Inlet dynamics and shoal processes – a complete numerical, laboratory and field study.

A Research Proposal
of
Indian Institute of Technology Madras, Chennai

Submitted to
Ministry of Shipping
Government of India

under

National Technology Centre for Ports, Waterways and Coasts (NTCPWC)

Prof. V.Sundar and Prof. K. Murali
Department of Ocean Engineering
Indian Institute of Technology Madras
Chennai – 600036
India

Inlet dynamics and shoal processes – a complete numerical, laboratory and field study

1. Project Advisor & Coordinator : **Prof. V.Sundar**
Department of Ocean Engineering
Indian Institute of Technology Madras
Chennai 600 036.

2. Name of the Project Investigator(s) : **Prof. K.Murali**
Department of Ocean Engineering
Indian Institute of Technology Madras
Chennai 600 036.

3. Institution and address : IIT MADRAS
Department of Ocean Engineering
CHENNAI 600036.

4. Description of Project :

The coastal zone is an area of interaction between land and sea. It includes both terrestrial as well as marine resources, which may be renewable as well as non-renewable. In addition, interaction between various natural processes and human activities are important factors in the coastal area. The coastal zone in India assumes its importance because of high productivity of its ecosystems, concentration of population, exploitation of natural resources, discharge of waste effluent and municipal sewage, development of industries, increasing load on harbours, spurt in recreational activities and petroleum exploration activities. Thus, there is a need to protect the coastal environment, while, ensuring continuing production and development.

4.1 GENERAL

The coastal zone is an area of interaction between land and sea. India has a coastline of about 7500km, behaviour of which varies between stretches. A substantial portion of the India, particularly the east-coast of India is affected by erosion, where, a significant portion of land sacrificed to the sea. A detailed analysis and understanding of the above processes require numerical modelling of the near shore circulation and sediment transport due to tides, waves and winds. Additionally, any interaction of the wave in the near shore with an existing inlet/outlet needs to be considered.

4.2 TIDAL INLETS

Tidal inlets are the portion of water body between the sea and a river/backwater that is subjected to ingress of tide during high tide and flushing during low tide. This is commonly associated with the mouth of a river or stream. It provides a regular exchange between the bay and estuarine water with the open ocean. The exchange of water at the inlet is either maintained by the cyclic ingress and flushing of tide or closed off due to heavy longshore drift. The tidal flow deposits sand on either the landward or seaward side of an inlet. The suspended sand from the outgoing tide usually settles to the seabed at the seaward side of inlet. This tends to change the shoreline dynamics. A detailed analysis and understanding of the above processes require numerical modelling of the near shore circulation and sediment transport due to tides, waves and winds. Typical view of the tidal inlet is shown in Fig. 1.

4.3 PROBLEMS ASSOCIATED WITH TIDAL INLETS

Tidal inlets are usually small (inlet width is of the order 50 ~ 200m) and occur in micro tide-wave dominated coastal environment where seasonal variation of stream flow and wave climate are experienced. These inlets are closed to the ocean for a number of months every year due to the formation of sand bars across their entrances, usually during summer when the stream flow is low and long-period swell waves dominate, or when longshore transport rates are high (Fig.1). There are larger inlets, estuaries of major rivers, having several kilometers of width. Classical examples are entrances to harbours of Cochin, Kolkata, Haldia, Kandla, Goa, Chilika lake etc. Many of these inlets are being used as harbours for small to moderate size fishing boats and as recreational activities. So, the seasonal closure or silting of inlet leads to two main problems. Primarily the ocean access for ships and boats is limited, and the secondary problem is water quality in the lake/estuaries/lagoon will become poor during the months of inlet closure. To have year-around navigability and to improve the flushing of the lake/estuaries/lagoon there has been increased interest in finding ways of keeping the inlet permanently open. However, attempts by engineers to prevent inlet closure have largely been unsuccessful up to date (Kraus, 2005) – despite provision of training works several inlets close annually. The main issue in the inlet sedimentation is the lack of understanding and tools to study the process of inlet dynamics. This challenge is being addressed in this project.

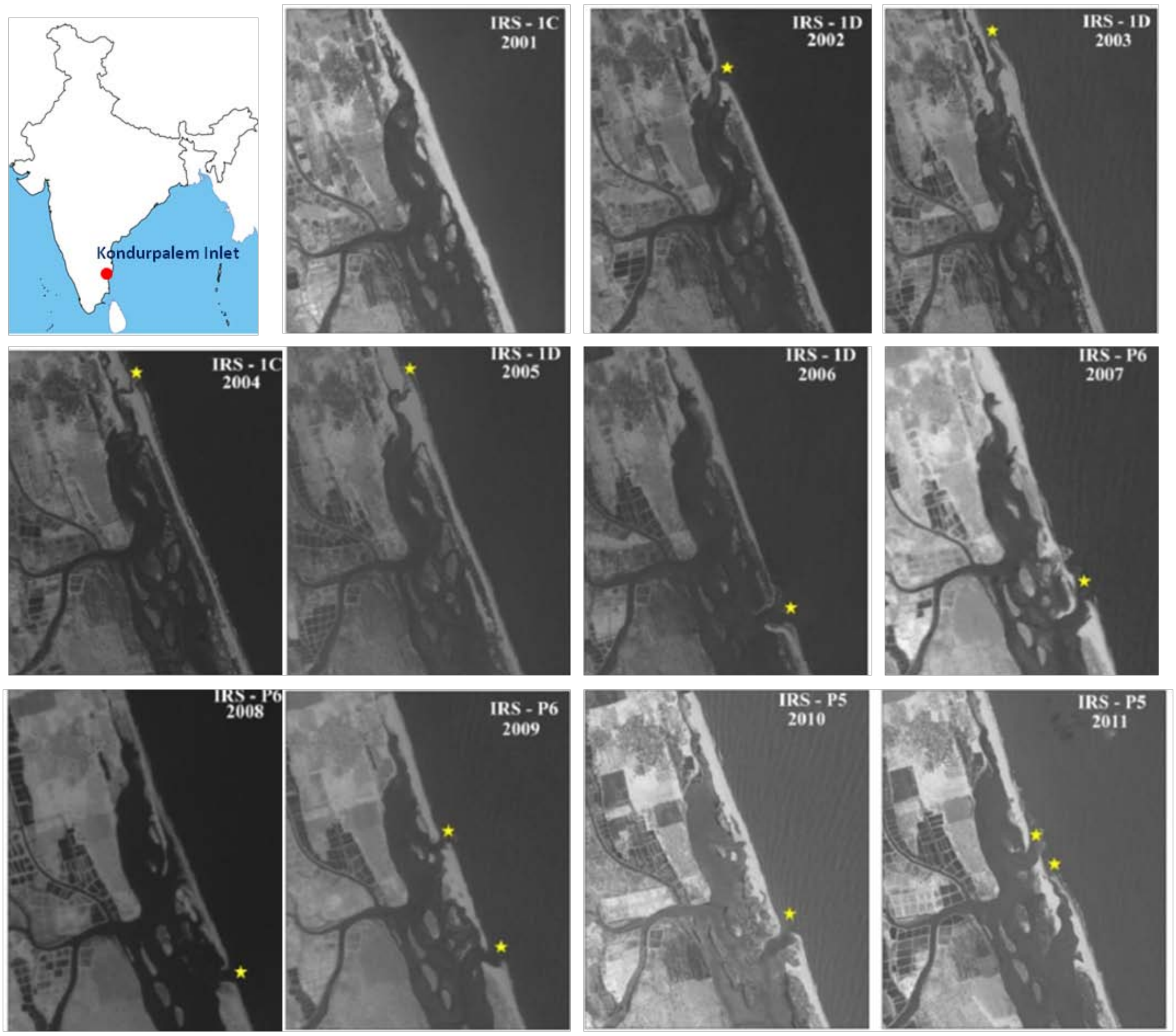

Fig. 1 A typical Inlet and its dynamics along East coast of India – Kondurpalem Inlet.

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4.4. Previous work in this area

Most of the tidal inlets along the Indian coast close during the non-monsoon season and opens during the monsoon. Closure of inlets leads to two main problems. Primarily, the ocean access from the estuary/lake is limited. Secondly the water quality in the lake/estuary will deteriorate drastically. Inlet closure leads to other issues such as the migration of species from estuary/lake to the ocean and vice versa. This affects the ecology of the estuary/ocean. In order to ensure that the inlet be open, its stability need to be maintained throughout the year. This is achieved by preventing or minimizing accretion at and in the vicinity of the river mouth. An inlet which has a tidal range up to 1m is called 'micro-tidal inlet (Hayes 1979). The relation between the cross sectional area and the tidal prism was considered. Brunn (1986), investigated several major inlets across United States, Europe and India. Among the inlets considered in the US and Europe, the minimum depth in the inlet gorge is 4.5m and the maximum depth in the gorge is 18m. These inlets were located in semi-diurnal tidal regimes, with a spring tidal range of approximately 3m. Twelve inlets along the Indian coast have been investigated by detailed survey and observation during the monsoon and off monsoon season. For Inlets in India, the maximum depth at inlet gorge is 7m (Honavar estuary, 14^{0}30’41”N,74^{0}54’57”E) and the minimum depth at inlet gorge is 0.5m for Krishnapatnam,(14^{0}14’50”N, 80^{0}08’02”E) and Ponnani,(10^{0}47’12”N,75^{0}54’42”E) estuaries. Brunn concludes that the inlet process is a complex one understands due to the dynamics at inlet. However, a stability relationship has been proposed considering the inlet tidal prism and littoral transport. A detailed numerical analysis of stability of Wilson inlet (Ranasinghe, 1999a) of Australia has been carried out by applying Brunn’s criteria(1986).

Ranasinghe et al. (1999b) have developed a morphodynamic model for the simulation of longshore, cross-shore sediment process and validated for the inlet stability for idealized conditions. Thanh et al., (2012) compared the cross sectional stability between empirical and numerical approach. Furthermore, Kraus (1998), Suprijo and Mano (2004) and Van de Kreeke (1998, 2004) considered other parameters like tidal cycle period, tidal velocity, channel width and longshore sediment transport rate in discussing about the stability of tidal inlets. In the Delft 3D numerical model the relation between the cross sectional area and stability has been used. Cross-sectional area and tidal prisms correlated by numerical approach using a power function and found that the values of the coefficient and the power of the correlation function are close to the range of values found in nature. This method is claimed to be used to determine the equilibrium cross-sectional areas and corresponding tidal prisms for a set of similar inlets having the same tidal period, littoral drift and sediment characteristics. Suresh and Sundar (2011) have reported a good comparison between compared the measured and simulated shoreline along the east coast of India. The simulated shoreline was predicted using the formulas of Van Rijn(2001) and Kamphuis(1986) . Stive et al., (2012) reviewed the theory behind the inlet cross sectional behaviour and developed the conceptual model based on the Escofier diagram which is extended for the seasonal variation of both equilibrium and closure curve. Bertin et.al, (2013) studied the physical process of controlling the dynamics of two wave dominated mesotidal (tidal range between 1m to 3m) inlets along the west coast of Portugal and found that the inlet development during the fair weather season was caused by tidal distortion which leads to inlet closure. It was suggested that this physical process analysed in their site might be partly site-specific and this can be extended to other wave dominated inlets to arrive the reasons to inlet closure. Recently, we have carried out detailed investigations of stability of Kodupalem inlet through field and numerical investigations. The input data for the nearshore circulation due to waves and currents are mostly measured from the field. These approaches have been applied to Kondurpalem inlet ($14^0$01’07”N, $80^0$09’24”E) along the east coast of Indian peninsula and its seasonal variation is assessed. The state of stability of the inlet is re-assessed by providing necessary training works.

4.5. Objectives

The objective of the present proposal is to understand the inlet dynamic by concurrent application of numerical, laboratory and field studies and to create tools to model the shoaling process in order to predict operation difficulties. The work is relevant to river ports and Inland Water Transport.

The detailed scope of work of the project is,

I. To investigate wave and current fields, morphological dynamics, and sediment transport within the groin fields through field measurements. Compare the results with numerical model investigations using Public domain model and commercial nearshore software.

II. Application of numerical models for prediction of waves and wave-cum-tide induced currents; sediment transport and littoral drift in major and minor inlets of Indian coast.

III. Perform moving bed shallow water experiments for the above scenarios considering key parameters pertaining to wave, current, beach and sea bed bathymetry. This shall be carried out in the proposed facility of NTCPWC.

IV. Comparison of the experimental measurements and field data with the numerical model studies as detailed above.

V. Demonstrate application of near shore current and transport models for establishment of littoral drift and morphological dynamics at the inlet with specific focus to Spit & Shoal formation.

4.6. Methodology

The project will be implemented in 3 years. Field data on winds, waves, tides, currents, sediments, beach profiles, bathymetry etc. will be collected for the period between 2001 and now at selected locations along a referenced coast. Seasonal variations on water levels, wave climate, currents, sediment transport, shoreline changes etc. will be studied. By incorporating the field data model investigations on shoreline changes will be conducted. The out come of the project work are estimation of wave climate, nearshore circulation, sediment transport and the resultant erosion/ depositional trends along the coast. Suitable shoreline management plans for protection of coastal stretches with various vulnerabilities will be suggested.

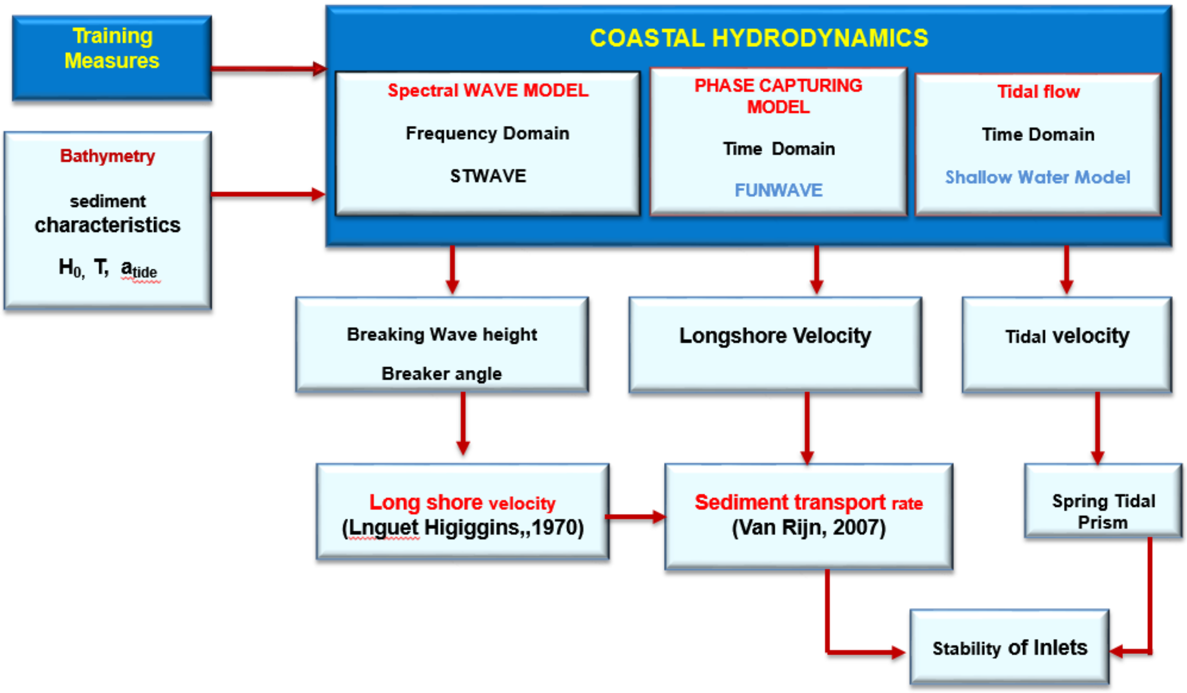

Fig. 2. Schematic diagram of modeling approach

Prediction of wave climate will be based on refraction and refraction-diffraction models. Pubic domain and In house codes will be used. The predicted wave climate will be used to establish radiation stresses that would in turn drive the near shore currents. The near shore current models will be coupled with sediment transport models for establishment of transport and littoral drift and finally morphological dynamics. Figure 2 depict the schematic sketch of modelling system which would be adopted in this project. Further details of the numerical and experimental program are presented below.

The modelling of swash and shallow water sediment dynamics will be carryout in the new SEMaTeB under NTCPWC. This will be carried out in combination with numerical models by combining a collection of models in order to account for all the processes that take place in the surf zone, swash zone and on the beach. Details of the modelling zone in the coastal environment for prediction shoals and spit formation is given in Fig.3 for the situation of a beach with coastal features fronted by training works. The wave transformation and current patterns in the inlet area and the corresponding morphodynamics will be modelled. This will be mainly dominated by littoral drift. The model will be calibrated for the observed annual littoral transport and in the laboratory. The above processes will be solved in 2D (in the horizontal plane) depth integrated equations.

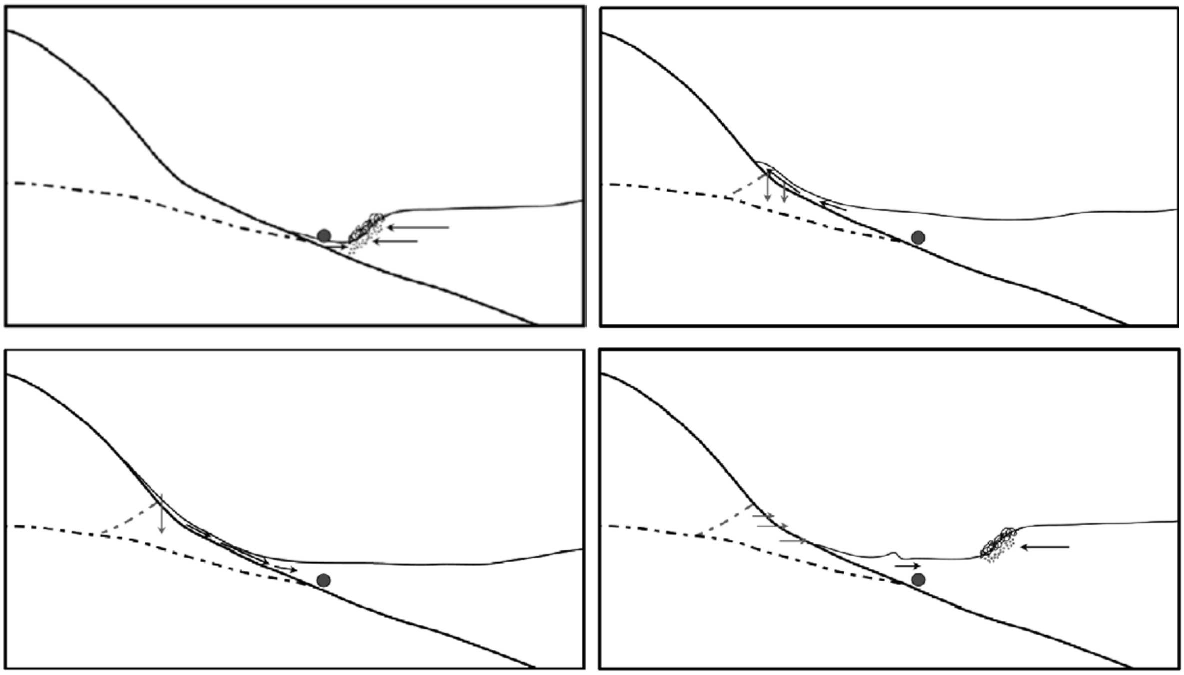

Fig.3. Typical swash dynamics to be included in the numerical modelling study in addition to surf zone dynamics.

5. Details of equipment etc., Computer needed and justification :

The following equipments are required to be purchased from the present project grants.

S.No	Instrument/equipment required	Justification
1	Laboratory computer – 2 & Data Storage devices.	For laboratory measurements and downloading of various instrumental data
2	Computing server and peripherals – 2	For computing, data storage, downloading field data, model runs, instrument set up, field set up etc.
3	Acoustic profiler	Under NTCPWC
4	ADV	Under NTCPWC

6. Schedule

Major milestones	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Recruitment of project staff	▨											
Procurement of equipments and setup		▨	▨									
Data collection and Analysis of data		▨	▨	▨	▨	▨	▨	▨				
Numerical adaptation and application		▨	▨	▨	▨	▨	▨	▨				
Comparison of results and parametric study					▨	▨	▨	▨	▨	▨	▨	
Final report and technical papers											▨	▨

Note: Q-Quarter of the year

7. Budget (man power, consumables, equipment, conitngency, travel and overheads etc. along with detailed justification for each item)

Budget Head	1st year	2nd year	3rd year	Total
1. Research Staff				
P.O. (Ph.D)	546000	546000	468000	**1560000**
P.A. (M.S)	468000	468000	421200	**1357200**
2. Specific Equipment	1800000	-	-	**1800000**
3. Boat hire charges	400000	400000	400000	**1200000**
3. Consumables	600000	300000	300000	**360000**
4. Contingency	200000	200000	200000	**600000**
5. TA /DA	300000	300000	300000	**900000**
6. Total	4314000	2214000	2089200	7777200
7. Overheads (at 20%)	862800	442800	417840	**1723440**
Grand total	5176800	2656800	2507040	9500640

i) Manpower:

1 SPO, 1 PA and 1 technical asst. are essential for model studies and analysis. The candidates for SPO will be selected with minimum post graduation qualification in coastal engineering/related field. The candidate for PA will be selected with minimum engineering degree.

12. Deliverables

- The results and output obtained from the project work are highly useful for developing sustainable methodologies for river training and management of dredging that could be applied for several parts of the Indian coast.
- Revision of the littoral transport and inlet stability along the study area considering also the effects of the neighboring ports and inlets.
- Knowledge generation on the detailed mechanism of interaction of the various flow at the inlet with that of the coastal environment pertaining to wave transformation, current patters, sediment transport patterns, shoreline evolutions trends, and their extreme value prediction considering long term distribution of the environmental parameters.
- Generation of knowhow as to appropriate application of field numerical modeling techniques for investigation of effects of coastal structures on the coastal environment.
- Generation of knowhow on application of numerical models for prediction of coastal processes in areas of such high littoral movement and vegetal population. This includes application of tidal hydrodynamics models, wave models, sediment transport models, morph dynamic models, shoreline evolution models etc. The calibration parameters derived out of this investigation will be of extreme importance as such data has never been produced for east coast of India.
- Development of numerical techniques and models for prediction of the above in addition to application of exiting research codes and commercial models. This pertains to overcoming limitations of existing models for field specific situations.
- The final report forms a base report for the decision makers of coastal zone management.
- 1 Ph.D and 2 M.S theses.
- Joint publications on results in reputed journals

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(Prof. K.Murali) **(Prof. V.Sundar)**

Department of Ocean Engineering,
Indian Institute of Technology Madras,
Chennai