Chapter 7

SUMMARY AND CONCLUSIONS
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Sediment budgeting studies are done to bring out the coastal processes at work, to understand the beach-innershelf sedimentary dynamics and to assess the stability of any coastal stretch. There is a dearth of such studies as far as the Indian coast is concerned. The Chavara coast of Kollam district, Kerala, is world famous for its rich heavy mineral resources. These mineral resources are being commercially mined by the Indian Rare Earths Ltd. (IREL) and Kerala Minerals and Metals Ltd. (KMML), two Public Sector Undertakings located in the area. The impact of mining on stability of the beach has been a point of debate among the local people as well as researchers. Hence a sediment budgeting study was taken up for this coast as it offered a very interesting and challenging research problem. The study was taken up with the following objectives:

- Study the hydrodynamic processes and mechanisms involved in the sediment movement along the Chavara coast
- Identify the different sources and sinks of beach sand along the coast
- Quantify the sediment input/output into/from the coast
- Assess the erosion/accretion scenario of the coast based on the study

The investigation covered the coastal stretch of 22km length from Neendakara to Kayamkulam which is referred to as the Chavara coast. A comprehensive field measurement programme taking care of the data requirements for the investigation was meticulously planned and implemented. Wave and current data for different periods spanning over a period of 27 months (ie. more than 2 years) were collected and analysed. Beach based field programmes were also implemented successfully. Close grid beach profiling was carried out at two sites while coarse grid profiling was carried out along the rest of the 22km long coastline. Bathymetric survey was carried out over a region extending 70 km along the coast encompassing the study area and extending out to 60m depth. In addition, seasonal bathymetric surveys were carried out in the inshore regions coupled with SLED measurements to study the seasonal changes in the nearshore profile. The field data were processed to understand the
hydrodynamic and beach-innershelf sedimentary processes and to set up numerical models for sediment budget computations.

A study of the wind pattern in the area was taken up using the IMD data for Alleppey, considering the importance of wind as an important forcing factor in the hydrodynamic regime. The distribution of wind is characterized by the seasonal variation. During fair weather period of November-April, the speeds are generally low with a good scattering. In the rough weather months of May-October, the speeds are higher with a focusing of the direction in the SW-NW quadrants. However, during the rough weather also, the easterlies which are generally weak when compared to the strong westerlies are prevalent. The highest wind speed recorded in the study area was 11m/s.

Analysis of the extensive wave data shows that the wave climate of Chavara coast in general is characterized by monsoonal high and non-monsoonal low wave activity. The seasonal variations are typical of the pattern observed for other locations of the southwest coast of India. The wave characteristics during the peak monsoon period (June, July and August) are characterised by relatively higher wave heights and shorter wave periods. This is attributed to the proximity of the coast to the wave generating zones in the Arabian Sea during the peak monsoon. The highest wave recorded during the study period has a height of 3.8m. Intermittent breaks in intensity of waves for periods extending for 10 to 15 days are observed during monsoon in all the three years and this is in tune with the normal characteristic of the monsoonal climate. Low wave heights (<1m) and a wide range in periods (7-15s) characterize the waves during the pre-monsoon and post-monsoon seasons. The long periods are associated with swells that originate far away in the Indian Ocean. The shorter wave periods recorded during these seasons indicate sea waves generated locally by persisting NW wind. During the period of wave recording that covered three monsoon periods, though the annual cyclic pattern of changes were same, inter-annual changes were significant.
The exhaustive set of measured current data at two offshore sites spanning over a period of more than two years, which is unique for the Indian coast, is used to study the currents. Currents show seasonal changes with stronger currents during monsoon and weaker currents during fair weather. The maximum observed current is 70 cm/s and the common maxima are around 15-20 cm/s. It is found that both in nearshore and offshore sites alongshore components of the currents are mostly much stronger than the cross-shore flows. The observed current appears to be a resultant of tidal currents, wind-driven currents and continental shelf currents. The influence of tides on the current is quite evident from the semidiurnal oscillations seen in the time series distributions for different measurement periods. A good correspondence is seen between wind and currents on many occasions in the study area. The predominant NW winds in this region, according to theory, can generate currents mostly longshore to the south on the inner shelf. The dominance of southerly flow is quite evident from the recorded data. On this wind-driven pattern is superimposed a shelf current associated with larger-scale circulation in the Indian Ocean which is characterised by the Lakshadweep High and Low. It is deduced from the data that when the northwest wind abates the shelf currents flows in response to the general circulation, although the net movement is southward. In addition to the tidal, wind driven and continental shelf currents, there could also be the contribution of coastal trapped waves and baroclinic flow associated with the plumes of fresh water coming from the estuaries.

Significant seasonal variability is observed in the case of littoral environmental parameters in line with the variability in wave parameters observed in the offshore zone. The beach generally has maximum width during the fair weather months and the lowest in the months of May-June-July, when the wave intensity is at its maximum. The seasonal cycle is maximum at sites, which are not fronted by sea walls. During the period June '99 to June '00 volume change is 60 m$^3$/m of beach while in the subsequent year the volume change is 70 m$^3$/m, indicating a more or less steady condition on an annual basis. Five-year beach profile data at selected stations show conditions different from this starting from 2001 with cumulative erosion at station VMS7.
Wave is found to be the predominant force influencing the beach processes. Offshore transport of sediments induced by steep waves takes place during the peak monsoon leading to intense erosion. Re-building of beach takes place during the fair weather months when onshore transport of sediments takes place. The wave induced longshore currents bring about spatial variations in the erosion/accretion pattern. It is observed that there is a good correlation between the wind and erosion/accretion pattern of beach. This is attributed to the wind induced circulation in the innershelf. Westerly wind generates offshore bottom current leading to erosion while northerly wind generates onshore current resulting in accretion. Winds along this coast being predominantly NW, a slight rotation of wind would lead to changes from net erosion to accretion. Mining of beach sand for heavy mineral extraction is an anthropogenic activity which has an impact on the beach as seen at station VMS7.

Based on the investigation, it is concluded that the beach sediment budget of the Chavara coast is constituted by the longshore and cross-shore transport together with the intake due to mining. There are two longshore fluxes; first, there is a flux to the north of an average yearly value of 1,67,000 m$^3$ along the beaches in and adjacent to the surf zone which is driven by the waves that approach predominantly from the south to south-west quadrants. The second flux is to the south on the inner continental shelf of value 1,72,000 m$^3$, beyond the surf zone. This is driven by a prevailing wind from the north to north-west quadrant that induces southbound currents for much of the year. The two longshore transports are linked by the onshore and offshore transport which are also more or less balanced. Thus there is a balancing between the longshore and cross-shore transport leading to a dynamic equilibrium.

Due to the strong connection between the beach and innershelf, the impact of sand mining is not felt on the beach when the mining is within an optimum level equivalent to the quantum of sand replenished by the natural processes. When the quantum of mining exceeded the supply of sand by the natural processes, local impacts by way of beach erosion is seen. The five yearly beach profile data which shows cumulative erosion at station VMS7 starting from 2001 conclusively proves this point. It is concluded that, though sand mining will cause erosion in the innershelf, the level and
time taken for a measurable impact can be long if the extraction volumes are much less than the volumes being moved naturally on/offshore and alongshore.

**Recommendations for Future Work**

The present work is a pioneering effort in sediment budgeting studies. The study has proved beyond doubt the usefulness of such studies in understanding the beach-innershelf sedimentary system, in apportioning the role of each contributing factor in the erosion/accretion scenario of the coast and for making a final assessment of the stability of the coast under different scenarios. Thus sediment budgeting studies should be made mandatory for all coastal systems that are critically eroding or are under threat due to anthropogenic activities such as mining or coastal engineering projects.

While all efforts have been made to conduct the study within reasonable accuracy level utilizing the then available infrastructure and numerical models, future studies could be directed to take care of some of the limitations of the study with regard to numerical models and instrumentation. Some of the efforts in future that would greatly enhance the reliability of the sediment budgeting studies are given below.

- Longshore transport models are very sensitive to wave breaker angles. Though a directional wave gauge was initially used in the present study, the data collection could not be continued due to malfunctioning of the equipment. A directional wave gauge should be made an essential component of the instrumentation system.
- The vertical profile of currents is another desirable data that could help in the calibration of models and computation of cross-shore sediment flux. An ADCP could ideally replace the current meters.
- An important addition to the offshore instrumentation could be an underwater video camera that could give vital information on bed form, which is required in understanding the physical environment as well as providing some empirical coefficients in numerical modelling.
• Wind data is very essential in sediment budgeting studies. Shore-based records of wind have limitations as seen in the present study. Hence wind data based on offshore data buoys would be the ideal choice.

Further refining of numerical models engaged for the work is essential. Attempts could be focused in the following directions.

• Many of the beaches are fronted by sea walls. In such a condition the longshore transport model in its present form which doesn’t take care of this situation should be appropriately modified. The longshore transport rates estimated using the present models in such cases are over estimates.

• Coefficients/constants relevant for the coast should be worked out for input into the models. Under water video images should be used for providing appropriate values for bed characteristics and friction coefficient.

It can be said with confidence that sediment budgeting studies incorporating the above suggestions will be a real boon for investigation of coastal erosion problem including future projections and suggestion of appropriate mitigation measures.