CHAPTER 1

INTRODUCTION

1.1 GENERAL

Coastal lagoons are shallow water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented parallel to the coast (Kjerfve 1994). They are highly productive ecosystems of great economic, social and scientific interest. In addition to their unique properties, they possess characteristics of both terrestrial and aquatic ecosystems. Tidal inlets are a common feature found along major part of the Indian coastline. They play an important role in coastal ocean processes and provide a passageway for ships and small boats to navigate from ocean to sheltered waters (Kreeke 2013). Over the past two centuries, industrialization, urbanization and deforestation have led to the closure of the inlets and loss of such lagoons and wetlands resulting in the extinction of countless species. Management of coastal lagoons involves constant monitoring of the tidal openings, which affect the exchange of water between sea and the lagoon and hence its water quality and biological productivity (Jayaraman et al 2007).

1.2 ECOLOGICAL IMPORTANCE OF LAGOONS

Lagoons are areas where salt water oceans and fresh water rivers mix together, forming brackish water. Coastal lagoons, which occupy 13% of the world’s coastline, are rich, but very fragile ecosystems (Farnworth &
Golley 1974). The lagoons are important on account of their biological, geological, physical and chemical characteristics. They support a range of natural services which include fisheries productivity, storm protection, and tourism and so on (Gonenc & Wolflin 2005). The direct values of wetlands are the benefits derived from fish, agriculture, fuel wood, recreation, transport, wildlife harvesting, peat/energy, vegetable oils etc. Coastal lagoons support a rich biodiversity, like plants, animals or microbes. They act as spawning grounds for marine fish and invertebrates, and resting areas for many species of migratory birds (Aliaume et al 2007). These semi-enclosed systems are vulnerable to contamination by pollutants. They maybe overfed by nutrients and become hypoxic, or choked by opportunistic green algae. The indirect benefits of the wetlands are nutrient retention, flood control, storm protection, groundwater recharge, external ecosystem support, micro-climatic stabilization, shoreline stabilization and so on (Lambert 2003). Unfortunately, in the last decade, marine pollution and other anthropogenic activities have caused the health of the lagoons to deteriorate, and wildlife and plant abundance has decreased drastically.

1.3 TIDAL INLETS

Tidal inlets provide the link between the coastal oceans and the protected tidal embayment. They exchange fresh and saline water, coarse and fine sediments, nutrients, living organisms and pollutants between them (Kreeke 2013). Significant social, economic and environmental impacts occur when new inlets form or old inlets close. Besides their importance as pathways for water, sediments and various suspended matters, tidal inlets play a key role in the morphologically high dynamic system, which interlinks the adjacent coast and the tidal basin or back-barrier area. Inlets play a crucial role in coastal sediment budgets and shoreline erosion, and thus in long-term coastal evolution. Understanding coastal, inlet hydrodynamic and morphodynamic processes driven tides, wind-generated waves, and river
inflow is crucial to flood prevention, sediment management, shoreline erosion control, navigation channel maintenance, and to design coastal infrastructure (Ding & Wang 2008). Sediment transport, consisting of long-shore and cross-shore sediment movements and river sediment supply into coasts and inlets, leads to complex morphological changes such as shoreline erosion/accretion, barrier/levee breaching, river bank erosion, variations of river mouth bars, navigation channel refilling, migration of offshore bars, etc. Tidal inlets interrupt the long-shore transport of sediments, affecting both the supply of sand to the down drift beaches and erosion-depositional process along the inlet shoreline (Fitzgerald 1988). The morphological interaction between the coast, inlets and basins play a crucial role in this. The consequence of tidal inlet processes includes the greatest magnitude of shoreline changes along barriers that occurs in the vicinity of inlets. The changes may be due to inlet migration, concentrated wave energy, large bars migrating onshore, sand losses to the back-barrier, and other processes.

1.3.1 Characteristics of Natural Inlets

Some inlets are fairly permanent features of the coast whose existence may antedate historical records; other inlets are temporary, formed possibly by storms or floods and subject to closure by natural forces (Escoffier 1977). The rise and fall of the water level in the bay is caused by the flow of water into and out of the inlet. The flood current carries the littoral drift which arrives at an inlet and partly deposited at the inner end of the channel to form a bay shoal. The ebb current then carries part of the sand back to the sea where some is deposited as an outer bar at the seaward end (Figure 1.1). The sand that is lost from long shore sediment transport gets deposited on the bay shoal. This loss is likely to cause some erosion of adjacent down drift beaches. The migration of the inlet is caused by the excess of incoming sand. The rate at which sand is bypassed exceeds the long shore sediment transport during the up drift migration of the inlet. Tides cause
the flow of water through inlets. The flow through the inlet depends primarily on the difference between the sea and bay water levels. Diurnal component (1 lunar day period) and semidiurnal component (one-half a lunar day) are the components of tide used for calculations of flow at the inlet.

![Figure 1.1 Typical barrier beach tidal inlets (Source: Escoffier 1977)](image)

**1.3.2 Inlet Stability**

Most of the tidal inlets of engineering importance are of littoral drift origin. The geometry and stability of the inlets is a function of river locations, discharges and sediment loads, offshore topography, onshore-offshore and long shore movements of sediment, tidal flows, and storm action, including setup and abnormal wave action (Escoffier 1977). The dynamic equilibrium of the inlet and its stability is determined by littoral sediment transport conditions. Stability of the inlet depends on the resultant state of the forcing parameters between the tidal prism and the littoral drift across the mouth. The lake ecosystem is affected by high rate of littoral
transport, reduced inlet cross section, low tidal prism and migration of the mouth. A stable inlet during ordinary weather may be unstable during a severe storm. A relationship that defines the stability of inlets was presented by O'Brien (1931, 1966). He found a close relationship between the cross-sectional area in the gorge of an inlet and the tidal prism in its bay by the formula:

\[ a_c = b\Omega^N \]  

(1.1)

where \(a_c\) is the cross-sectional area in the gorge measured below mean sea level, and \(\Omega\) is the tidal prism or volume of water stored in the bay between the high and the low waters corresponding to the diurnal or the spring range of tide. Various theories relating to the stability of inlets have been proposed. Brunn & Gerristen (1960) and Brunn (1966, 1973) proposed the ratio \(\Omega/M\) as a measure of stability where \(M\) is the annual gross littoral drift. Brunn (1973) observed that:

\[ \Omega/M > 200 \] gave good stability  

(1.2)

\[ 200 > \Omega/M > 100 \] gave fair stability  

(1.3)

\[ 100 > \Omega/M \] gave poor stability  

(1.4)

Carothers & Innis (1960) discussed the stability of inlets and explained the processes of accretion and erosion. According to the authors, when the littoral drift brings an excess of sediment into an inlet, the sediment is deposited on the outer bar during the floodtide and is removed by the ebb tide, and returned to the littoral drift. Johnson (1973) studied inlets on the coasts of Washington, Oregon, and California and concluded that, wave power appears to be the most important factor that affects the stability of tidal inlets.
1.3.3 Inlet Management Considerations

The following issues are generally considered for efficient management of tidal inlet.

- The physical processes such as catchment hydrology, flooding and tidal prism.
- The water quality processes including the consequences of fresh water inflows, flushing time and catchment runoff on the production and harvesting.
- Ecological/ Biological considerations, such as the provision of breeding grounds for migratory birds and the presence of aquatic flora and fauna at the inlet.
- Social and economic issues, such as the impact of the entrance closure on navigation and recreation in the estuary.

1.3.4 Inlet Morphodynamics

A thorough understanding of the geomorphology is a critical pre-requisite for coastal engineers to design and analysis successfully. For example, any project attempting to create or maintain an inlet channel cannot be assured of success without first acquiring knowledge of hydrodynamics, migration characteristics of that inlet and sediment transport. In general, successful design and implementation requires an ability to predict the behavior and performance of a tidal inlet. The best source of information for predicting the behavior of tidal inlets comes from a thorough understanding of their geomorphology and sedimentation.
1.4 MODELLING TECHNIQUES

Modelling is a useful tool for engineering design and analysis. Modelling techniques help in seamless management of lagoons by solving physical problems using appropriate mathematical equations. With increase in computational technology, many numerical models have been developed for various engineering practices (Central Federal Lands Highway Division 2013). The accurate predictions of oceanographic variables such as water level, currents, temperature, and salinity by the models enable use of model output to study ecological processes (NOAA 2013). Many of the species in the estuary are significantly affected by their environmental conditions, such as water temperature, salinity, and current velocity. The parameters and mixing processes of coastal lagoons can be simulated by time-dependent, nonlinear equations of conservation of mass and momentum. These simulations help in impact analysis for various conditions, once the processes are established by measurements.

1.5 SOCIO ECONOMIC ASSESSMENT OF FISHING COMMUNITY

The lagoons provide a range of natural services highly valued by society. These ecotones between terrestrial, fresh water and marine ecosystems help maintain atmospheric composition, habitats for migratory species and nursery areas (Basset & Abbiatti 2004). The comprehensive analysis and understanding of the present socio economic status and issues of the fishermen community lead to design an effective lagoon management strategy. This will preserve both environmental and ecological sustainability and enhance the socio economic status of the fishing community.

Assessment of socio economic issues of fishing community is an important aspect in framing a strategy for the preservation of ecosystems
which leads to sustainable lagoon management. Declining water quality, drainage patterns, eutrophication and catchment disturbances such as development, loss of natural vegetation and poor agricultural practices are changing their fundamental ecology (Drake et al 2011). The conservation of these habitats depends largely on the assessment of their natural characteristics, especially biodiversity, which is one of the main criteria used when elaborating wetland protection policies. In order to assess the conservation status of the lagoons, it is necessary to incorporate the socio economic status of the fishing community. An understanding of these aspects and their relationship with specific demographic factors provide useful information for developing appropriate management strategies which lead to their successful conservation (Rao et al 2003, Allendorf 2006, Xu et al 2006).

1.6 STUDY AREA

India has three major lagoons, the Chilika Lake (978 sq. km.) in Orissa, the Pulicat Lake (350 sq. km.) between Andhra Pradesh and Tamil Nadu, and the Vembanad Lake (300 sq. km.) in Kerala. Pulicat lagoon is the second largest brackish water lake in India next to Chilika. It straddles the border of Andhra Pradesh and Tamil Nadu states on the Coromandal Coast of South India. The lake encompasses the Pulicat Lake Bird Sanctuary. The Pulicat lagoon is connected to the sea through three tidal inlets, one each at Kondurupalem, Rayadoruvu and Pulicat mouth from north to south, respectively (Kumar 2009). Kondurupalem, one of the tidal inlets of Pulicat lagoon, is taken for this study. The lagoon’s boundary limits range between 13.33° and 13.66° N and 80.23° and 80.25°E, with a dried part of the lagoon extending up to 14.0°N; with about 84% of the lagoon in Andhra Pradesh and 16% in Tamil Nadu. The Pulicat lagoon is a nursery for several species of fish and used by the stakeholders for fishing and collecting prawns. The Kondurupalem inlet is not a simple passage of water into lake but a bio
corridor for survival of aquatic fauna including distant and local migrant species. The fish, prawns and migratory birds of the backwater lagoon flourish in the entrance channel of the Kondurupalem inlet. The lagoon is an important habitat for over 160 different fish species, belonging to 26 families (Center for Research on New International Economic Order 2011), more than 100 varieties of terrestrial and aquatic birds and small mammals and reptiles. Flamingoes are the most frequent visitors to the lake, about 15,000 of them visit every year (Sanjeevaraj 2010).

1.7 ISSUES OF THE STUDY AREA

The Pulicat lagoon faces ecological problems like closure of sea mouth, siltation, shrinkage of the lake, pollution, over fishing, shortage of food (fishes, crustaceans, planktons) required for migratory birds and fishermen, degradation and destruction of natural habitats in the environment (Kumar et al 2010). The major environmental threats to the lake are pollution from sewage, pesticides, agricultural chemicals and industrial effluents. It is speculated that the Arani and Kalangi rivers draining into the lake bring in fertilizers and pesticides with the runoff from the agricultural field in the drainage basin (Centre for Science and Environment 2010). The domestic sewage forms a more diffuse input. Effluents and wastes from numerous fish processing units are also major sources of pollution. The oil spill from the mechanized boats is always a potential hazard. Because of the environmental and ecological threats in the Pulicat lagoon, the social and economic status of the fishing community is very much affected.

The present study envisages four apparent elements namely 1) water quality of the study area 2) socio-economic assessment of the fishing community 3) morphodynamics of the inlet and 4) numerical modelling. These elements are inter-connected. For instance, the socio-economic condition of the fisher folk is affected by fish abundance, which is affected by
water quality and habitat of the inlet, which in turn is affected by water exchange between lagoon and ocean, which can be enhanced by inlet modification. The socio-economic condition of the fishing community is also affected by the health and education facilities provided by the Government and the quality of water is also affected by inputs of nutrients and sediments from land-based sources. Hence, there is an immediate need for an integrated management plan for Kondurupalem lagoonal inlet which demands a thorough understanding of the linkages between socio-economic assessment of the fishing folk, water quality study, inlet morphodynamics and numerical modelling. The major objectives of the environmental management plan (EMP) are outlined in Section 4.12. Figure 1.2 represents the linkages between the study elements.

Figure 1.2 Schematic representation of the linkages between the study elements
1.9 OBJECTIVES OF THE STUDY

The objectives of the present study are to:

- Assess the water quality and socio economic condition of the fishermen community of Kondurupalem lagoonal inlet.
- Study the inlet morphodynamics using remote sensing data.
- Study the hydrodynamic behaviour of tidal inlet using numerical models and develop remedial measures for preventing siltation at the inlet.
- Prepare an Environmental Management Plan for Kondurupalem tidal inlet of Pulicat lagoon ecosystem.