CHAPTER 1
INTRODUCTION

The coastal zone acts as the major interface between land and oceans. The demand of this zone has been increasing day by day due to anthropogenic activities like construction of coastal structures, housing, fishing, dredging, mining and drilling, development of harbours and ports and so forth. Estuaries located near such coastal sites act as a connecting passage between rivers and adjoining seas and have a very special significance in the context of coastal zone management. According to Dyer (1979) estuaries are very important centres for human activity and serve as ideal sites for development owing to their fertile waters, sheltered anchorage and navigational access, even though they may occupy only a very small geographical area. Studies conducted all over the world (Lauff, 1967) show that most estuaries are the most productive, diversified but sensitive zones in coastal areas which support organisms in a wide range of tolerance. The transport of vital nutrients to the nearshore from the terrestrial regions is through the estuarine waterways. This in turn, results in recognising estuaries as an indispensable regime for the support of marine life and its existence. Large input of suspendate and bed load material eventually reach the coastal zone through such "gateways". Part of the material eventually settle in the estuarine bottom or in the nearby coastal areas. Major ports or harbours located in and near the coastal zone (many within estuarine bounds) are centres of intense marine activities, depending on the number and frequency of operational vessels at the site. Towards smooth marine traffic operations an important prerequisite is
guaranteed adequate depth requirements. Seldom natural conditions favour free harbour operations at a time of enhanced human intervention in modifying coastal regimes within expanding horizons of advance technological means. In this context, sedimentation is one of the major conundrum facing many a ports of the world.

Sedimentation is a process of accumulation of suspended material as a part of natural processes in rivers, estuaries or seas. According to Dyer (1979), often the fine grained sediments like clay and silt get collided with other materials to form aggregates in seawater. In estuaries, however, the tidal currents and salinity have an important role in the sedimentation and flocculation processes. During a tidal cycle, after the completion of high/low tide, the current strength in the estuary gradually decreases and the slack period lasts for a few minutes/hours without the prevalence of strong currents. The speed of transportation of sediment within the estuary thence gradually reduces, when sedimentation rate maximizes and results in the settlement of suspended sediments on the estuarine bottom. With time, as the reverse process develops, the tidal currents gradually gain momentum after the high/low slack period which may likely disturb the bottom and resuspend the freshly sedimented particles but, concomitantly allowing sedimentation to continue depending on the hydrodynamic conditions. Again after a few hours, the slack period prevails leading to increased sedimentation rates. In short, during the intervention of the slack period (short time duration) sedimentation results and the depth of the estuary (channel(s) in case of harbours which are dredged) reduces. The periodic continuous reduction of the depth would thus adversely affect the usage of waterways within the
port and harbour and also inhibits trade, commercial and recreational activities. The sedimentation problems in harbour areas including environmental impacts is not a new topic having been reported from both developed and developing countries; examples of a few are from Toronto and Dalhousie harbours in Canada, Boston harbour, Port of Liverpool, Thames port, Port Hamble and port of Dover in England, Port of Amsterdam and Rotterdam in Netherlands, Chugjiang estuary mouth in China, Gray harbour in Washington, Sulaibikhat bay in Kuwait, Western port & Esperance harbour in Australia, New York harbour & Norfolk harbour in U.S.A. etc. (Weinmann and Malek, 1978; Mahon, 1979; Bakker, 1979; Zhaosen, 1981; Fuhrmann and Dayal, 1982; Diamond, 1983; Tosswell and Webber, 1984; Berger et al., 1985; Coy and Goddard, 1987). A large number of reviews are available, highlighting the various aspects of sedimentation/desilting and its related issues (Windom, 1976; PIANC, 1977; Jones, 1981; Hunt and Bartel, 1983; Russell, 1984; Wildish and Thomas, 1985; Senten, 1989; Tortell et al., 1992; Peter, 1993 and Gill, 1995).

In India too, the major ports, namely Calcutta, Bombay, Madras and Cochin are facing serious threat from sedimentation. At all these ports, activities are critically connected which essentially are depth dependent for entry/exit of marine vessels. The port authorities spend large amounts on dredging for channel maintenance to afford smooth harbour operations.

The utilisation of waterways for business and recreational activities continues to grow day by day. The import and export of commodities are also increasing as ever before, necessitating a minimum draft in such operational routes. In order to remove the
settled sediments on estuarine/rivers/nearshore seabeds, the planners usually adopt dredging techniques. According to Canter (1985) dredging is the counterpart of sedimentation, and involves the removal of several variable materials from the bottom of the sea, estuary or lakes in adverse conditions and subsequent disposal of dredged material spoil in open distant waters or on land. Dredging is an art but at present, is a science where man's large scale intervention in the marine environment has many fold manifestations (Cooper, 1974). The preliminary objectives of dredging are to improve navigation, implement flood control programmes, conduct mining operations, construction and reclamation activities in coastal zone and towards beach nourishment purposes.

The dredging activities may be conveniently divided into two (Bray, 1979). One is capital dredging which involves the construction of a new bed configuration in the marine environment and the other is maintenance dredging involving the upkeep of channel depths by retaining a constant bed configuration. According to Scott (1991) the efficiency of dredging operations is dependent on many variables within the dredging environment. These are sediment and water properties, current pattern, environmental restrictions, transportation and disposal requirements of dredged material. Akin to any other artificial process, dredging also brings about positive and negative impacts on the environment. These and allied aspects are discussed hereunder, first on environmental impact assessment briefly, followed by dredging impact assessment, in detail.
2. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Lash et al. (1974) had defined environmental impact assessment as the process of attempting predictive studies on a proposed development, analysing and evaluating the results of the said development. The scientifically based environmental assessments are composed of two distinct phases: (a) predictive phase, means to predict the effects of expected impacts before development occurs and (b) a monitoring and assessment phase, which is meant to measure and interpret environmental effects during the development and after it has been completed (Rosenberg et al., 1981). According to Munn (1975), EIA is defined as objective and subjective cataloging of the total physical and biological effects of a proposed development. The study may also be held at a site under "environmental stress" where no such attempts were conducted beforehand; in such cases, experience from other instances will serve much to the cause. It requires continuous collection of the relevant data before, during and after the event; analysis of the data, followed by interpretation of the data and re-evaluation etc. Based on the report of the EIA, developmental activities may be carried out at any site. Dredging is one such activity which attracts impact assessment studies. This ensures that the impacts on the environment remains a minimum and provide adequate scope and protection of the ecosystem at the proposed site.

According to Golden et al. (1979), there are three basic steps to determine whether a proposed project requires an environmental impact statement. These are
1. definition of the purpose and scope of the proposed action
2. preparation of an initial environmental assessment and
3. evaluation of whether there could be significant impacts for the proposed action.

The environmental assessment is an environmental report prepared to determine whether the proposed action requires the preparation of an environmental impact statement. The environmental assessment may be based on checklists, matrices, networks and specific studies of various parameters interlinked in the project (Golden et al., 1979; Rosenberg et al., 1981). The environmental assessment include,

(A) Data collection: in order to obtain the general characteristics of the site and the proposed action.
(B) Analytical technique: measure the impact with proper scientific equipments.
(C) Preparation of environmental assessment: it consists of analysing the impacts associated with the proposed action.

The environmental assessment narrates the following: (Munn, 1975)
(1) Describe the proposed action (2) Describe the environment to be affected (3) Identify all relevant environmental impact areas (4) Evaluate the potential environmental impact (5) Identify adverse impacts that cannot be avoided, in which case, should action be implemented (6) Identify the conflicts with state, regional and local plans and programmes (7) Evaluate alternative to the proposed
action (8) Discuss any existing controversy regarding the action. It has now been a standard practice in developed and developing countries to embark upon an assessment before new projects are sanctioned. In many a worse scenario, for existing exigency impact studies are being held, routine monitoring conducted and remedial steps implemented to correct the situation.

3. DREDGING IMPACT ASSESSMENT (DIA)

It is affirmatively stated that associated with any developmental activity involving (close) interaction with nature, dredging too, creates direct/indirect impacts on the marine environment. A study in this direction will include the effects of dredging, measurement and remedial measures. The picture evolves around the history of dredging (Gower, 1968) to concept on dredgers for fighting pollution control (Keneko & Watari, 1983) and there has been notable development in design and utility of dredging crafts (Bates, 1978). Alternate approach to maintenance form of dredging in estuarine harbour region has been proposed by Skelly (1983), in the context of DIA. The concept of restricted draft geometry (Roseman and Barr, 1983) and implementation of innovative dredging techniques is of recent origin (Aurant and Mamantov, 1983; Grover, 1983). Recognising the need for better environmental protection new approaches include both innovative and conventional dredging (Hayes et al., 1988) special projects and eco-friendly dredging concepts (Mc Cartney et al., 1991; Kirby, 1993). Gaining momentum on efforts to reduce the environmental effects to dredging programme proposed by Calhoun et al. (1984), a new awareness on EIA related to dredging (Ridell, 1985) are good instances in understanding the issues related
to environmental management. Dredging impacts are site specific and may be categorized as (after Bray, 1979)

(a) Dredging site
(b) Transportation site and
(c) Disposal site

The dredging site is affected directly and indirectly by dredgers in operation. According to above author, this include the movement of dredger around the dredging site and consequent risk of collision, snapping, rubbing or jumping of wires attached to points on the shore which could cause damage to personal and property, accidental damage to underwater pipelines and cable, turbidity caused by agitation, overflow of dredged material, the formation of density layers from overflow waters and the destruction of fauna at the dredging site. Indirectly, the dredging processes are likely to cause noise disturbances and possibly annoyance to the local population.

The direct effects after dredging are the possibility of subsidence of adjacent works due to undermining and subsoil failure, alterations of local soil characteristics, change of local flow pattern together with changes in siltation in the dredged channels, destruction of spawning grounds by alterations in the habitat and the destruction of flora and fauna causing a depletion in local fish communities. The indirect effects are the possibility of beach drawdown i.e., the movement of material towards the sea due to the removal of offshore deposits, the refraction of waves caused by the change in the seabed, and consequent erosion and deposition, change of tidal flushing characteristics of an estuary consequent to
alteration of sediment load, habitat damage etc.

At the transportation site, the effects are by leakage and loss of spoil enroute which leads to increased turbidity and issues related to short term toxicity.

At the disposal site, direct/indirect effects are noticed during and after dumping the spoil. These include the turbidity generated at the dump site due to the passage of spoil through the water, the movement of dredged spoil into the adjacent areas, consequent alteration of water quality and bed material, the refraction of waves caused by the alteration of sea bed and consequent changes in the coastal regime.

Environmental impacts of dredging are short listed as follows:
1) resuspension of bottom sediments
2) release of toxic substances
3) oxygen depletion
4) reduced primary production
5) temperature alterations
6) altered nutrient levels
7) benthic community alterations
8) problem at the sediment disposal site
9) sediment textural variations
10) change of extinction coefficients
    and
11) mixing zone changes.

All the above changes have direct or indirect effects on the environment (Canter, 1985) elaborated as hereunder.
1. Resuspension of bottom sediments

During dredging, the sediment at the bottom gets disturbed and on resuspension is brought to the surface layers causing the turbidity of the water column to increase. Studies reveal that continuous or persisting turbidities have detrimental effects on organisms. According to Bray (1979), the resuspended sediments cause the clogging of fish gills, functionally create problems for filter feeders, place hurdles to migration etc. Sherk (1971) has elaborated on turbidity related effects due to dredging in the aquatic environment.

2. Release of toxic substances

The dredged sediments have a wide range of physical and chemical characteristics. Ports/harbours or estuaries located near industrial areas often receive discharge of wastes and effluents that bring about the build up of heavy metals, pesticides and other chlorinated hydrocarbons in bottom sediments. The pollutants which rapidly accumulate in the deposited sediments are released during dredging, often turning the aquatic media toxic around the dredged site and immediate neighbourhood. Windom (1976), has pointed out that among the toxic substances, the heavy metals, i.e. copper and zinc are common to all harbours which have received special attention as prime water quality indicators immediately after dredging process.

3. Oxygen depletion

Surface waters of the coastal area in contact with atmosphere, helps to retain high amounts of oxygen in the surface
mixed layers. But at the time of dredging the surface waters mix with bottom waters which would have lesser amounts of oxygen and this adversely affects the quality of the water and that of the prevailing ecosystem. Frankenberg and Westerfield (1968) and Odum (1970) have identified the problem related to dredging in estuarine waters and observed the depletion of oxygen availability in such dredged areas.

4. Reduced primary production

The adequate presence of plankton in the ecosystem is an essential link in the marine food. Considerable variations in phytoplankton content has often been noticed in dredging areas. During dredging, the turbidity of the surface waters increase and consequently light penetration is reduced inhibiting photosynthesis to a large extent, so that phytoplankton blooming is eventually curtailed. Abundance in plankton content are highly susceptible to dredging and its related impacts. Another change in the phytoplankton content may occur due to the increase in nutrient release during dredging which likely would lead to enhancement in phytoplankton blooming.

5. Temperature alteration

Temperature change due to dredging is not of much importance in large tropical estuaries. Mixing with bottom waters, which leads to the decrease of surface temperatures, is mostly a localized phenomenon.
6. Altered nutrient levels

The deposited sediments of terrigenous or marine origin contain large amount of nutrients in the form of soluble phosphorous and nitrogen. On agitation, sediments which contain available nutrients are placed in suspension in the vertical, leading to enhanced nutrient levels by the action of continuous or maintenance dredging. These enhanced levels are not maintained for long but are incorporated by marine organisms; of significance is the fact that diversity increases depending on the changes in nutrient levels (Flint, 1979).

7. Benthic community alterations

Bottom terrain disturbances always disrupt the benthic community set up. The settlement of such organisms within the port area is considerably disturbed due to dredging to a large extent. A study by the Swedish scientist Rosenberg (1977) indicates that the reduction in number and of diversity of organism are the aftermath of the deleterious effects. The larval development in the vicinity of the dredged area is often strongly affected. The study from the Chesapeake bay area indicates that the benthic community showing seasonal fluctuations, never attains equilibrium after dredging activities. The study of the benthic community at the Botany Bay shows that the benthic fauna at the dredged area is different from the nearby non-dredged areas with respect to species composition and richness, both of which are closely related to the sediment type (Jones & Candy, 1981). They also conclude that the macrobenthic faunal variations in the Botany bay is an indirect impact of dredging. A very recent report narrates the outcome of dredging on
benthic recovery in Galveston Bay, Texas (Ray and Clarke, 1995).

8. Problems at the sediment disposal site

Criteria to locate a suitable place for sediment dumping is very important for dredging operations to succeed. Before the conduct of dredging and selection of site it is desirable to know the proper flow regime at the disposal site, tidal currents, waves and sediment characteristics and longshore drift features.

Usually the dredged sediments are disposed at offshore areas or utilized for developing recreational sites or for harbour development in order to construct bridges, roads or railways. The presence of marine organisms, their diversity and abundance are also to be considered at a disposal site, offshore area, beforehand. Generally, the following aspects are considered for site selection:

(a) location sediment characteristics
(b) flow regime including waves and currents
(c) tidal pattern
(d) the presence of marine organism.

and

(e) distance from the dredged location.

The spoil is also used for land reclamation purposes which will serve the following positive considerations (Bray, 1979):

(a) it is cheaper to place the dredged spoil in a reclamation area
(b) it is ecologically acceptable for reclamation
(c) it is useful for port development, agricultural practices and for recreational uses.
9. Sediment textural variations

The variation is prominent at the dredged site and also at the disposal site, but indirect variations are observed at the nondredged site too. Generally, for a given set of sedimentation rate(s), the fine grained material deposit last after the coarse grained sediments due to density variation. On dredging, the pattern of layers on bottom is altered and bedload movements may be expected at the site of excavation. At the disposal site, especially in offshore areas, the effects of textural variations are pronounced on the benthic community (Canter, 1985).

The dredged sediment may be used for beach nourishment. This is artificial addition of suitable quality/quantity of sediments to construct a beach to provide stern protection of the coastal area and which would also serve recreational purposes. At the reclamation site, if the dumped sediments are of same texture as that of the region, the strength of the reclamation area will be very high, otherwise will be covered by sediments unconsolidated in nature, bound loosely.

10. Change of extinction coefficients

During dredging, the turbidity of the surface waters increase which leads to reduction of light penetration, so that transparency reduces considerably. This aspect may be considered along with primary production changes for a designated site.

11. Mixing zone changes

Mixing zone is where seawater and freshwater come in contact (say for an estuary) and phenomena like dispersion and mixing takes
place to attain medium homogeneity. This zone may extend a few kilometers from the lower estuary to upper estuary. Dredging processes could totally disturb the mixing zone range thereby affecting the hydrodynamic stability. The accompanying variations are listed as follows:

a. hydrographic change
b. horizontal, vertical and longitudinal variations in salinity structure
c. channel morphology and stability
d. saltwater intrusion pattern
e. sediment pattern distribution
f. location of turbidity maximum
g. transport rates of nutrients to the sea
h. aquifer recharge
i. groundwater table levels
j. bank erosion
k. velocity alterations

and

l. pollution flushing and tidal prism.

The above listed changes will consequently alter the prevailing ecosystem characteristics too.

In many of the above listed environmental impacts of dredging most are negative in the upkeep of quality/quantity of existing coastal zone where harbours and ports are located. On the other hand positive impacts are best judged by their utility and application for a given scenario. To list a few (PIANC, 1977), these are:
a. improved navigation  
b. removal of polluted sediments  
c. collection of construction material  
d. beach nourishment, as the case may be  
e. mining for minerals  
f. reoxygenation of sediments  
g. salinity wedge limits may be beneficially controlled  
h. land reclamation  
i. compensation of land subsidence and  
j. improvement of vista  

Additional information related to experience on DIA and its allied aspects are available from Australia (Crabb, 1986), the United States experience (Herbich, 1985), the picture in China (Zhaosen, 1981) followed by the European experience (Parker, 1981) demonstrative and forceful experience of new Singapore airport (Ong, 1982), a small but important illustration from Bangladesh (Burren et al., 1981) coupled with India's another neighbour (Anon, 1977) and finally the Indian scenario (Anon, 1979) are worthy reading materials. The Dutch policy is illustrated by Bos (1987) and that for the northern Europe Anon (1991) addresses additional issues of dredging and environment.

4. DREDGING IMPACT ASSESSMENT (DIA) AT COCHIN PORT

Cochin is the second largest port along the west coast of India. Historically, this area is known for trade, commerce and cultural activities with other countries especially Arabia, Portugal and Holland. This harbour and its neighbourhood environment is most natural (Bristow, 1967) which has a free permanent connection (Cochin
gut - tidal inlet) with the sea allowing land drainage derived from terrestrial sources. It has three dredged channels, one being the approach channel oriented along east-west direction of around 10 km length and 500 m width and the two inner channels located on either side of the Willingdon Island, i.e., Ernakulam channel of around 5 km length with a width of 250-500 m and Mattancherry channel of 3 km long with a width of around 170-250 m. All the three dredged channels are maintained at a depth of 10-13 m. The tropical estuarine environment shows multitudinal features (Joeanto, 1971; Kurup, 1971; Wellershaus, 1971; Manikoth and Salih, 1974; Qasim et al., 1974; Joseph, 1974; Joseph and Nair, 1975; Sankaranarayanan and Panampunnayil, 1979; Lakshmanan et al., 1982; Venugopal et al., 1982; Remani et al., 1983; Anirudhan et al., 1987; Lakshmanan et al., 1987; Sarala Devi and Venugopal, 1989; Balchand et al., 1990; Shibu et al., 1990; Joseph and Kurup, 1990; Ouseph, 1992; Nair and Balchand, 1993; Nair et al., 1993; Ajith and Balchand, 1994; Balchand and Nair, 1994; Shibu et al., 1995; Rasheed et al., 1995a,b & Ajith and Balchand, 1996) which characterize freshwater and seawater mixing (Gopinathan and Qasim, 1971; Wyatt and Qasim, 1973; Udaya Varma et al., 1981; Sankaranarayanan et al., 1986; Joseph and Kurup, 1987; Joseph, 1989; Chandramohan, 1989 & Sundaresan, 1989) and affords breeding ground for the marine organisms in juvenile form (Remani et al., 1983; Nair et al., 1988 and Sarala Devi et al., 1991).

Cochin backwaters is now well known to face serious environmental threat by way of intertidal land reclamation, pollutional discharges, expansion for harbour development, dredging activities, urbanisation and for many other factors (Gopalan et al., 1983). The construction of Thaneermukkom bund near Vaikom also
created severe environmental consequences within and out of adjacent Kuttanad agricultural fields (Balchand, 1983). Extensive studies have been carried out in Cochin estuary especially on the physical, chemical and biological aspects as cited above but the issues dealing with environmental impacts of dredging was never addressed well but for scanty reports (Gopinathan and Qasim, 1971; Anto et al., 1977; Sundaresan, 1980; Rasheed and Balchand, 1995).

The sedimentation features at the Cochin port varies according to season(s). There are three seasonal conditions prevailing in this estuary i.e., monsoon (June - September), postmonsoon (October-January) and premonsoon (February-May). During the monsoon period, heavy rainfall result in heavy discharge through the rivers eventually reaching the estuary and waterways of port. Stratification often develops and results in conditions with less dense river water at surface and high dense seawater at the bottom layers. Such typical hydrographic features and circulation pattern complicates the sedimentation features in the estuarine channels.

In the postmonsoon season, the river discharge gradually diminishes and tidal influence gain momentum as the estuarine conditions change to a partially mixed type leading to weakening of stratification. This is mainly a transitional period.

In the premonsoon season, the river discharge is minimum and the seawater influence is maximum upstream; the estuary shows well mixed characteristics and homogeneity exists within the vertical water column. The development of turbidity maxima which occurs during high tide within the estuary is well noticeable.

During the pre and postmonsoon period, the sedimentation rate in the inner channels (Mattancherry and Ernakulam) is higher than in
monsoon due to the tidal influence. The circulation pattern helps to bring more silt and clay into the estuary and especially during the slack period, sedimentation is the highest. But during the monsoon period, the physical processes alter leading to sedimentation in the approach channel (Gopinathan & Qasim 1971). This sedimentation feature results from the heavy discharge of water plus sediments brought out to the Cochin gut and deposited in the outer harbour. Simultaneous processes (turbulence due to currents) in the inner harbour leads to re-suspension of sediments and thus accumulation of sediment is reduced. Compared to the Ernakulam channel, maximum silting occurs in Mattancherry channel (Gopinathan and Qasim, 1971). Nearly 1/3rd of the reported silting from the three dredged channels during the year occurs in the Mattancherry channel. This may be due to the pattern of circulation in that part of the estuary where weak currents prevail.

The sedimentation in the port area creating a reduction of depth up to 1-2 m per year is clearly a problem for smooth conduct of marine traffic operations. According to Ducane et al. (1938), the heavy silting observed in certain years at Cochin port was definitely influenced by the appearance and movements of mudbanks in the close vicinity of the gut. Anto et al., (1977) observed that the longshore currents could also bring sediments into the channels. The primary income of the port depends on loading and unloading operations, transfer of oil and fertilizer, export of spices, coir etc. The maintenance type of dredging in the three channels is thus a very important activity for the uninterrupted port function throughout the year. In Cochin estuary, different types of dredgers are in operation. This include grab dredger, cutter suction
dredger and trailing suction hopper dredger. For continuous maintenance dredging trailing suction hopper dredgers are most useful. This helps to dredge the sediment within short span of time over a wide area. For purpose oriented dredging near a berth or jetty, grab dredging has been very useful and is practiced in Cochin port too.

The following aspects attract a careful study in Cochin estuary (dredging site) and especially for Cochin port in the context of dredging and its net impacts on the coastal zone:

1. investigate the proper bathymetry of the Cochin port area
2. current pattern with seasonal variations
3. influence of waves and tides
4. salinity variations and stratification features
5. sediment availability and silting features
6. water quality changes
7. benthic community and fisheries

Within the scope of this thesis, DIA has been carried out at the dredging site of Cochin port. The scheme of the work is detailed as below.

5. SCHEME OF THE WORK

The approach to the present study is depicted in Flow Chart 1. Before commencement of the actual field work, an attempt is made to define the developmental activity going to be implemented along with a clear and concise definition of the scientific objectives. Before
Flow Chart 1. Parametric based approach to DIA
the implementation of the proposed project, background may be obtained from literature review, case history studies - similar to the proposed project - and reconnaissance of the region involved. Based on the preparatory work, the parameters relevant to the scientific objectives can fairly be identified; even those parameters which are likely to be affect while actually implementing the developmental process, that which may reflect the physical, chemical, biological and geological aspects of impacts could be designated for detailed analysis (Rosenberg et al., 1981). Selection of such parameters may be for short and long term impact studies. Within the scope of this thesis a total of eight parameters have been identified (currents, salinity, turbidity, transparency, sediment texture, nutrients, chlorophyll and benthic fauna) as of important interest. On identification, continuous monitoring / experiments / analysis of the parameters were conducted at the site, modelling, if required so. Based on the results, a judicious attempt helps to understand the system and to predict the various aspects of impact(s). An assessment of the environmental impact follows. Recommendations are also incorporated which is logically derived from analysis and (re-)predictions which include both positive and negative impacts are made. Based on this system approach the system may be refined for betterment. The above parametric based approach to DIA has been followed in this study.

The prime objective of this work is to get a detailed report on the positive and negative impact on the estuarine environment while conducting dredging operations on short term and long term basis and to work out the remedial measures to reduce the negative impacts at the dredging site.
The doctoral thesis consists of six chapters. Chapter 1 gives a general introduction to the topic and conducts a review on the dredging operations and impacts on the environment.

The material and methods required for the field investigation, analysis and interpretation of the data are given in chapter 2. Chapter 3 presents the results on dredging impacts at Cochin, a tropical estuarine port by conduct of field study on various parameters during the last two years. Highlighted are the positive and negative impacts on study on turbidity, sediment texture, nutrients and bottom fauna.

The short term impacts at a dredging site and the results thereof form part of the special field survey(s) related to dredging under chapter 4.

Chapter 5 deals with Dredging Impact Assessment (DIA) and provides a critical assessment of dredging based on the results from chapters 3 and 4; also included are viable means and alternate technology to mitigate issues concerned with sedimentation and dredging. An attempt is also made to evolve a DIA matrix on process vs impacts for future reference and guidance.

Chapter 6 gives summaries and the results of the present study.

It is hoped that the results of the present study will beneficially serve environmentalist/authorities who are concerned with the dredging operations or such similar projects affording them adequate opportunities to minimize/mitigate the negative impacts. They are also encouraged to run a criteria based evaluation of operations under DIA so as to evolve eco-friendly mode of environmental management.