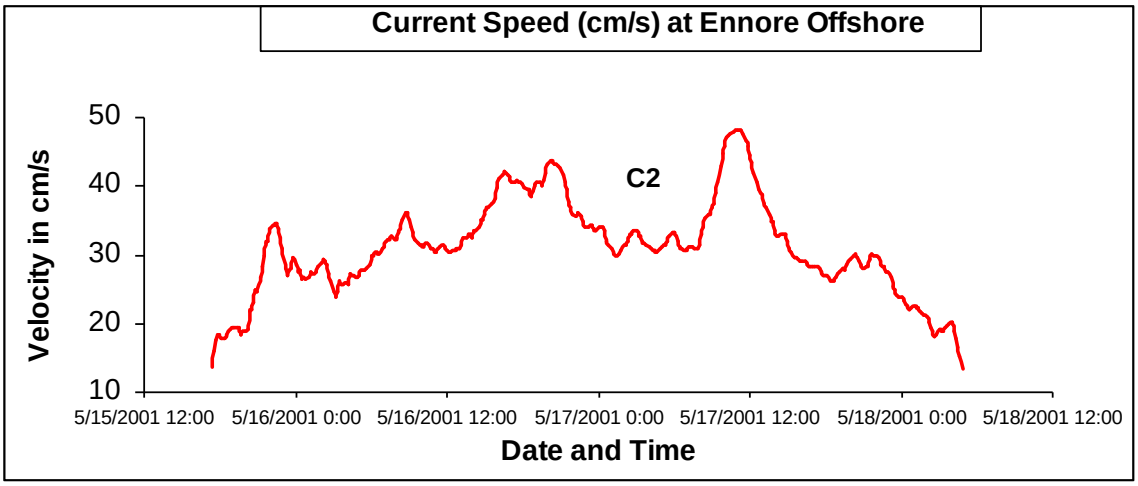
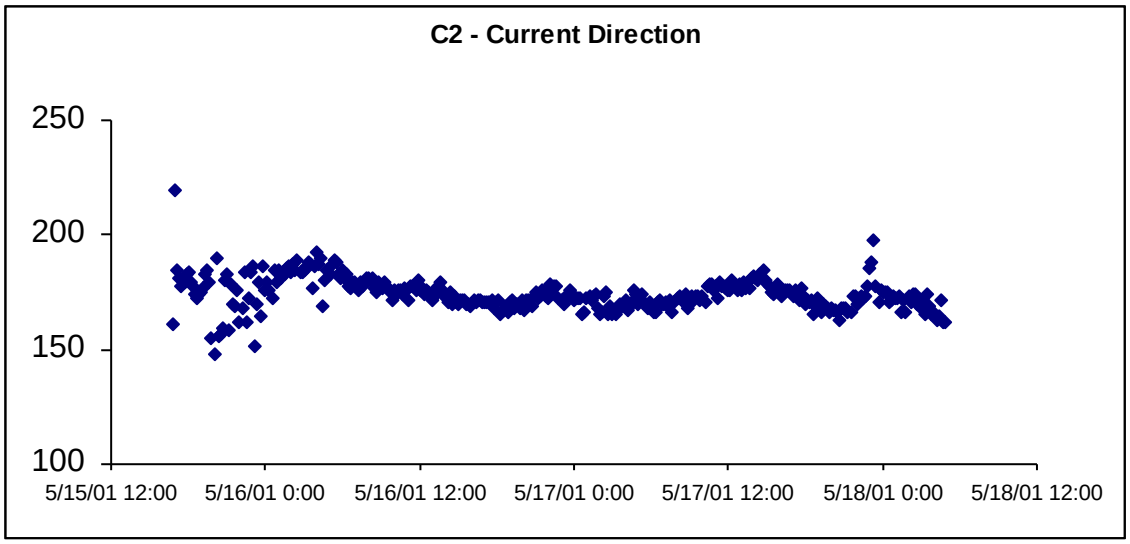


Figure 6.10 Current pattern in the study area





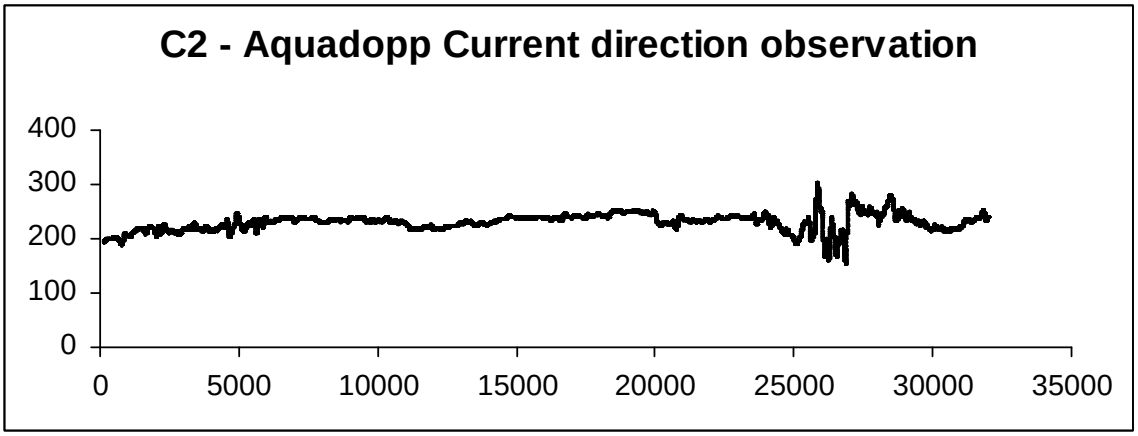
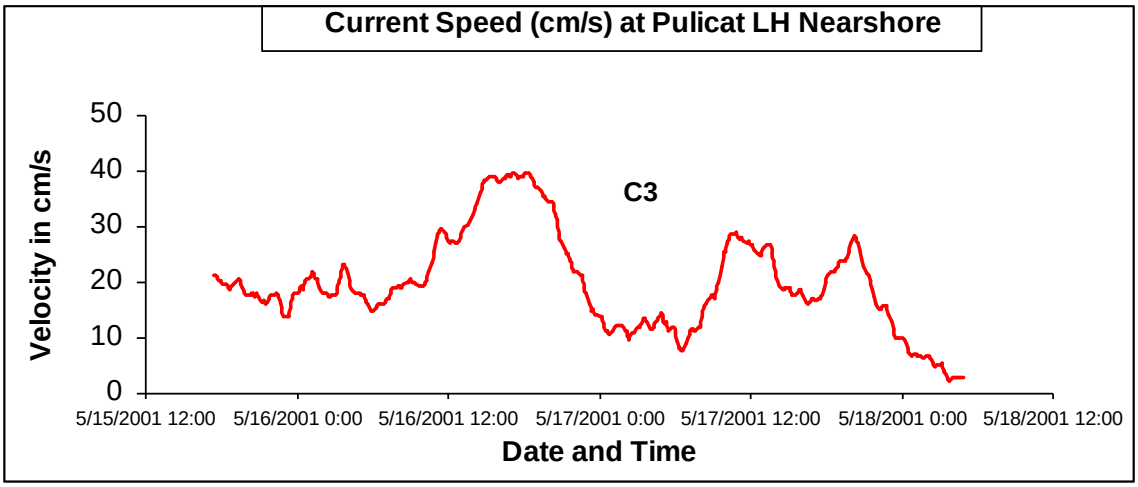
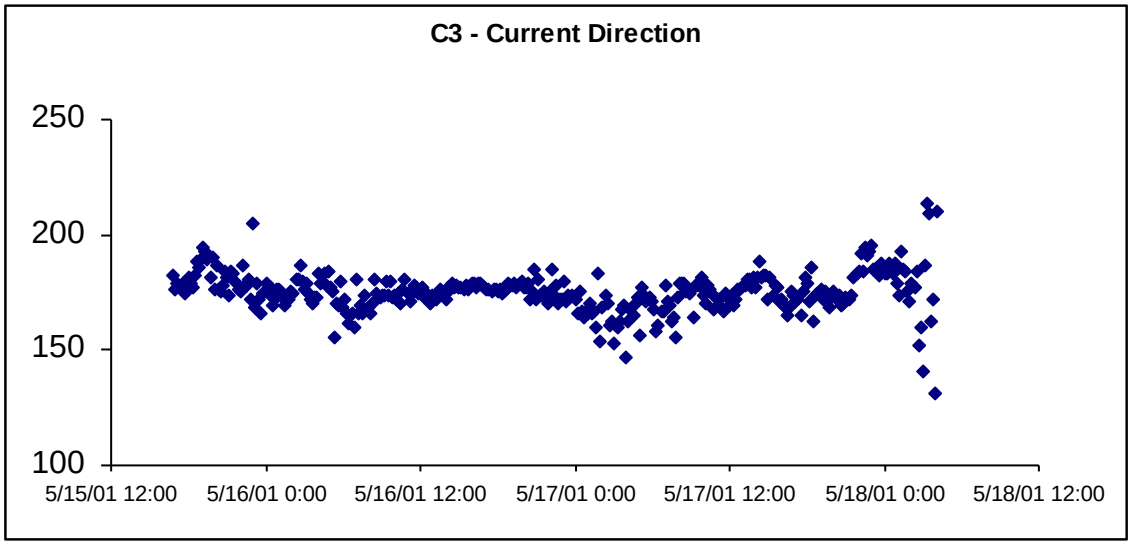


Figure 6.11 Current pattern in the study area





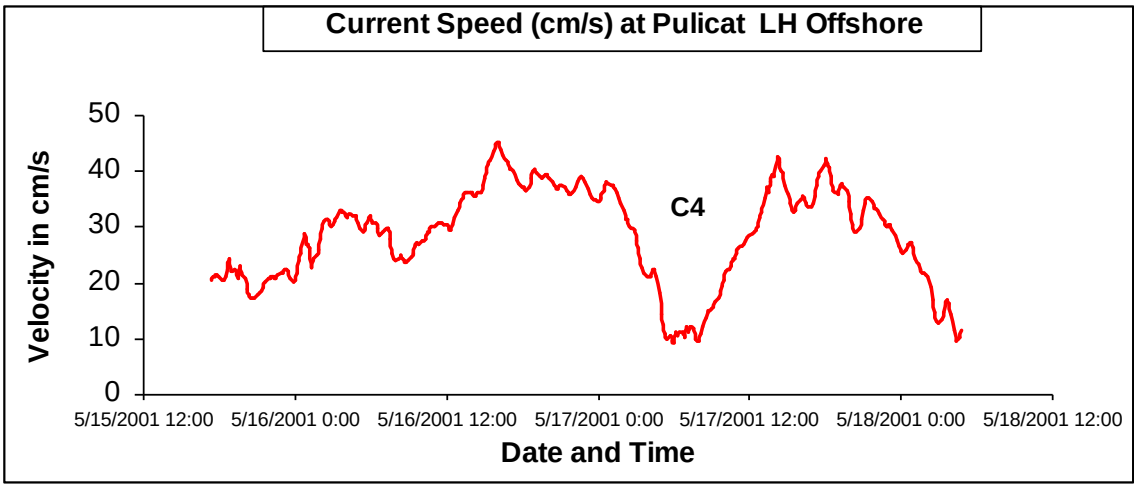
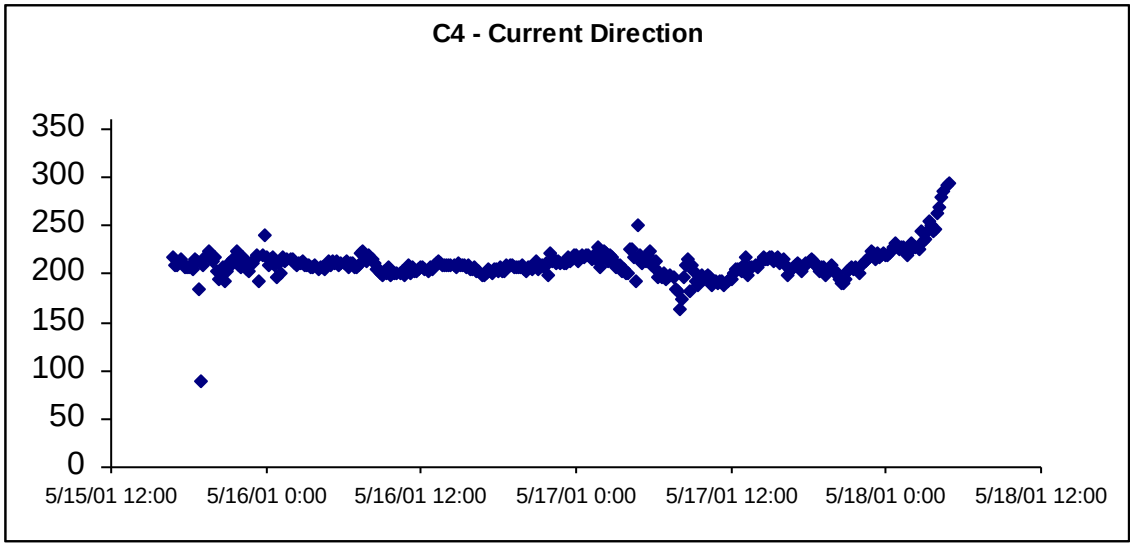
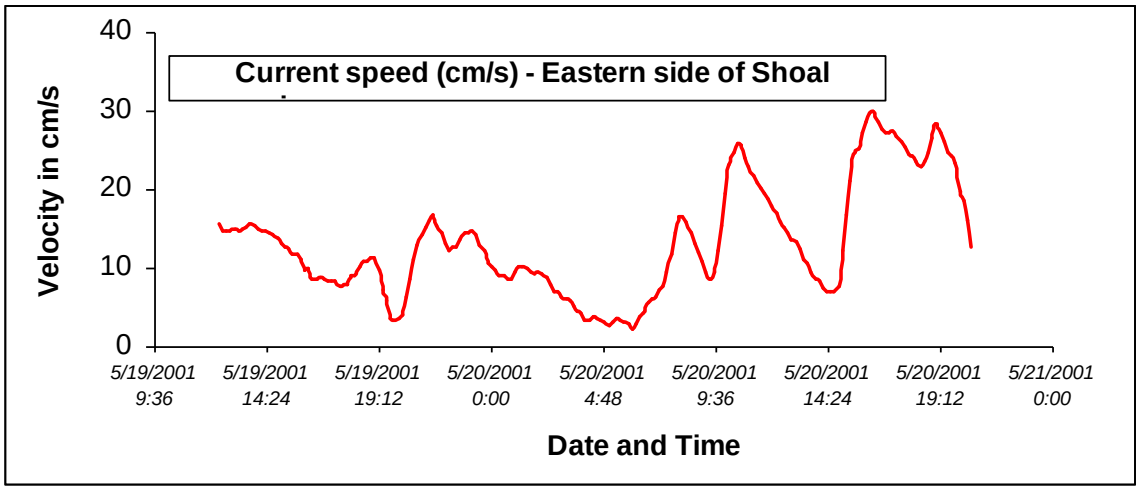


Figure 6.12 Current pattern in the study area





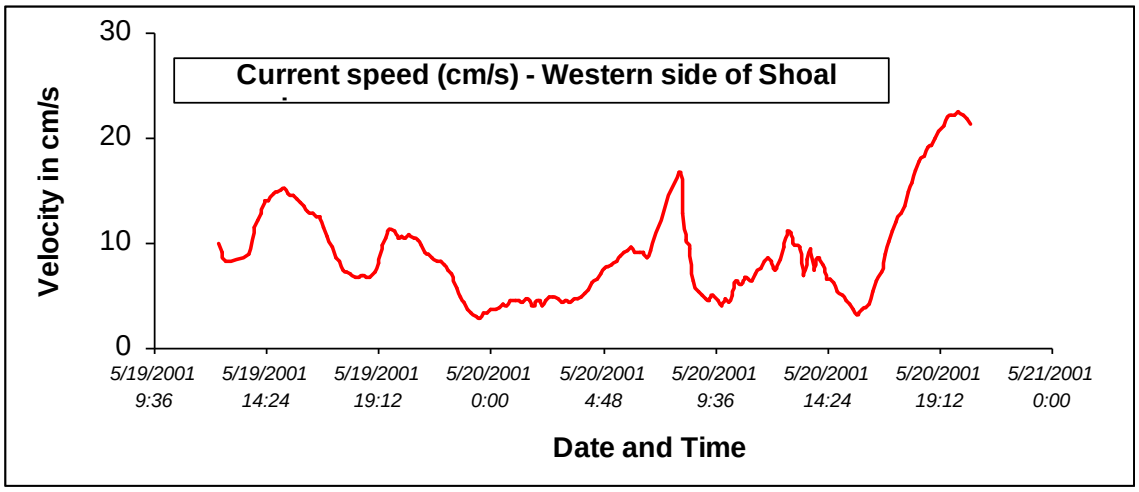


Figure 6.13 Current pattern in the study area

Table 6.2 Observed Current Speed (cm/s) and Direction (degrees) Near Ennore Port at C1 and C2

	C1		C2	
Date/time	Current speed	Direction	Current speed	Direction
5/15/2001 16:50	2.0531	98.0964	8.799	160.681
5/15/2001 17:00	3.5196	37.6212	12.3186	219.047
5/15/2001 17:10	5.2794	15.4704	15.2516	184.238
5/15/2001 17:20	1.1732	216.586	17.8913	181.426
5/15/2001 17:30	0.8799	36.5664	18.1846	177.91
5/15/2001 17:40	5.2794	35.16	18.7712	178.964
5/15/2001 17:50	3.5196	22.854	18.4779	182.48
5/15/2001 18:00	2.6397	17.58	17.598	183.535
5/15/2001 18:10	1.7598	4.5708	17.0114	179.668
5/15/2001 18:20	2.933	347.029	18.4779	177.206
5/15/2001 18:30	4.3995	311.166	19.9444	174.042
5/15/2001 18:40	6.71657	150.836	19.6511	172.284
5/15/2001 18:50	10.5588	184.942	18.1846	174.394
5/15/2001 19:00	3.8129	274.951	19.6511	174.745
5/15/2001 19:10	2.933	318.901	20.531	176.503
5/15/2001 19:20	4.6928	263.348	19.3578	182.832
5/15/2001 19:30	7.3325	279.17	17.598	184.942
5/15/2001 19:40	5.5727	271.787	15.5449	179.316
5/15/2001 19:50	5.5727	305.189	23.1707	154.704
5/15/2001 20:00	5.2794	317.495	19.3578	148.375
5/15/2001 20:10	5.866	308.353	18.7712	189.512
5/15/2001 20:20	5.866	341.755	26.1037	155.759
5/15/2001 20:30	5.5727	347.732	24.0506	156.814
5/15/2001 20:40	2.6397	24.2604	23.464	159.275
5/15/2001 20:50	5.866	349.139	26.1037	180.019
5/15/2001 21:00	5.5727	333.668	24.9305	182.832
5/15/2001 21:10	7.6258	358.28	32.263	158.572
5/15/2001 21:20	7.3325	17.9316	29.6233	178.613
5/15/2001 21:30	11.1454	6.6804	32.263	170.174
5/15/2001 21:40	9.0923	2.1096	32.5563	169.12
5/15/2001 21:50	7.9191	354.764	33.1429	176.152
5/15/2001 22:00	6.1593	341.404	37.5424	161.736
5/15/2001 22:10	7.6258	331.91	33.7295	168.065
5/15/2001 22:20	4.6928	329.449	32.8496	183.887
5/15/2001 22:30	7.3325	344.568	34.3161	162.088
5/15/2001 22:40	6.1593	359.687	34.6094	172.636
5/15/2001 22:50	8.799	337.888	28.4501	183.887
5/15/2001 23:00	7.0392	356.522	25.8104	185.996
5/15/2001 23:10	9.0923	347.381	23.1707	151.54
5/15/2001 23:20	9.6789	342.107	30.5032	169.471

5/15/2001 23:30	6.4526	342.107	31.6764	179.316
5/15/2001 23:40	8.2124	343.865	26.6903	164.9
5/15/2001 23:50	9.6789	9.8448	29.6233	185.996
5/16/2001 0:01	8.2124	1.758	26.397	175.8
5/16/2001 0:10	7.0392	0.7032	27.8635	179.316
5/16/2001 0:20	9.6789	340.349	26.9836	175.8
5/16/2001 0:30	6.1593	0.3516	24.6372	172.636
5/16/2001 0:40	7.3325	12.6576	27.5702	184.59
5/16/2001 0:50	7.6258	349.139	26.397	179.316
5/16/2001 1:00	7.6258	356.874	28.4501	184.238
5/16/2001 1:10	6.7459	9.8448	28.1568	181.426
5/16/2001 1:20	9.6789	7.7352	26.397	183.535
5/16/2001 1:30	7.9191	356.522	26.397	182.48
5/16/2001 1:40	9.6789	356.522	29.6233	185.645
5/16/2001 1:50	10.8521	1.4064	30.7965	186.348
5/16/2001 2:00	8.5057	4.5708	28.7434	183.887
5/16/2001 2:10	9.3856	4.9224	28.7434	187.051
5/16/2001 2:20	12.0253	358.28	28.4501	184.942
5/16/2001 2:30	10.5588	7.7352	28.7434	188.809
5/16/2001 2:40	11.732	11.6028	23.464	183.535
5/16/2001 2:50	11.732	14.4156	24.3439	183.887
5/16/2001 3:00	12.0253	11.2512	22.2908	184.238
5/16/2001 3:10	12.6119	358.984	25.8104	186.7
5/16/2001 3:20	13.4918	4.2192	26.397	188.106
5/16/2001 3:30	15.8382	11.9544	30.2099	187.403
5/16/2001 3:40	15.8382	11.9544	20.8243	176.855
5/16/2001 3:50	17.3047	8.0868	25.2238	185.996
5/16/2001 4:00	18.7712	12.6576	27.5702	192.325
5/16/2001 4:10	18.7712	16.8768	28.7434	187.403
5/16/2001 4:20	18.7712	12.6576	27.5702	189.512
5/16/2001 4:30	17.8913	11.2512	24.3439	169.12
5/16/2001 4:40	18.1846	11.6028	26.9836	180.371
5/16/2001 4:50	17.8913	9.4932	27.5702	184.238
5/16/2001 5:00	17.3047	5.274	29.33	182.832
5/16/2001 5:10	19.0645	11.2512	27.2769	187.403
5/16/2001 5:20	19.6511	11.9544	26.9836	189.161
5/16/2001 5:30	19.0645	9.4932	27.8635	187.754
5/16/2001 5:40	16.4248	7.3836	29.6233	182.48
5/16/2001 5:50	14.9583	7.7352	30.2099	181.074
5/16/2001 6:00	16.4248	9.8448	31.9697	184.238
5/16/2001 6:10	15.2516	11.2512	28.1568	181.074
5/16/2001 6:20	17.3047	19.6896	31.3831	182.48
5/16/2001 6:30	16.1315	8.79	29.9166	177.558
5/16/2001 6:40	15.2516	12.6576	30.7965	176.503
5/16/2001 6:50	14.0784	14.7672	31.3831	179.316
5/16/2001 7:00	12.3186	13.3608	32.8496	178.964
5/16/2001 7:10	11.732	10.8996	32.5563	176.152
5/16/2001 7:20	9.6789	20.7444	32.263	179.668

5/16/2001 7:30	10.5588	22.854	31.6764	177.91
5/16/2001 7:40	9.6789	23.2056	34.6094	178.964
5/16/2001 7:50	11.4387	21.7992	30.7965	180.722
5/16/2001 8:00	6.1593	15.4704	32.8496	180.722
5/16/2001 8:10	8.5057	13.0092	34.9027	180.019
5/16/2001 8:20	6.7459	30.9408	36.6625	181.074
5/16/2001 8:30	7.6258	39.7308	36.0759	176.855
5/16/2001 8:40	5.2794	33.7536	36.9558	175.097
5/16/2001 8:50	5.5727	41.8404	34.9027	179.316
5/16/2001 9:00	5.5727	14.064	32.263	177.206
5/16/2001 9:10	6.7459	31.9956	32.5563	176.503
5/16/2001 9:20	5.5727	34.4568	33.4362	179.316
5/16/2001 9:30	4.6928	16.1736	31.0898	176.503
5/16/2001 9:40	2.3464	50.6304	29.33	174.745
5/16/2001 9:50	2.933	49.224	31.9697	171.932
5/16/2001 10:00	3.2263	31.644	32.8496	176.152
5/16/2001 10:10	0.5866	144.156	30.5032	174.394
5/16/2001 10:20	2.0531	74.5392	31.6764	176.152
5/16/2001 10:30	2.3464	24.2604	31.6764	176.152
5/16/2001 10:40	0	339.646	29.6233	174.394
5/16/2001 10:50	0.5866	4.9224	30.2099	176.503
5/16/2001 11:00	0.8799	120.95	30.7965	176.152
5/16/2001 11:10	1.4665	89.3064	31.0898	171.581
5/16/2001 11:20	1.4665	215.179	31.3831	177.206
5/16/2001 11:30	2.0531	92.1192	31.6764	177.91
5/16/2001 11:40	2.3464	147.672	31.3831	175.8
5/16/2001 11:50	1.1732	164.549	29.33	180.019
5/16/2001 12:00	2.3464	168.065	30.2099	176.152
5/16/2001 12:10	5.866	149.078	30.7965	176.855
5/16/2001 12:20	3.8129	127.982	31.0898	174.394
5/16/2001 12:30	4.9861	156.11	30.7965	175.448
5/16/2001 12:40	3.8129	172.284	30.2099	174.745
5/16/2001 12:50	3.5196	206.741	31.9697	174.394
5/16/2001 13:00	3.8129	155.759	31.0898	171.932
5/16/2001 13:10	6.1593	170.174	32.5563	175.448
5/16/2001 13:20	2.933	113.918	34.0228	174.042
5/16/2001 13:30	2.3464	200.06	31.9697	177.558
5/16/2001 13:40	5.866	182.48	33.7295	179.316
5/16/2001 13:50	5.5727	209.554	32.5563	176.152
5/16/2001 14:00	5.2794	219.047	31.6764	172.284
5/16/2001 14:10	5.2794	225.376	36.0759	170.526
5/16/2001 14:20	5.5727	220.453	34.0228	174.745
5/16/2001 14:30	1.4665	226.43	34.9027	170.174
5/16/2001 14:40	2.0531	212.015	35.7826	173.339
5/16/2001 14:50	6.1593	191.974	35.196	170.878
5/16/2001 15:00	4.1062	212.366	38.129	169.823
5/16/2001 15:10	2.3464	200.412	37.5424	171.932
5/16/2001 15:20	4.6928	174.042	36.3692	171.229

5/16/2001 15:30	1.4665	255.613	37.2491	171.581
5/16/2001 15:40	1.1732	171.229	39.5955	169.471
5/16/2001 15:50	1.7598	179.316	40.1821	169.471
5/16/2001 16:00	1.4665	152.946	42.5285	169.12
5/16/2001 16:10	1.1732	219.75	41.9419	171.581
5/16/2001 16:20	1.1732	183.535	41.6486	170.526
5/16/2001 16:30	0.5866	141.695	42.5285	171.229
5/16/2001 16:40	1.1732	155.407	41.9419	171.229
5/16/2001 16:50	2.0531	161.384	40.4754	170.526
5/16/2001 17:00	2.6397	145.914	40.1821	170.526
5/16/2001 17:10	2.3464	35.8632	39.5955	170.526
5/16/2001 17:20	2.933	348.436	42.2352	170.878
5/16/2001 17:30	3.2263	40.7856	41.062	170.878
5/16/2001 17:40	1.4665	55.5528	39.8888	171.932
5/16/2001 17:50	2.6397	23.9088	39.3022	168.416
5/16/2001 18:00	4.3995	359.687	40.7687	170.878
5/16/2001 18:10	3.2263	52.74	39.3022	171.581
5/16/2001 18:20	4.1062	20.3928	38.7156	165.252
5/16/2001 18:30	2.3464	22.854	38.4223	167.362
5/16/2001 18:40	3.5196	48.5208	37.2491	168.768
5/16/2001 18:50	4.1062	28.4796	42.8218	165.955
5/16/2001 19:00	4.3995	27.4248	41.6486	170.526
5/16/2001 19:10	4.6928	19.338	40.1821	171.581
5/16/2001 19:20	5.2794	33.402	37.8357	168.416
5/16/2001 19:30	5.5727	9.4932	41.062	170.174
5/16/2001 19:40	6.1593	32.6988	44.2883	170.174
5/16/2001 19:50	6.4526	28.8312	44.2883	167.713
5/16/2001 20:00	4.9861	14.7672	43.1151	171.229
5/16/2001 20:10	7.3325	342.458	42.8218	167.362
5/16/2001 20:20	8.5057	45.0048	43.4084	171.932
5/16/2001 20:30	6.4526	8.4384	43.1151	171.229
5/16/2001 20:40	8.2124	32.3472	43.4084	168.768
5/16/2001 20:50	11.4387	18.6348	41.9419	172.987
5/16/2001 21:00	11.1454	18.9864	42.2352	174.745
5/16/2001 21:10	11.732	18.6348	39.3022	172.636
5/16/2001 21:20	12.3186	13.0092	39.3022	172.987
5/16/2001 21:30	11.732	15.822	37.2491	176.152
5/16/2001 21:40	15.2516	14.064	35.196	175.097
5/16/2001 21:50	14.3717	12.6576	36.0759	173.69
5/16/2001 22:00	17.0114	15.4704	35.196	172.636
5/16/2001 22:10	15.8382	17.58	36.3692	178.261
5/16/2001 22:20	14.3717	24.2604	36.9558	176.152
5/16/2001 22:30	12.6119	14.4156	34.6094	177.206
5/16/2001 22:40	13.7851	4.5708	34.3161	177.91
5/16/2001 22:50	13.1985	8.4384	33.4362	172.284
5/16/2001 23:00	11.1454	1.4064	33.7295	171.932
5/16/2001 23:10	12.0253	8.0868	35.196	169.823
5/16/2001 23:20	15.2516	9.1416	34.6094	173.69

5/16/2001 23:30	12.3186	20.3928	33.7295	173.339
5/16/2001 23:40	13.1985	355.819	31.9697	175.448
5/16/2001 23:50	13.7851	356.522	34.3161	174.394
5/17/2001	12.6119	2.1096	36.0759	171.229
5/17/2001 0:10	13.4918	4.2192	33.7295	172.284
5/17/2001 0:20	14.0784	6.6804	31.6764	172.636
5/17/2001 0:30	12.9052	3.516	32.263	172.636
5/17/2001 0:40	12.0253	7.3836	30.5032	165.604
5/17/2001 0:50	14.0784	6.6804	31.3831	166.307
5/17/2001 1:00	13.4918	16.1736	29.33	172.284
5/17/2001 1:10	14.3717	4.2192	29.0367	173.339
5/17/2001 1:20	12.6119	5.274	29.6233	171.932
5/17/2001 1:30	14.9583	356.874	31.3831	172.987
5/17/2001 1:40	13.4918	1.4064	30.5032	174.042
5/17/2001 1:50	13.7851	7.032	31.3831	168.416
5/17/2001 2:00	13.4918	4.5708	32.263	165.604
5/17/2001 2:10	14.3717	354.764	31.3831	165.955
5/17/2001 2:20	15.5449	355.116	32.5563	172.987
5/17/2001 2:30	14.9583	2.4612	34.9027	174.745
5/17/2001 2:40	14.0784	8.4384	33.1429	165.252
5/17/2001 2:50	12.9052	358.28	34.0228	169.12
5/17/2001 3:00	10.2655	14.7672	31.9697	165.252
5/17/2001 3:10	9.6789	5.9772	31.6764	166.658
5/17/2001 3:20	9.3856	8.79	33.4362	165.604
5/17/2001 3:30	6.7459	25.3152	30.5032	170.174
5/17/2001 3:40	9.0923	17.58	30.7965	168.768
5/17/2001 3:50	10.5588	29.5344	31.3831	169.12
5/17/2001 4:00	8.799	28.128	31.9697	171.229
5/17/2001 4:10	8.799	23.9088	29.6233	167.01
5/17/2001 4:20	9.9722	24.2604	29.9166	169.12
5/17/2001 4:30	8.5057	10.8996	31.3831	170.878
5/17/2001 4:40	10.5588	6.3288	30.7965	175.448
5/17/2001 4:50	10.8521	4.2192	31.9697	174.042
5/17/2001 5:00	8.5057	21.4476	30.5032	169.471
5/17/2001 5:10	7.0392	27.4248	31.9697	171.932
5/17/2001 5:20	9.6789	18.9864	31.6764	174.042
5/17/2001 5:30	7.0392	26.37	33.7295	170.526
5/17/2001 5:40	8.5057	6.6804	33.4362	167.713
5/17/2001 5:50	5.2794	34.1052	33.7295	170.878
5/17/2001 6:00	2.933	8.4384	32.263	169.12
5/17/2001 6:10	4.3995	60.1236	31.3831	166.658
5/17/2001 6:20	3.8129	52.74	30.5032	166.307
5/17/2001 6:30	3.8129	56.6076	30.7965	170.526
5/17/2001 6:40	4.1062	28.4796	30.7965	171.932
5/17/2001 6:50	4.6928	75.9456	30.5032	169.823
5/17/2001 7:00	0.8799	90.7128	31.3831	169.823
5/17/2001 7:10	3.8129	62.9364	31.9697	170.526
5/17/2001 7:20	4.1062	142.046	31.0898	168.768

5/17/2001 7:30	4.6928	113.918	30.5032	171.229
5/17/2001 7:40	4.3995	134.311	29.9166	166.307
5/17/2001 7:50	3.2263	138.882	31.6764	170.526
5/17/2001 8:00	4.9861	152.946	34.0228	172.284
5/17/2001 8:10	8.2124	112.864	36.0759	173.339
5/17/2001 8:20	7.9191	157.517	34.6094	171.932
5/17/2001 8:30	9.9722	170.174	36.6625	171.229
5/17/2001 8:40	6.1593	159.978	35.7826	174.394
5/17/2001 8:50	9.0923	177.206	37.2491	168.416
5/17/2001 9:00	7.3325	174.745	37.8357	171.229
5/17/2001 9:10	9.9722	160.681	38.7156	172.987
5/17/2001 9:20	9.6789	201.467	42.2352	171.229
5/17/2001 9:30	11.4387	182.129	43.4084	173.69
5/17/2001 9:40	14.9583	175.448	47.5146	173.69
5/17/2001 9:50	16.4248	189.512	46.0481	171.229
5/17/2001 10:00	17.0114	186.348	46.6347	172.987
5/17/2001 10:10	19.3578	191.622	47.8079	170.878
5/17/2001 10:20	20.2377	189.161	48.9811	177.558
5/17/2001 10:30	22.2908	186.7	47.5146	178.261
5/17/2001 10:40	23.7573	186.348	47.5146	178.261
5/17/2001 10:50	25.2238	185.996	48.3945	175.448
5/17/2001 11:00	22.8774	185.645	49.2744	177.558
5/17/2001 11:10	23.464	185.645	47.8079	172.284
5/17/2001 11:20	23.1707	190.216	47.5146	179.668
5/17/2001 11:30	20.8243	196.544	46.0481	177.558
5/17/2001 11:40	17.8913	199.006	44.8749	177.206
5/17/2001 11:50	16.7181	208.147	44.8749	176.855
5/17/2001 12:00	12.6119	197.951	42.2352	175.8
5/17/2001 12:10	8.5057	206.038	41.3553	176.152
5/17/2001 12:20	6.4526	231.353	39.0089	180.019
5/17/2001 12:30	6.4526	229.946	39.3022	177.558
5/17/2001 12:40	4.6928	265.458	39.0089	176.152
5/17/2001 12:50	4.9861	262.997	38.7156	178.613
5/17/2001 13:00	3.2263	312.221	38.129	176.152
5/17/2001 13:10	4.9861	340.7	33.7295	179.668
5/17/2001 13:20	6.7459	342.107	36.6625	176.503
5/17/2001 13:30	7.9191	330.504	34.9027	179.316
5/17/2001 13:40	7.0392	9.4932	34.3161	176.855
5/17/2001 13:50	6.1593	349.842	33.1429	181.426
5/17/2001 14:00	9.6789	348.436	31.9697	181.777
5/17/2001 14:10	9.6789	352.655	31.0898	181.074
5/17/2001 14:20	11.1454	351.6	34.3161	180.019
5/17/2001 14:30	7.9191	352.303	34.9027	182.48
5/17/2001 14:40	11.1454	348.436	31.6764	184.59
5/17/2001 14:50	14.0784	347.732	31.3831	180.371
5/17/2001 15:00	11.1454	346.326	29.9166	178.613
5/17/2001 15:10	12.0253	347.732	30.5032	177.558
5/17/2001 15:20	11.732	353.71	30.2099	175.097

5/17/2001 15:30	13.4918	350.897	28.1568	174.394
5/17/2001 15:40	9.9722	339.646	29.33	176.503
5/17/2001 15:50	12.9052	340.349	29.9166	178.261
5/17/2001 16:00	8.5057	343.513	28.4501	176.152
5/17/2001 16:10	12.0253	348.436	28.1568	173.339
5/17/2001 16:20	10.8521	332.262	29.33	175.8
5/17/2001 16:30	13.7851	339.294	28.4501	175.8
5/17/2001 16:40	6.7459	349.49	27.5702	175.8
5/17/2001 16:50	10.5588	349.842	27.5702	175.448
5/17/2001 17:00	9.6789	355.468	29.33	173.339
5/17/2001 17:10	8.799	351.248	28.7434	175.8
5/17/2001 17:20	9.6789	350.897	27.5702	172.987
5/17/2001 17:30	6.4526	339.997	26.6903	171.581
5/17/2001 17:40	9.3856	319.604	26.9836	176.503
5/17/2001 17:50	7.0392	351.248	26.9836	173.339
5/17/2001 18:00	5.5727	352.655	27.2769	170.174
5/17/2001 18:10	5.5727	345.974	26.6903	171.229
5/17/2001 18:20	7.6258	328.746	24.3439	170.878
5/17/2001 18:30	27.8635	308.705	26.9836	171.932
5/17/2001 18:40	14.3717	286.554	26.6903	165.252
5/17/2001 18:50	5.866	355.468	28.7434	169.12
5/17/2001 19:00	5.5727	340.7	26.397	172.636
5/17/2001 19:10	7.3325	339.997	28.4501	166.307
5/17/2001 19:20	5.2794	328.746	28.7434	169.471
5/17/2001 19:30	6.7459	341.404	27.8635	169.12
5/17/2001 19:40	4.3995	345.623	29.6233	168.416
5/17/2001 19:50	3.2263	323.824	30.2099	166.658
5/17/2001 20:00	3.5196	327.34	30.2099	168.416
5/17/2001 20:10	4.9861	313.979	29.33	167.362
5/17/2001 20:20	2.3464	335.778	30.5032	167.362
5/17/2001 20:30	3.8129	352.655	28.4501	166.658
5/17/2001 20:40	2.3464	46.4112	28.4501	162.791
5/17/2001 20:50	1.1732	292.883	26.9836	167.713
5/17/2001 21:00	4.3995	291.828	28.4501	168.065
5/17/2001 21:10	2.0531	270.732	29.6233	167.713
5/17/2001 21:20	2.933	275.654	29.0367	166.658
5/17/2001 21:30	3.5196	312.572	30.5032	166.307
5/17/2001 21:40	4.3995	283.39	31.3831	172.987
5/17/2001 21:50	3.2263	253.504	29.0367	173.339
5/17/2001 22:00	5.2794	245.065	28.1568	169.471
5/17/2001 22:10	5.866	282.686	29.9166	172.284
5/17/2001 22:20	2.6397	301.321	27.2769	173.69
5/17/2001 22:30	1.4665	347.029	27.8635	172.284
5/17/2001 22:40	5.866	304.837	28.4501	173.69
5/17/2001 22:50	2.6397	326.988	26.6903	177.91
5/17/2001 23:00	5.5727	332.262	26.6903	185.645
5/17/2001 23:10	4.1062	6.3288	24.6372	188.106
5/17/2001 23:20	6.1593	351.6	23.464	197.951

5/17/2001 23:30	4.9861	13.3608	24.3439	177.206
5/17/2001 23:40	4.6928	339.997	24.0506	170.526
5/17/2001 23:50	4.6928	0.3516	23.7573	175.8
5/18/2001	3.8129	18.6348	23.7573	175.097
5/18/2001 0:10	4.6928	9.1416	21.9975	174.745
5/18/2001 0:20	5.2794	344.216	21.7042	175.097
5/18/2001 0:30	2.933	20.3928	22.5841	170.878
5/18/2001 0:40	3.2263	357.577	22.2908	171.229
5/18/2001 0:50	4.1062	334.723	22.5841	173.69
5/18/2001 1:00	6.1593	0.3516	22.5841	172.636
5/18/2001 1:10	6.7459	335.426	21.4109	172.636
5/18/2001 1:20	5.866	349.842	22.2908	173.69
5/18/2001 1:30	5.5727	343.162	21.1176	166.658
5/18/2001 1:40	3.2263	330.504	20.8243	171.581
5/18/2001 1:50	6.1593	322.417	21.1176	166.307
5/18/2001 2:00	6.4526	318.55	20.531	172.987
5/18/2001 2:10	4.3995	0	18.4779	170.878
5/18/2001 2:20	4.6928	5.274	17.3047	174.394
5/18/2001 2:30	5.5727	11.2512	18.7712	174.042
5/18/2001 2:40	5.5727	9.1416	18.1846	170.174
5/18/2001 2:50	4.3995	30.9408	19.6511	170.174
5/18/2001 3:00	4.3995	43.95	19.9444	167.713
5/18/2001 3:10	3.5196	340.7	17.8913	171.229
5/18/2001 3:20	4.3995	56.9592	17.598	165.252
5/18/2001 3:30	5.866	340.349	22.2908	174.042
5/18/2001 3:40	4.1062	4.5708	20.8243	168.768
5/18/2001 3:50	3.5196	27.4248	18.7712	165.604
5/18/2001 4:00	3.5196	18.6348	18.4779	165.955
5/18/2001 4:10	4.6928	36.2148	17.8913	162.791

Table 6.3 Observed Current Speed (cm/s) and Direction (degrees) near Pulicat Light House at C3 and C4

	C3		C4	
Date/time	Current Speed	Direction	Current Speed	Direction
5/15/2001 16:50	20.2377	182.129	18.7712	217.289
5/15/2001 17:00	21.4109	176.152	22.2908	208.499
5/15/2001 17:10	22.2908	178.964	19.0645	209.554
5/15/2001 17:20	21.4109	178.261	21.4109	214.828
5/15/2001 17:30	20.531	179.316	22.2908	211.312
5/15/2001 17:40	19.3578	174.394	21.7042	206.038
5/15/2001 17:50	19.3578	176.503	20.8243	207.444
5/15/2001 18:00	21.4109	181.777	19.3578	206.038
5/15/2001 18:10	18.4779	179.316	20.531	209.905
5/15/2001 18:20	19.3578	177.558	21.7042	204.631
5/15/2001 18:30	17.598	182.129	23.1707	214.476
5/15/2001 18:40	19.3578	188.809	24.3439	212.718
5/15/2001 18:50	21.4109	185.645	28.7434	183.184
5/15/2001 19:00	19.9444	189.512	12.6119	89.658
5/15/2001 19:10	19.6511	194.435	23.7573	209.905
5/15/2001 19:20	21.1176	193.028	22.8774	216.586
5/15/2001 19:30	18.1846	189.512	24.3439	223.618
5/15/2001 19:40	17.598	181.777	21.1176	219.75
5/15/2001 19:50	17.0114	190.216	18.1846	213.07
5/15/2001 20:00	18.7712	176.152	19.6511	216.586
5/15/2001 20:10	17.0114	186.348	17.0114	203.225
5/15/2001 20:20	18.1846	176.152	16.4248	194.786
5/15/2001 20:30	17.8913	175.448	16.7181	200.06
5/15/2001 20:40	16.4248	178.261	19.0645	206.741
5/15/2001 20:50	19.3578	184.238	17.0114	192.325
5/15/2001 21:00	15.8382	181.426	18.4779	203.225
5/15/2001 21:10	14.665	173.339	18.7712	212.015
5/15/2001 21:20	16.7181	183.887	20.2377	209.202
5/15/2001 21:30	17.598	183.184	19.9444	214.828
5/15/2001 21:40	16.4248	179.668	21.7042	222.563
5/15/2001 21:50	17.0114	176.503	21.9975	209.202
5/15/2001 22:00	19.6511	175.097	20.2377	207.444
5/15/2001 22:10	18.4779	186.7	20.2377	217.64
5/15/2001 22:20	16.7181	177.91	21.9975	213.421
5/15/2001 22:30	16.1315	178.261	21.4109	204.28
5/15/2001 22:40	15.5449	180.722	22.8774	202.17
5/15/2001 22:50	13.1985	172.284	20.8243	210.96
5/15/2001 23:00	11.1454	205.334	22.5841	210.96
5/15/2001 23:10	15.8382	168.768	23.464	214.828
5/15/2001 23:20	15.5449	179.316	23.1707	219.047
5/15/2001 23:30	19.3578	172.284	19.3578	192.325
5/15/2001 23:40	17.3047	165.955	17.0114	219.047

5/15/2001 23:50	20.2377	174.394	21.7042	240.143
5/16/2001 0:01	15.5449	178.964	24.3439	216.937
5/16/2001 0:10	21.4109	174.745	23.7573	208.85
5/16/2001 0:20	19.6511	176.855	26.6903	214.828
5/16/2001 0:30	18.1846	169.12	26.397	216.586
5/16/2001 0:40	22.5841	171.932	38.4223	209.202
5/16/2001 0:50	22.2908	176.503	17.598	197.248
5/16/2001 1:00	20.2377	176.152	25.2238	211.312
5/16/2001 1:10	21.9975	175.097	24.3439	199.709
5/16/2001 1:20	21.9975	172.636	23.464	217.64
5/16/2001 1:30	18.7712	169.471	24.3439	213.421
5/16/2001 1:40	19.6511	171.581	27.5702	214.476
5/16/2001 1:50	16.1315	171.932	28.7434	214.476
5/16/2001 2:00	18.1846	175.448	31.0898	215.531
5/16/2001 2:10	18.7712	174.745	31.3831	211.312
5/16/2001 2:20	18.7712	180.722	32.5563	209.554
5/16/2001 2:30	15.5449	180.722	30.5032	211.663
5/16/2001 2:40	17.0114	187.051	30.2099	210.96
5/16/2001 2:50	19.9444	179.668	27.8635	213.421
5/16/2001 3:00	18.1846	176.503	32.8496	209.554
5/16/2001 3:10	19.3578	178.964	33.1429	208.85
5/16/2001 3:20	22.2908	174.745	32.8496	208.85
5/16/2001 3:30	24.6372	171.932	33.1429	207.092
5/16/2001 3:40	25.2238	170.174	31.3831	207.444
5/16/2001 3:50	20.531	172.987	33.4362	208.147
5/16/2001 4:00	16.4248	172.636	31.6764	203.928
5/16/2001 4:10	19.3578	183.535	30.2099	207.092
5/16/2001 4:20	18.1846	178.613	33.7295	206.741
5/16/2001 4:30	19.3578	183.184	32.5563	205.686
5/16/2001 4:40	15.5449	178.261	31.9697	209.202
5/16/2001 4:50	18.7712	183.887	29.9166	213.421
5/16/2001 5:00	17.3047	177.206	28.1568	208.499
5/16/2001 5:10	18.7712	175.097	28.7434	213.07
5/16/2001 5:20	15.8382	155.759	30.2099	210.96
5/16/2001 5:30	15.5449	169.823	32.263	213.421
5/16/2001 5:40	13.7851	169.471	31.3831	209.905
5/16/2001 5:50	14.0784	180.019	32.263	210.96
5/16/2001 6:00	16.1315	168.065	31.6764	211.312
5/16/2001 6:10	16.1315	172.284	28.1568	212.366
5/16/2001 6:20	15.2516	166.307	30.5032	207.796
5/16/2001 6:30	16.4248	161.384	28.7434	210.257
5/16/2001 6:40	17.0114	165.955	26.9836	210.96
5/16/2001 6:50	15.5449	159.626	29.33	207.444
5/16/2001 7:00	16.7181	180.371	31.9697	206.741
5/16/2001 7:10	18.7712	166.307	30.2099	209.905
5/16/2001 7:20	17.3047	169.471	27.5702	220.805
5/16/2001 7:30	19.3578	166.307	21.7042	222.914
5/16/2001 7:40	21.1176	173.339	21.9975	216.937

5/16/2001 7:50	18.4779	167.362	26.397	214.124
5/16/2001 8:00	18.1846	168.065	25.5171	218.344
5/16/2001 8:10	19.3578	166.307	23.464	214.476
5/16/2001 8:20	20.2377	170.526	24.6372	210.608
5/16/2001 8:30	21.1176	180.722	24.3439	204.631
5/16/2001 8:40	19.6511	174.394	23.464	205.334
5/16/2001 8:50	19.3578	172.987	21.9975	201.467
5/16/2001 9:00	22.2908	173.69	25.8104	198.302
5/16/2001 9:10	18.4779	173.339	27.2769	203.225
5/16/2001 9:20	19.9444	179.668	25.8104	201.467
5/16/2001 9:30	18.4779	174.042	27.2769	207.444
5/16/2001 9:40	19.9444	179.668	28.1568	197.951
5/16/2001 9:50	18.4779	172.987	26.9836	200.764
5/16/2001 10:00	20.531	173.339	27.2769	199.709
5/16/2001 10:10	19.9444	172.284	28.1568	201.115
5/16/2001 10:20	22.2908	174.745	29.33	200.412
5/16/2001 10:30	24.6372	170.526	30.5032	201.818
5/16/2001 10:40	27.2769	176.503	28.7434	198.654
5/16/2001 10:50	28.1568	180.371	31.9697	202.873
5/16/2001 11:00	28.7434	174.394	29.33	208.85
5/16/2001 11:10	29.33	171.229	31.3831	201.467
5/16/2001 11:20	30.2099	174.745	30.7965	207.444
5/16/2001 11:30	30.5032	177.91	31.0898	202.873
5/16/2001 11:40	26.1037	177.558	30.2099	202.17
5/16/2001 11:50	25.8104	174.745	30.2099	205.686
5/16/2001 12:00	27.2769	175.448	30.2099	206.038
5/16/2001 12:10	28.7434	177.206	28.1568	207.092
5/16/2001 12:20	27.8635	172.636	29.9166	203.928
5/16/2001 12:30	24.6372	174.745	33.4362	202.873
5/16/2001 12:40	27.2769	173.339	34.9027	206.038
5/16/2001 12:50	30.5032	170.526	34.3161	205.686
5/16/2001 13:00	29.9166	173.339	34.9027	208.499
5/16/2001 13:10	29.33	171.581	35.4893	212.015
5/16/2001 13:20	30.5032	173.69	36.6625	213.421
5/16/2001 13:30	31.9697	176.152	37.2491	210.96
5/16/2001 13:40	32.5563	175.097	35.4893	208.85
5/16/2001 13:50	30.7965	174.394	36.0759	209.202
5/16/2001 14:00	33.1429	171.932	35.4893	208.499
5/16/2001 14:10	36.3692	177.206	35.196	209.202
5/16/2001 14:20	36.3692	176.503	36.0759	209.905
5/16/2001 14:30	38.129	179.316	37.5424	208.499
5/16/2001 14:40	37.5424	177.558	35.4893	206.389
5/16/2001 14:50	39.8888	178.261	40.7687	210.257
5/16/2001 15:00	37.8357	176.855	41.9419	209.554
5/16/2001 15:10	39.8888	176.855	41.3553	208.85
5/16/2001 15:20	38.4223	176.503	41.3553	209.202
5/16/2001 15:30	40.4754	177.91	42.8218	206.389
5/16/2001 15:40	37.8357	176.152	48.6878	208.147

5/16/2001 15:50	38.129	177.91	46.6347	204.983
5/16/2001 16:00	36.3692	178.613	43.1151	204.28
5/16/2001 16:10	39.8888	178.613	42.5285	206.389
5/16/2001 16:20	39.8888	177.558	43.995	203.225
5/16/2001 16:30	38.129	178.964	41.9419	202.873
5/16/2001 16:40	39.3022	179.316	39.3022	199.357
5/16/2001 16:50	40.4754	177.91	41.6486	199.006
5/16/2001 17:00	38.7156	177.558	40.4754	201.467
5/16/2001 17:10	39.8888	176.503	39.8888	203.928
5/16/2001 17:20	38.129	176.503	37.8357	202.873
5/16/2001 17:30	38.4223	175.8	36.0759	201.115
5/16/2001 17:40	39.8888	176.503	37.8357	204.631
5/16/2001 17:50	39.5955	176.503	38.129	204.983
5/16/2001 18:00	38.7156	175.8	36.6625	203.225
5/16/2001 18:10	40.4754	176.152	35.7826	206.038
5/16/2001 18:20	39.3022	174.745	35.7826	203.576
5/16/2001 18:30	38.129	175.448	39.8888	203.576
5/16/2001 18:40	37.2491	176.152	43.1151	209.554
5/16/2001 18:50	37.5424	178.613	41.9419	209.554
5/16/2001 19:00	35.7826	178.261	36.3692	208.499
5/16/2001 19:10	37.2491	178.261	38.129	207.796
5/16/2001 19:20	34.9027	178.964	39.8888	207.444
5/16/2001 19:30	34.6094	177.206	40.4754	207.796
5/16/2001 19:40	35.4893	178.613	38.129	207.092
5/16/2001 19:50	34.6094	180.019	39.5955	208.147
5/16/2001 20:00	33.7295	177.206	39.3022	205.334
5/16/2001 20:10	34.6094	177.558	38.4223	202.873
5/16/2001 20:20	31.6764	178.964	34.6094	207.092
5/16/2001 20:30	28.7434	171.581	37.5424	206.038
5/16/2001 20:40	30.2099	175.8	37.5424	205.686
5/16/2001 20:50	23.464	185.293	38.129	213.773
5/16/2001 21:00	26.6903	171.932	37.2491	204.631
5/16/2001 21:10	24.6372	180.371	36.9558	206.741
5/16/2001 21:20	25.5171	173.339	36.9558	208.147
5/16/2001 21:30	24.3439	173.339	35.196	206.038
5/16/2001 21:40	21.9975	175.448	35.196	210.608
5/16/2001 21:50	22.2908	170.526	36.3692	197.599
5/16/2001 22:00	19.6511	175.097	37.5424	221.508
5/16/2001 22:10	23.7573	184.59	39.3022	212.718
5/16/2001 22:20	20.531	174.042	39.3022	214.828
5/16/2001 22:30	21.4109	178.261	39.5955	211.312
5/16/2001 22:40	19.0645	169.823	38.129	212.366
5/16/2001 22:50	14.9583	171.932	37.8357	211.663
5/16/2001 23:00	16.7181	171.932	36.3692	210.96
5/16/2001 23:10	14.0784	179.668	34.6094	211.663
5/16/2001 23:20	14.0784	171.229	35.196	216.234
5/16/2001 23:30	15.2516	173.339	34.9027	212.718
5/16/2001 23:40	13.7851	172.987	34.6094	215.179

5/16/2001 23:50	13.4918	174.042	35.4893	219.75
5/17/2001	12.3186	172.284	34.0228	219.75
5/17/2001 0:10	14.3717	165.955	37.5424	214.124
5/17/2001 0:20	9.6789	175.448	38.4223	216.234
5/17/2001 0:30	9.3856	166.658	36.6625	220.102
5/17/2001 0:40	12.0253	164.549	39.3022	217.64
5/17/2001 0:50	11.4387	167.01	36.9558	218.344
5/17/2001 1:00	12.9052	166.307	36.6625	219.398
5/17/2001 1:10	11.732	170.526	37.5424	215.531
5/17/2001 1:20	13.4918	165.955	36.3692	218.344
5/17/2001 1:30	11.1454	167.01	34.0228	214.828
5/17/2001 1:40	13.1985	159.978	32.8496	227.134
5/17/2001 1:50	11.4387	183.535	33.7295	207.444
5/17/2001 2:00	9.9722	154.001	31.0898	214.476
5/17/2001 2:10	9.3856	168.768	28.1568	222.563
5/17/2001 2:20	8.5057	173.339	32.263	221.86
5/17/2001 2:30	14.0784	169.823	28.4501	214.124
5/17/2001 2:40	11.4387	161.033	29.9166	218.695
5/17/2001 2:50	9.6789	162.088	27.5702	216.234
5/17/2001 3:00	12.6119	152.946	24.6372	213.07
5/17/2001 3:10	13.4918	161.033	22.8774	207.444
5/17/2001 3:20	14.3717	159.978	22.2908	208.499
5/17/2001 3:30	12.9052	162.439	21.7042	203.576
5/17/2001 3:40	12.9052	167.713	20.8243	204.983
5/17/2001 3:50	10.8521	169.12	19.9444	201.115
5/17/2001 4:00	9.9722	146.617	21.7042	199.709
5/17/2001 4:10	13.1985	162.791	21.7042	226.079
5/17/2001 4:20	13.4918	167.362	24.6372	225.376
5/17/2001 4:30	14.665	165.252	21.4109	217.64
5/17/2001 4:40	12.0253	170.526	17.0114	191.974
5/17/2001 4:50	17.8913	172.987	10.5588	249.636
5/17/2001 5:00	9.9722	156.11	8.5057	220.102
5/17/2001 5:10	10.8521	176.855	14.0784	210.608
5/17/2001 5:20	12.9052	173.69	10.8521	213.421
5/17/2001 5:30	12.0253	171.229	6.1593	219.398
5/17/2001 5:40	11.1454	171.581	11.4387	223.969
5/17/2001 5:50	11.1454	172.987	10.5588	209.554
5/17/2001 6:00	9.0923	170.878	8.799	206.038
5/17/2001 6:10	5.866	167.362	14.3717	213.07
5/17/2001 6:20	7.6258	157.868	8.799	195.841
5/17/2001 6:30	9.9722	160.33	13.1985	199.709
5/17/2001 6:40	7.6258	166.658	8.5057	196.544
5/17/2001 6:50	10.2655	166.658	10.2655	200.412
5/17/2001 7:00	12.3186	178.261	17.0114	195.49
5/17/2001 7:10	11.732	170.878	9.6789	197.248
5/17/2001 7:20	12.3186	169.471	11.4387	199.357
5/17/2001 7:30	10.5588	162.791	9.3856	196.896
5/17/2001 7:40	10.5588	163.846	9.0923	183.535

5/17/2001 7:50	13.7851	155.407	8.5057	182.48
5/17/2001 8:00	14.665	172.987	11.732	163.494
5/17/2001 8:10	17.0114	179.316	14.3717	174.745
5/17/2001 8:20	15.8382	178.964	14.3717	195.841
5/17/2001 8:30	16.7181	179.316	15.2516	208.147
5/17/2001 8:40	18.7712	175.448	14.9583	215.179
5/17/2001 8:50	18.1846	174.745	16.1315	181.777
5/17/2001 9:00	16.7181	176.152	15.5449	209.905
5/17/2001 9:10	14.0784	164.549	16.7181	202.17
5/17/2001 9:20	26.1037	177.91	17.8913	191.622
5/17/2001 9:30	23.464	177.91	18.4779	188.106
5/17/2001 9:40	27.5702	178.261	21.1176	197.951
5/17/2001 9:50	24.3439	181.074	20.531	195.49
5/17/2001 10:00	26.9836	173.69	21.7042	195.841
5/17/2001 10:10	29.0367	170.526	24.6372	199.006
5/17/2001 10:20	30.7965	177.91	22.5841	197.248
5/17/2001 10:30	28.4501	176.152	23.1707	188.809
5/17/2001 10:40	26.9836	174.745	26.1037	192.677
5/17/2001 10:50	29.33	167.713	25.8104	193.028
5/17/2001 11:00	27.2769	172.284	26.6903	190.919
5/17/2001 11:10	27.8635	171.581	26.6903	192.677
5/17/2001 11:20	27.2769	168.416	27.5702	191.622
5/17/2001 11:30	26.9836	167.01	26.9836	188.106
5/17/2001 11:40	26.397	174.745	28.4501	191.622
5/17/2001 11:50	28.4501	172.636	29.6233	193.732
5/17/2001 12:00	24.6372	169.12	29.33	194.435
5/17/2001 12:10	27.2769	174.042	28.4501	200.764
5/17/2001 12:20	23.1707	169.471	29.33	203.928
5/17/2001 12:30	25.2238	172.284	31.0898	204.983
5/17/2001 12:40	24.9305	176.152	32.263	205.686
5/17/2001 12:50	26.397	176.503	33.7295	202.873
5/17/2001 13:00	27.8635	177.206	34.3161	208.85
5/17/2001 13:10	26.1037	178.261	40.1821	217.289
5/17/2001 13:20	26.9836	180.722	39.8888	199.006
5/17/2001 13:30	26.1037	180.722	29.9166	207.092
5/17/2001 13:40	21.7042	177.558	43.1151	206.038
5/17/2001 13:50	21.1176	181.426	44.5816	209.554
5/17/2001 14:00	19.0645	176.855	38.4223	206.389
5/17/2001 14:10	18.7712	181.074	43.995	210.257
5/17/2001 14:20	19.0645	188.458	39.8888	214.124
5/17/2001 14:30	18.4779	181.777	38.129	217.64
5/17/2001 14:40	19.3578	182.129	37.2491	215.531
5/17/2001 14:50	18.7712	182.129	35.196	215.531
5/17/2001 15:00	19.6511	171.932	33.4362	216.586
5/17/2001 15:10	18.1846	181.074	31.6764	216.234
5/17/2001 15:20	14.665	173.69	32.8496	212.366
5/17/2001 15:30	18.7712	178.261	32.5563	215.882
5/17/2001 15:40	21.1176	176.855	35.4893	217.289

5/17/2001 15:50	18.7712	170.878	36.6625	211.312
5/17/2001 16:00	15.8382	171.932	34.9027	215.179
5/17/2001 16:10	15.8382	170.174	35.7826	208.85
5/17/2001 16:20	15.2516	168.768	33.7295	198.654
5/17/2001 16:30	17.8913	164.9	32.263	205.334
5/17/2001 16:40	17.3047	168.768	32.263	204.631
5/17/2001 16:50	16.4248	175.8	36.0759	207.444
5/17/2001 17:00	16.1315	173.339	36.6625	208.85
5/17/2001 17:10	17.598	171.229	37.2491	210.257
5/17/2001 17:20	18.1846	172.284	39.8888	209.554
5/17/2001 17:30	16.7181	165.252	42.8218	203.576
5/17/2001 17:40	19.0645	175.448	40.7687	206.741
5/17/2001 17:50	21.1176	181.426	40.7687	210.96
5/17/2001 18:00	22.8774	178.964	44.5816	213.07
5/17/2001 18:10	21.7042	171.229	39.5955	214.828
5/17/2001 18:20	22.5841	185.996	37.5424	214.124
5/17/2001 18:30	20.2377	162.439	34.9027	208.147
5/17/2001 18:40	22.5841	173.339	34.3161	206.741
5/17/2001 18:50	24.3439	174.745	37.5424	203.225
5/17/2001 19:00	24.3439	174.745	37.2491	206.741
5/17/2001 19:10	24.3439	176.152	39.3022	206.038
5/17/2001 19:20	22.2908	171.932	36.6625	197.951
5/17/2001 19:30	24.0506	175.8	34.9027	202.873
5/17/2001 19:40	27.5702	168.416	35.196	204.631
5/17/2001 19:50	27.5702	172.987	31.9697	209.202
5/17/2001 20:00	29.33	175.8	27.5702	203.225
5/17/2001 20:10	28.4501	172.636	27.2769	200.06
5/17/2001 20:20	25.5171	171.581	29.6233	194.435
5/17/2001 20:30	25.5171	173.339	31.9697	190.567
5/17/2001 20:40	23.1707	169.12	30.5032	190.567
5/17/2001 20:50	21.9975	170.526	34.0228	194.786
5/17/2001 21:00	21.4109	172.636	36.0759	202.873
5/17/2001 21:10	19.9444	171.932	36.0759	204.983
5/17/2001 21:20	21.9975	171.932	35.4893	206.741
5/17/2001 21:30	17.598	174.042	34.0228	204.28
5/17/2001 21:40	15.2516	181.426	32.5563	207.796
5/17/2001 21:50	15.2516	183.535	33.1429	203.928
5/17/2001 22:00	15.8382	183.887	33.4362	200.764
5/17/2001 22:10	14.665	192.325	32.8496	208.147
5/17/2001 22:20	15.8382	184.238	30.2099	213.773
5/17/2001 22:30	16.7181	194.786	29.6233	215.179
5/17/2001 22:40	15.5449	190.919	31.0898	217.992
5/17/2001 22:50	14.665	193.028	30.2099	223.969
5/17/2001 23:00	9.9722	195.49	29.33	220.453
5/17/2001 23:10	11.1454	184.942	30.7965	214.476
5/17/2001 23:20	10.8521	184.942	28.1568	220.805
5/17/2001 23:30	8.5057	185.645	26.397	216.234
5/17/2001 23:40	9.6789	182.48	25.5171	219.75

5/17/2001 23:50	11.4387	187.754	25.8104	221.156
5/18/2001	10.2655	183.535	26.397	220.102
5/18/2001 0:10	7.9191	183.535	23.7573	220.102
5/18/2001 0:20	6.7459	187.403	28.1568	221.86
5/18/2001 0:30	7.9191	184.942	29.33	228.54
5/18/2001 0:40	5.866	182.832	26.9836	232.408
5/18/2001 0:50	6.4526	187.754	24.6372	228.188
5/18/2001 1:00	8.2124	179.316	24.6372	226.43
5/18/2001 1:10	6.1593	173.339	21.7042	227.485
5/18/2001 1:20	6.7459	193.028	21.9975	227.134
5/18/2001 1:30	6.1593	184.942	21.1176	224.672
5/18/2001 1:40	6.1593	184.238	22.5841	219.398
5/18/2001 1:50	6.1593	175.8	21.7042	224.321
5/18/2001 2:00	8.2124	170.878	20.531	231.353
5/18/2001 2:10	4.9861	178.964	19.3578	228.188
5/18/2001 2:20	4.6928	176.855	15.2516	228.54
5/18/2001 2:30	3.8129	184.238	12.6119	224.672
5/18/2001 2:40	6.4526	151.891	11.4387	243.307
5/18/2001 2:50	5.2794	159.978	13.7851	233.814
5/18/2001 3:00	4.9861	140.64	13.4918	236.275
5/18/2001 3:10	4.9861	186.7	15.2516	243.307
5/18/2001 3:20	2.0531	213.421	16.1315	254.207
5/18/2001 3:30	1.7598	209.202	18.7712	249.636
5/18/2001 3:40	3.2263	162.088	18.1846	244.01
5/18/2001 3:50	2.0531	171.932	11.732	247.175
5/18/2001 4:00	4.6928	130.795	9.3856	261.942
5/18/2001 4:10	1.4665	210.257	7.3325	269.326

6.7 BATHYMETRY

In the study of coastal processes and its impact on coastal erosion problems, surface morphology of the ocean bottom playing a major role. Even though bathymetry chart like NHO are available, to use the data in fine grid for prediction modeling for the near shore phenomena it is utmost important to know the exact bathymetry of the study region. Keeping in mind the importance of the sea bottom surface features, bathymetry survey was carried out in fine grid interval of 100 x 100 m from Ennore port to Pulicat Lighthouse region using Echo sounder fixed with HYPACK software. Survey was carried out with a consultancy of M/s Indomer Coastal Hydraulics (P) Ltd., during May 2001. Bathymetry survey clearly brought out the nature of Ennore shoals in the study region and its orientation. Recorded details were brought into GIS platform for map preparations. Shoals are detached in nature and extending in the direction of NE-SW direction from the northern side of the north breakwater with almost 7 m elevation difference with the surrounding regions. This bathymetry data was used for the numerical modeling studies by reducing the grid size into 20 x 20 m in MIKE 21 software for the Nearshore wave module to predict the movement of waves in the near shore region. Wave module outputs were used for the calibration to run the LITPACK simulations.

Bathymetry map of the study area and a three dimensional view of the Ennore Shoals are shown in Figures 6.14 and 6.15. From the figures it is observed that the shoal exhibits features, which are different from those depicted in the admiralty charts. Presence of ridges and runnels are distinct in the shoal region. On the north of the Ennore port, these shoals extend for a distance of about 15 km is aligned along north-south direction with water depth varying between –4 m and –8 m near the shoal. The water depths at the top of the ridges are of the order of 4.5 metres and along the runnels the water depths are of the order of 11.5 metres. The alignment and positioning of the ridges and runnels indicate that they are migratory in nature due to relatively long interaction

with the southeast waves. While traversing from offshore boundary of the shoal to the Ennore coast it is observed that the water depth vary from about 24 metres along the offshore boundary, decreases to 4.5 metres on the ridges and then increases to a water depth of about 17 metres adjacent to the Ennore coast. This indicates that the seabed is steep adjacent to the coast. Presence of ridges and runnels act as a wave damper and protect the Ennore coast from wave attack.

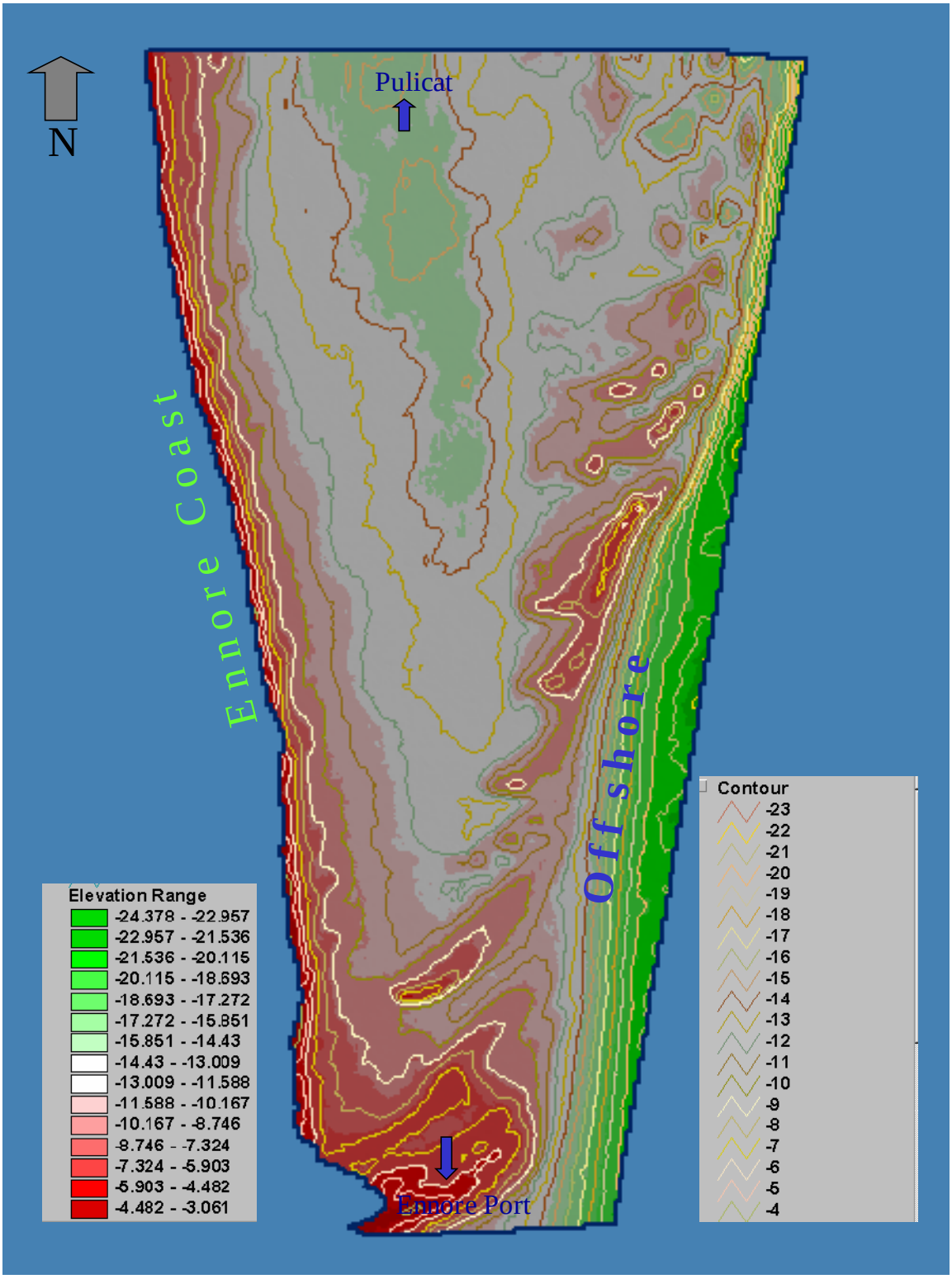


Figure 6.14 Bathymetry scenario of the study region

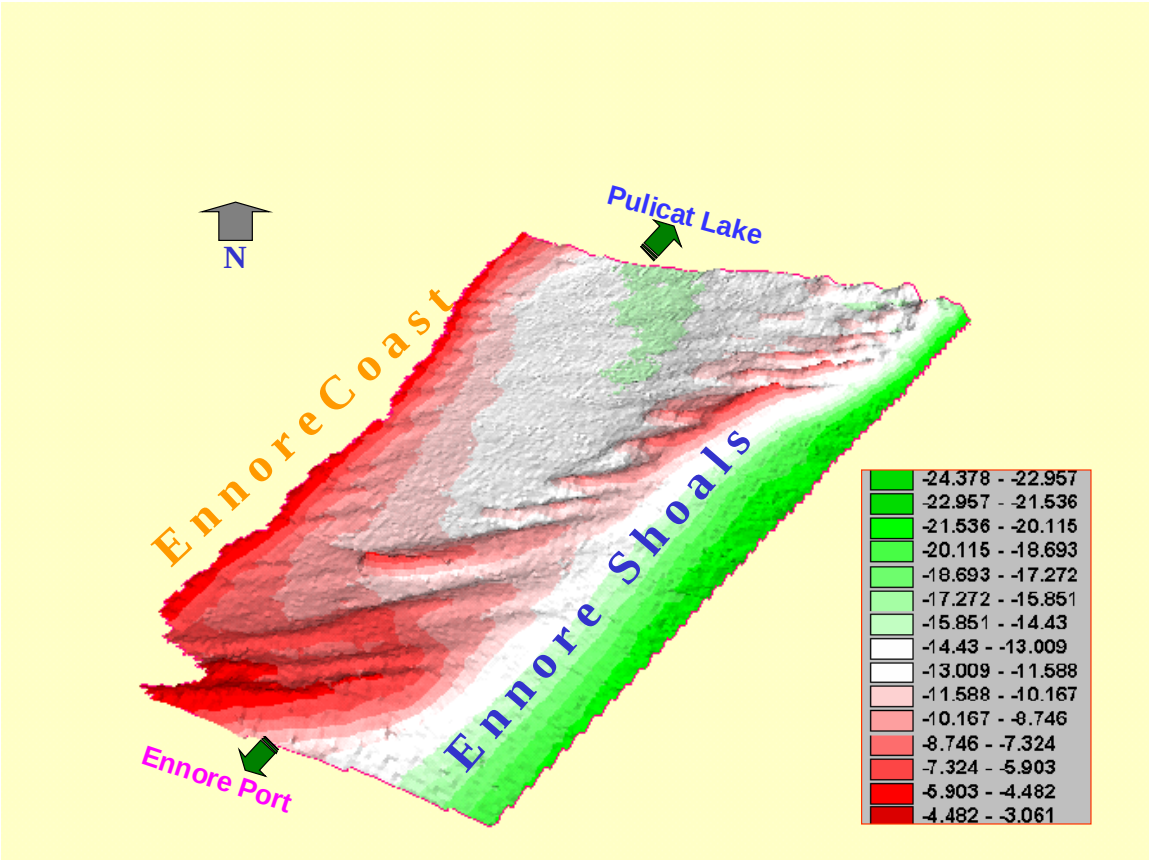


Figure 6.15 A 3D View of Ennore Shoals