

Final Report on EVALUATION OF CENTRAL SECTOR SCHEME ON R&D SCHEME FOR PORT SECTOR



Submitted to
Ministry of Ports, Shipping and
Waterways
Government of India



Submitted by
National Productivity Council
(Under DPIIT, Ministry of Commerce &
Industry, Govt. of India)



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Study Team, NPC

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Abbreviations

BOQ - Bill of quantities

BFS - Blast Furnace Slag

CWPRS - Central Water and Power Research Station

CPT - Cochin Port Trust

CSD - Cutter Suction Dredger

DPR - Detail Project Report

DMD - Director, Marine Department

DCI - Dredging Corporation of India

EAF - Electric Arc Furnace

FTD - Field Trial Dredging

FEM - Finite Element Method

GGBFS -Ground Granulated Blast Furnace Slag

HDC - Haldia Dock Complex

Hs-Sc-Aasc - High Strength Self-Compacting Alkali Activated Slag Concrete

ICTT - International Container Transshipment Terminal

KSM - Keep Sediment Moving

KSN - Keep Sediment Navigable

KSO - Keep Sediment Out

KoPT - Kolkata Port Trust

LAB - Lower Auckland Bar

OPC - Ordinary Portland Cement

RRM - River Regulatory Measures

SILAS - Seismic Bottom Profiling

SPT - Standard Penetration Test

SSC - Suspended Sediment Concentration

TDM - Tonnage Dry Matter

TSHD - Trailing Suction Hopper Dredgers

UKC - Under Keel Clearance

UJS - Upper Jellingham Shoal

WID - Water Injection Dredging



Executive Summary

Ministry of Ports, Shipping and Waterways (MoPSW) has been implementing Central Sector Scheme (CS) namely; Research & Development Scheme for Port Sector through Research Institutions, IITs for development of Infrastructure for Port Sector with the objective to carryout Research in the Port and Harbour Sector to find solution for field problems in formulation, design and execution of Harbour Projects.

MOPSW has engaged the National Productivity Council (NPC) for evaluation of 6 studies executed under the R&D scheme in last five financial years.

Since two out of six projects are ongoing projects and no reports or questionnaire responses were available with regard to these two projects, the detailed evaluation couldn't be completed for these two projects. Preliminary assessment was done based on the review of proposal and scope of work assigned.

The methodologies adopted by NPC for evaluation of these R&D studies primarily involved desktop review of the reports submitted by the concerned project proponents, the findings of their research work, understanding the outcomes & deliverables against the scope defined and assess the usefulness of these studies for the Port sector. The summary of evaluation for 4 projects is indicated below:

S. No	Name of the project	Recommendations by the project proponent	NPC's findings from evaluation of report & Usefulness of the study for port sector
1	Use of Dredged Material during Maintenance Dredging in the Hooghly Estuary. Project Proponent: Kolkata Port Trust;	a) The dredged material can be used for vegetation, filling of low-lying areas, any other construction etc. b) There is no adverse environment impact of dredging; marine biological environment is not affected. c) Four locations were identified by KoPT for shore disposal. Out of the above four options, Nayachara island is selected as the best suitable option. d) Shore disposal of Auckland	a) The report is mostly based on secondary data review and records made available by KoPT. Ideally a R&D study should focus on primary data analysis. b) Test reports placed in report indicate that as per Hazardous and other waste (Management and Transboundary movement) Rules 2016, the dredged material will fall under the category of hazardous waste. c) The suitability of heavy metal bearing dredged material for



	<p>Cost: 30.00 Lakhs</p>	<p>channel is not considered in present shore disposal scheme.</p> <p>e) Nandi gram location has also been ruled out as the land is not under the ownership of KoPT.</p> <p>f) Current and Alternate options for disposal of dredged material have been analysed and underwater / submerged pipeline method has been suggested for the shore disposal of dredged material.</p>	<p>agriculture or vegetation needs to be concluded only on the basis of analysis of toxicity of the material.</p> <p>d) The major portion of the problem of siltation in the navigation channel is not addressed completely as 78% material is dredged at Auckland and 22% at Jellingham. However, the shore disposal scheme is being taken up only for Jellingham channel as a priority.</p> <p>e) The R&D project is relevant to the port sector, however only the idea or the outcome of this study can be replicated across various other ports in the country.</p> <p>f) The scope of the R&D project should also include certain aspects of primary data analysis.</p>
2	<p>Implementation of Pilot Project in connection with Short-Term and Long-Term measures for improvement of draft in the Hooghly estuary by WAPCOS Ltd. in association</p>	<p>Short Term Measures:</p> <p>a) For Short Term Measures for draft improvement, a combination of conventional dredging with side-casting using rain-bowing was adopted for site trial at different locations in Hooghly estuary.</p> <p>b) Possible impact of side cast dredging on environmental and channel prism were studied using analytical</p>	<p>a) The details of conventional dredging technique are limited in the report.</p> <p>b) The methodology of side casting / rain bowing of dredged material was experimented in the actual river, which was never tried before, in different tidal conditions.</p> <p>c) Due to implementation of Short-Term Measure, the productivity of the dredging has improved and contributed for the improvement of</p>



<p>with HR Walling Ford, UK and CWPRS, Pune.</p> <p>Project Proponent: Kolkata Port Trust;</p> <p>Cost: 910.00 Lakhs</p>	<p>method and mathematical modelling.</p> <p>c) Additional mathematical model simulations were also undertaken by CWPRS, Pune using 2D MIKE21 HD and ST model of the estuary.</p> <p>d) The existing dredging contract with DCI has been examined and HR Wallingford has advised regarding Future Maintenance Dredging Contract and Tender Considerations.</p> <p>e) The improvement in navigation depth in Jellingham went from 3.5 m to 4 m whereas the same in Auckland rose from 4.1 m to 4.4 m.</p> <p>f) The report recommends the necessity to carry out close monitoring by undertaking frequent and timely hydrographic surveys with a dedicated survey vessel equipped with modern facilities for data processing, preparation of survey chart and online communication with the dredgers so as to have quick response during critical and adverse</p>	<p>navigable depth in the shipping channel leading to Haldia.</p> <p>d) The project report addresses the overall objective envisaged for this R&D project.</p> <p>e) As per the report, the current dredging expenditure is to the tune of Rs. 400 Crs. per annum in Upper Jellingham Shoal and Lower Auckland Bar. Hence, if the short-term measure is implemented, which envisages the expenditure of Rs. 316 cr annually, there shall be saving of more than 20 %.</p> <p>f) The study appears to be useful to ports sector. The results of the short-term measures are based on the pilot study undertaken for one year time span</p> <p>g) The Tendering Contract for the Dredging has been adequately addressed in this study report and is also an important output which can be tried out for other Ports with adequate modifications to cater to their conditions.</p>
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		developments.	
		<p>Long Term Measures:</p> <p>a) Long-Term Measures was undertaken to explore the possibility of establishing a new shipping route that would cut across Nayachara Island to Haldia Dock Complex.</p> <p>b) The quantity of capital and maintenance dredging in the Nayachara Island has been specified as 57.5 million m³ & 12 million m³ respectively.</p> <p>c) The provision of the proposed channel through Nayachara is likely to bring down the annual maintenance dredging quantity to 12 Mm³ as against present annual maintenance dredging of 18Mm³ for the route through Auckland and Jellingham.</p> <p>d) A separate detailed report on stability test of dyke embankment through the proposed navigational channel across Nayachara Island has been provided that concludes its suitability.</p> <p>e) The DPR has been prepared specifying the dredging plan, capital and maintenance</p>	<p>a) The objectives of this study have been met by the project proponent.</p> <p>b) The potential for opening a new channel that connects Haldia Dock with Rangafalla has thoroughly been investigated. This study has included in detail the aspects of hydrodynamic modelling, ship navigation studies, siltation studies and desk studies.</p> <p>c) The trial and simulation to open and operationalise a single channel between Haldia and Kolkata that constitutes recommended measures with less maintenance dredging and improved depth has been successful.</p> <p>d) This study can be a guiding document for other Ports to develop their own dredging strategy for their maintenance dredging/ Capital dredging.</p> <p>e) An internationally published peer reviewed paper “Mathematical model for studies for RRM for the improvement of draft in Hughli estuary, India“ was referred to while evaluating the study and the findings were found to be similar to this R&D study.</p>



		<p>dredging quantity, dredging methodology, choice of dredgers and project cost estimate</p> <p>f) The time frame envisaged for implementation of the long term measure is approximately 2 years for construction and then further 6 months for commissioning of the navigation channel.</p>	
3.	<p>Studies on siltation and optimal ameliorative measures at Cochin Port.</p> <p>Project Proponent: Cochin Port Trust ;</p> <p>Cost: 1073.00 Lakhs</p>	<p>a) Study aimed at reducing the recurring dredging expenses.</p> <p>b) Siltation processes were analysed in detail by means of dredging volumes, bathymetry and SILAS profiles in combination with rheological monitoring, data processing, interpretation, numerical modelling and nautical modelling, advanced technology such as bathymetry survey.</p> <p>c) The study recommends use of Tonnage Dry Matter (TDM) method over conventional sand in-situ volume calculation method.</p> <p>d) Nautical depth criteria has been developed along with monitoring and dredging strategies can help</p>	<p>a) Benchmark study</p> <p>b) Nautical depth criteria has been developed along with monitoring and dredging strategies can help developing sufficient drafts of ships accessing the harbour zones.</p> <p>c) Implementation of nautical depth criteria needs to be performed with extensive monitoring and evaluation.</p> <p>d) The study report lacks deliberation on the possible use of dredged material</p> <p>e) The study recommends better estimation of dredging volumes. However, this option may be tried in other Ports after due studies ascertaining the siltation/ sedimentation and discussions with the Dredging contractors.</p> <p>f) Environmental impact of sedimentation traps needs to be</p>



		<p>developing sufficient drafts of ships accessing the harbour zones.</p> <p>e) During the study, the siltation volume of 23 million m³ had occurred in Cochin Port during the duration of the project.(duration of the project to be mentioned)</p> <p>f) The principle and the basic knowledge that has been gained from this research study can be utilized for other Ports, especially the sediment particle and its characteristics.</p> <p>g) The study recommends implementation of a sediment trap in Cochin to reduce the siltation.</p>	<p>looked into before implementing.</p> <p>g) CoPT reports that after the implementation of Nautical Dredging Concept, the maintenance dredging quantity would reduce by 5 Mm³. Currently ~150 crores is being incurred for maintenance dredging. With dredging volume reduced by 5Mm³, more than 25% of maintenance dredging expenditure is likely to occur.</p> <p>h) An internationally published peer reviewed paper “Study on siltation for implementation of the nautical depth concept in the port of Cochin, India“ was referred to while evaluating the study and the findings were found to be similar to this R&D study.</p>
<p>Comprehensive Analysis of Siltation Behaviour at Deen Dayal Port (or Kandla Port</p> <p>Project Proponent: IIT Bombay (Deendayal</p>		<p>a) The project had been outlined to analyse the siltation behaviour and devise strategies to reduce the quantity of maintenance dredging in the channel.</p> <p>b) A three-way approach of initial field visits to observe certain parameters, combinations of numerical modelling and remote sensing analysis using satellite</p>	<p>a) The project has completed all the research components through a systematic and comprehensive analysis of the physical condition and an optimized engineering solution of providing silt-curtain is also proposed for minimizing the siltation and thereby cost of maintenance dredging in Kandla port navigational channel. The implementation of any pilot-scale testing of the proposal is in its</p>



<p>Port Trust);</p> <p>Cost: 90.77 Lakhs</p>	<p>imageries was adopted.</p> <p>c) Numerical modelling was carried out using available Delft3D model.</p> <p>d) The sedimentation pattern has been predicted through modelling and validated through images in the report</p> <p>e) The report, recommends that the effective solution to mitigate the problem is by using a silt curtain along a navigational channel with the alignment.</p>	<p>nascent stage.</p> <p>b) The usage of silt curtain reduced siltation by approximately 46 to 54%.</p> <p>c) The Development of numerical model and validation with field measurements method can be used for all the ports.</p> <p>d) The development of algorithm for Satellite imageries, validated with comprehensive field data collection of SSC is also a unique research study which may be applicable to other ports</p> <p>e) It is desirable that the study be shared with the Coastal Zone Authority and further studies on the Marine Environment be carried out if found essential by the CRZ.</p> <p>f) Environmental impact of usage of silt curtains needs to be looked into before implementation.</p>
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From the evaluation of the six R&D reports of Port sector, it may be concluded that each report is significant in its own unique way and is beneficial to the Port in particular and with further studies and adaptation measures can be useful to the other Ports. Such R&D projects should be taken up regularly. While approving the R&D Projects it is suggested that a component of Environment Impact Assessment too be included as these exercises will have a direct impact on the Marine Bio Diversity/ Terrestrial Environment.

Based on the evaluation of these 6 projects, few new domains for carrying out future R&D studies have been discussed in the report.



While the scope of each R&D project is different but largely the projects aim to address the similar issues being faced at all ports, for eg how to optimize the dredging volume, how to reduce siltation, what is cost effective technique for dredge disposal etc.

The R&D studies that were completed in the last 5 years have the following unique takeaway which may be adapted and customised for other ports:

S.No	Project	Unique take away
1.	Effective utilization and disposal of Dredged Material	Underwater / submerged pipeline method is relatively more suitable for the shore disposal of dredged material owing to its advantages of improved efficiency, traffic reduction, fuel savings, turbidity reduction and no draft concerns.
2 (a)	Short-Term measures for improvement of draft in the Hooghly estuary	Side casting combined with conventional dredging technique, with intense monitoring and control can result in improved navigational depth by 0.4 to 0.5 meters. Further, it has also resulted in reduced dredging volumes, saving of operational time of dredgers and considerable cost advantage to the Port.
2 (b)	Long-Term measures for improvement of draft in the Hooghly estuary	If the existing navigation channels suffer from high rates of sedimentation, then, to achieve less maintenance dredging and better navigational depth, opening & operationalizing a new route / navigational channel can also be accomplished through adequate field test trials.
3.	Studies on siltation and optimal ameliorative measures	When a river is the main source of sediment in a harbour, installing a sediment trap upstream can be an efficient measure against siltation. Also, proper formula should be used for estimating dredging volumes to avoid over estimation. Total Dry Matter (TDM) formula has been suggested in the silty conditions
4.	Comprehensive Analysis of Siltation Behavior	Providing silt curtain, an optimized engineering solution, can also minimize siltation and thereby cost of maintenance dredging.



		Use of satellite images for algorithm development is also a unique initiative to substantiate and strengthen the field data of suspended sediment concentration (SSC)
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Most of the above conclusions have been arrived at by series of field trials and backed by different modelling algorithms, tools and estimation. Considering the unique takeaways from the executed R&D projects, it is prudent and recommended to undertake more such research studies and come out with effective as well as creative solutions for common problems being faced by port sector.

It is also proposed that the techniques and algorithms applied in these studies and the methodologies adopted may be further considered as reference for future studies and standardisation of these techniques. Research studies for the port sector may be broadened to address other environmental and ecological considerations in addition siltation and dredging disposal problem that has been primarily taken up in these studies.

It is pertinent to highlight that the above evaluation is only with respect to the project's objective and outcome. The budgetary utilizations have not been assessed and will require separate evaluation.



Chapter – 1

ABOUT THE STUDY



Chapter 1

About the Study

1.1 Introduction

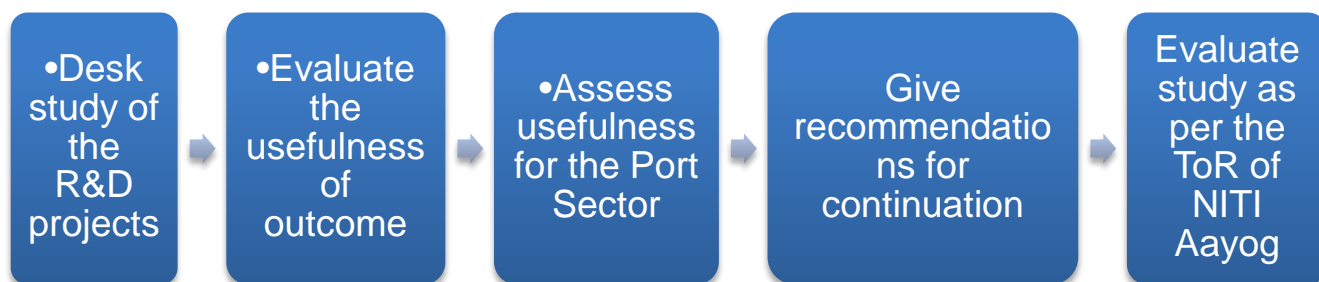
Ministry of Ports, Shipping and Waterways has been implementing Central Sector Scheme (CS) namely; Research & Development Scheme for Port Sector through Research Institutions, IITs for development of Infrastructure for Port Sector with the objective to carryout Research in the Port and Harbour Sector to find solution for field problems in formulation, design and execution of Harbour Projects.

1.2 Objectives of the Study

To evaluate the Research and Development Scheme for Ports Sector being implemented by the Ministry of Ports, Shipping and Waterways, Government of India for last five financial years.

1.3 Terms of Reference

The evaluation study of Research and Development Scheme for Ports Sector being implemented by the Ministry of Ports, Shipping and Waterways, Government of India for last five years was carried out in accordance with the outlined Terms of Reference (ToR). The Terms of Reference for the evaluation study are as follows:





1.4 Scope of Study

The scope of the study covers sample of six research and development projects; as per the terms of reference and considering the stipulated timeline, the evaluation was conducted for **four research** and development projects submitted by the project proponent. The two research and development projects could not be evaluated as the projects are still ongoing.

The Research and Development Schemes carried out during last 5 years with cost, date of sanction, project proponent, date of completion are as follows:

S. No	Name of the project	Cost (Rs. in lakh) & date of Sanction	Project proponent	Date of completion
1	Use of Dredged Material during Maintenance Dredging in the Hooghly Estuary.	30.00 01.01.2015	Kolkata Port Trust	March 2016
2	Implementation of Pilot Project in connection with Short-Term and Long-Term measures for improvement of draft in the Hooghly estuary by WAPCOS Ltd. in association with HR Walling Ford, UK and CWPRS, Pune.	910.00 25.11.2014	Kolkata Port Trust	June 2016
3	Studies on siltation and optimal ameliorative measures at Cochin Port.	1073.00 01.12.2014	Cochin Port Trust	March 2017
4	Comprehensive Analysis of Siltation Behavior.	90.77 13.04.2017	IIT Bombay (Deendayal Port Trust)	Nov. 2019
5	R&D Scheme "Preparation of guidelines for use of Geo-synthetics in ports, coasts and waterways."	11.80 Lakhs 24.01.2019	IIT Madras	In progress
6	R&D Project on "Utility of High Strength Self Compacting Alkali Activated Slag Concrete (HS-SC-AASC) filled steel tubes in enhancement of strength and	24.40 09.10.2020	IIT Roorkee	In progress



S. No	Name of the project	Cost (Rs. in lakh) & date of Sanction	Project proponent	Date of completion
	durability in Ports, Harbour and offshore structures.”			

1.5 Methodology

The evaluation study of schemes being implemented by the Ministry of Ports, Shipping and Waterways, Government of **India** was carried out in accordance with the outlined methodology as follows:



1.5.1 Situation Analysis & Desk Research

- During this phase, the reports, data & information were collected from Development Wing, Ministry of Ports, Shipping and Waterways, Government of India.
- **Meetings were** held with officials of Ministry of Ports, Shipping and Waterways, associated with “Research and Development Scheme for Ports Sector” at their New Delhi office so as to receive their feedback.
- **Virtual Interactions** were also held with project proponent officials (as per the details provided by Ministry), associated in the implementation of scheme to elicit their feedback in respect of the progress and outcome of the project.

1.5.2 Evaluation of Research Reports



- Detailed evaluation of research reports submitted by the project proponent was carried out to assess:
 - The outcome of the scheme vis-à-vis the objective outlined in the research project.
 - **Identifying** the specific areas/components where the project has been successfully implemented and the opportunities for improvement.
 - The targets set and achievements, against the backdrop of the plan of operations and the base line status at inception of the project.
 - The activities and initiatives **were** made by the implementing organization of the research project about the compliance in line with the recommendations of the research committee.
 - Contribution made by the research work and usefulness for the ports sector for continuation of the scheme.

1.5.3 Scenario Development, Conclusion & Report Writing

- Based on the evaluation and assessment of the research projects and on the basis of feedback received from project proponent, the composite observations in terms of outcome of the implementation of the scheme and recommendations arrived thereof pertaining to improvement in the scheme has been prepared as Draft Reports and being submitted to the Ministry.
- Presentation to the Ministry on the Draft Report and obtain comments on the same.
- Incorporation of the comments on the Draft Report and Final Report preparation and submission.

1.6 Data Collection

The information was obtained from the project **proponents as** per the questionnaire enclosed in **Annexure - I** of the report. Virtual interactions with project proponents were held and the responses/views were gathered through the pre-designed questionnaire. The project proponents were appraised about the purpose of the evaluation and were also explained in detail about the questionnaire for obtaining relevant facts about the implementation status and benefits accrued through the R&D scheme.



1.7 Limitations of the study

- Evaluation has only been done only on the basis of outcomes of R&D reports evaluated . The budgetary evaluation and utilization was not a part of the study.
- The scope of the study covers sample of six R&D projects; however the team encountered constraints in obtaining response from the two ongoing R&D projects i.e. (i) “Preparation of guidelines for use of Geo-synthetics in ports, coasts and waterways” and (ii) “Utility of High Strength Self Compacting Alkali Activated Slag Concrete (HS-SC-AASC) filled steel tubes in enhancement of strength and durability in Ports, Harbour and offshore **structures**” in spite of follow up by sending repeated reminders and telephonic calls.
- Due to non-availability of field level information from the two ongoing R&D projects, inferences could not be drawn.

Chapter – 2

ASSESSMENT OF R&D PROJECT-1: “Use of Dredged Material during Maintenance Dredging in the Hooghly Estuary”



Chapter 2

Assessment of R&D Project-1:

“Use of Dredged Material during Maintenance Dredging in the Hooghly Estuary”

2.1 Background of the R&D Project

The Haldia Dock Complex (HDC) at Haldia in the Hooghly estuary is under the administrative control of Kolkata Port Trust (KoPT). The HDC is located 44 Km inland from Sagar Island at the mouth of the estuary debouching into the Bay of Bengal. The Dock complex is facing a severe problem of high siltation and inadequate availability of draft in the navigation channels, because of which the survival of the port is at risk.

The entire navigation channel from Sagar to Kolkata is interspersed with shallow stretches classified as shallow crossings / bars/ shoals/ sand encroachments etc. Siltation in the navigation channel leading to HDC is of great concern to the Port Authority. Noticeable decrease in the navigable depth due to accumulation of sediments has reached a critical stage. Maintenance dredging of 19 – 20 million m³ per year by deploying quite a good number of Trailing Suction Hopper Dredgers (TSHD) throughout the year is ineffective in the present draught condition.

At present the dredged material is dumped within the estuarine system *i.e.*, open river disposal. KoPT has long navigation channels which are facing draft issues and hence KoPT is exploring ways and means to improve the navigation conditions by optimizing dredging and dredge disposal techniques. Dredging process is a blended essence of following three independent elements: excavation, transportation of excavated material and then usage or proper disposal of dredged material. After the initial excavation needed to establish a channel, dredging must be done periodically to keep it clear and safe for navigation. This is called maintenance dredging. Maintenance Dredging includes clearing of deposits (natural/man-made) and cleaning, widening or deepening of a water body using either a suction or dredger (scooping device). To improve the dredge disposal techniques for optimization of dredging activities in the navigation channels, KoPT *is mostly* exploring disposal of dredge in the close proximity to improve the turnaround time and minimize the expenditure involved in the process. The Hooghly



estuary fans out into three channels, out of which one channel passes through close proximity of Haldia Dock Complex. This channel is “Diamond Harbour – Balari- Haldia- Jellingham-Auckland- Sagar Island. Maintenance dredging is carried out in the Hooghly estuary primarily at the Auckland and Jellingham, in the shipping channel that leads to Haldia Dock Complex by KoPT by means of four Trailing Suction Hopper Dredgers (TSHDs) and experienced manpower.

For the aforesaid concerns, KoPT had engaged M/s RITES Ltd. for undertaking the R&D study on “Utilization and disposal of dredged material during maintenance dredging in Hooghly Estuary” in January 2015. The R&D study was completed by M/s RITES in March 2016.



Figure 2.1: River Hooghly Estuary – Project Area



2.2 Objectives of the R&D Project

1. Assessment of contamination of any hazardous materials/ heavy materials in the dredged materials, if any, and also give recommendation for suitability of utilization in the proposed reclaimed area.
2. Determination of the suitability of the materials for land filling / reclamations, construction activity and creation of fresh land through intertidal reclamation with or without suitable embankments/ retention measures etc.
3. Study on the land use, topography etc. of the proposed disposal / utilization site and quantify the percentage of utilization of the dredged material keeping the interaction of surrounding land use.
4. Assessment of availability of suitable location for utilization of dredged material considering techno- economic and environmental factors into accounts.
5. Assessment of the possibility of the utilization of dredged material for stabilization/ minimization of erosion in erosion prone areas, landscaping, road construction etc.
6. Assessment of the most suitable dredging methodology such as cutter suction/ trailing suction / hopper barge etc. to optimize dredging and transportation for utilization of dredged material.

2.3 Deliverables of the R&D Project

1. To have in depth study of ground reality, dredging methods including methodology of disposal of dredged materials.
2. Testing and analysis of dredged materials to assess suitability of the same in agriculture, brick manufacturing, road construction, land filling, land reclamation etc. and other field works.
3. Identifying probable locations adjoining the shipping channel namely Jellingham and Auckland for utilization and disposal of dredged materials in keeping with the present available depth, tidal window and type of dredgers being used during maintenance dredging considering techno- economic and environmental aspects in addition to the identified locations.
4. To indicate the method and modality of transfer of dredged material from river to shore, dimensions of dykes, details of specification of pipeline and other accessories including installation methodology, pontoons etc.



5. Comparison of conventional dredge cycle with suggested dredged cycle of dredgers considering shore disposal.

2.4 About Hooghly Estuary

The Hooghly estuary is one of the largest estuaries in the world formed by Ganga-Bhagirathi-Hooghly river system discharging into the Bay of Bengal through the **Sunderban** delta. The Bhagirathi River is the fresh water section, while the tidally influenced lower section is called the Hooghly River. The major discharges into Hooghly **river** are from Damodar Valley, which joins the Hooghly river through the Damodar River and the Rupnarayan river. Moving downstream, the estuary begins to broaden exponentially, a feature typical of most of estuaries. The portion between **Haldia** and Sagar with the Jellingham Bar and the Auckland Bar forms the inner estuary.

2.5 Auckland Channel

Deterioration in the Auckland passage depths was attributed to the passage of ebb flows through the western channel with sedimentation occurring along the passage of flow. It was recommended to construct secondary channel closure spur of over 3 Km length, across the western mouth of the estuary. The dredging quantity in Auckland was in the range of 19-20 million m³ in 2010 and reduced to 15 million m³ in 2014.

Current in Channel

The average current velocities recorded during the flood period are of order of 1.3 to 1.5 **m /sec**, whereas the current velocities during the ebb period are marginally high of 1.4 to 1.6 m / sec. In general, current velocities are stored during middle phase of the tide and weak during slack period of tide. The current direction is in line with the tidal flow of the estuary.

Currents were observed at three levels, surface, mid depth and bottom. While surface and mid depth currents are relevant for dredger movement, the bottom current is relevant for sediment movement as well as underwater dredger pipeline alignment.

Suspended silt in Channel



Suspended silt content in the waters of Hooghly estuary at Auckland bar locations were measured at the locations where current measurements were recorded. The suspended silt content in the water was estimated by collecting water samples at three levels, vertically down surface, mid depth and just above the sea bed. The collection of water samples was also correlated with respect to phase of tide. The silt content in the estuarine water of Hooghly varies from season to season in a year and also from flood to ebb tides. During monsoon the silt content in the water is usually high when compared to non-monsoon season. The minimum, average and maximum values of silt observed across samples taken in 27 locations of Auckland bar is 0.38 gm/lit.

Grain size analysis of dredged material

The bed samples were collected at the locations where current measurements were recorded at Auckland bar and analysed for various parameters. The median diameter of the sand grain is of order 0.1 mm.

The grain size analysis of the bed sample was undertaken. The median sediment size (D50) is 0.24 mm. The percentage distribution of medium sand is about 13%, fine sand is 83% and very fine sand is 3.8%.

2.6 Jellingham Channel

The depth in the Jellingham channel has deteriorated from a stable 7.0 m to approximately 5.0 m. This depth of 5.0 m is being maintained at a significant cost and effort. Dredging quantity has increased significantly over the last 10 years. The increased rate of deposition is attributed to lowering of the velocity flow in the Jellingham channel resulting in week flush out of sediment. The reduced hydraulic capacity of Haldia – Jellingham Channel is due to Balari Bar build up.

During flood, the water that enters from the Auckland area does not find adequate passage and thus there is a divergence of flow at Jellingham, causing drop of velocity. The reduced section at Balari also prevents adequate ebb flow from entering Haldi – Jellingham channel, resulting in low velocities as the cross section of the channel increases south of the Haldia River. The Belari bar built up has resulted in the increased dredging in Jellingham.



Current in Channel

Current observations were made for 24 locations at Jellingham Bar. The currents were recorded at intermittent period during 2006 to 2015 over a tidal cycle covering both ebb and flood periods. The average current velocities recorded during flood are 1.8 to 2.0 m/s, whereas during ebb period are 1.5 to 1.6 m/s, contrary to Auckland channel, where the current in ebb flows are marginally higher when compared to flood. Maximum current velocity recorded was 2.47 m/sec during flood tide and 1.86 m/s during ebb tide. The current direction is in line with the tidal flow in the estuary.

Suspended Silt in Channel

Suspended silt content in the waters of Hooghly estuary at Auckland bar locations were measured at the locations where current measurements were recorded. The minimum, average and maximum values of silt observed across samples taken in 24 locations of Auckland bar is 0.41 gm/lit.

The siltation studies carried out by Central Water and Power Research Station (CWPRS) revealed that the siltation rates in upstream of Haldia would be of order 1.3 million m³ per annum and in downstream it would be around 3.0 million m³ per annum.

Sub Surface Soil Profile

The sub soil data has been collected from boreholes drilled at Sagar Island and the results can be utilised for Auckland and Jellingham bar areas as the strata is more or less identical. The sub surface profile generally consists of deposit of Sandy silt, sandy clay. Based on the Standard Penetration test (SPT), the relative densities of silty sand ranged between loose and very dense. The clay was observed to be stiff and of hard consistencies.

2.7 Review of River Regulatory Measures (RRM)

In the present Auckland – Jellingham navigation channel the actual dredging quantities for 10 years (2005 – 2014) is given in the table below:

Year	Jellingham (Million m3)	Auckland (Million m3)	Total (Million m3)



2005	13.3	2.29	15.59
2006	12.15	2.77	14.92
2007	9.43	8.32	17.75
2008	7.5	9.61	17.11
2009	5.42	19.25	24.67
2010	4.37	19.62	23.99
2011	4.21	12.06	16.27
2012	3.64	12.71	16.35
2013	3.38	15.1	18.48
2014	3.45	15.42	18.87

The annual maintenance dredging quantities at Auckland and Jellingham varies from 15 to 25 million m³. The average dredging quantity for last 10 years is about 18.4 million m³. The review of River regulatory measures (RRM) study undertaken by Lanka Hydraulic institute for KoPT has proposed two options out of various options studied under RRM. Of the two options proposed, the option recommended to be implemented is the closure of the shore attached channel and open dredge cut channel in the Ballari passage with dimensions of 300 m x 5.0 m with a length of 11.5 Km. The estimated capital dredging in the proposed dredge channel is 17 million m³ and maintenance dredging is 4.5 million m³. Few of the recommendations of RRM study in line with the shore dredge disposal study are:

- Improved efficiency of disposal method by creating shore disposal grounds at the bank of Ballari Island, Nayachara Island, Rasulpur and Sagar Island.
- Dumping area of dredged material over Nayachara island within the dyke through shore disposal terminal
- Development of shore disposal terminal and dyke at western edge of Sagar island
- Trimming of western face of Nayachara Island
- Construction of dyke for shore disposal with a dyke crest up to +3.5 m MSL, 11.5 sq km area and 55 million m³ capacity.



2.8 Findings of the R&D Project

1. The Auckland and Jellingham bar pose challenge for navigation in Hooghly estuary. 92% of dredging is done only at these two critical locations. As trend of 4 years (2010-2014) indicate 78% material was dredged at Auckland and 22% at Jellingham Bar. Possibly the materials disposed of in the off shore area at Hooghly is getting recycled and settled at Auckland bar
2. An average of 1 to 1.5 million m³ per month of dredged material is required to be disposed to the shore at Auckland bar and 0.3 to 0.5 million m³ per month at Jellingham Bar.
3. Presently KoPT hires dredgers from Dredging Corporation of India (DCI) on daily / monthly rental for maintenance dredging of navigation channel. Around 3 dredgers together make multiple trips in a day at both Jellingham (7 to 8 cycles) and Auckland Channel (13-14 cycles) for maximum utilization of time.
4. Nayachara Island is near to Jellingham channel and the capacity of the dykes proposed is adequate for shore disposal for more than 10 years, this area has been selected to be best suitable for shore disposal.
5. If only one dredger is being utilized exclusively for Jellingham channel, the cost of disposal of dredged material becomes very high (~606 per m³). Hence for optimum utilization and cost reduction, it is being practiced to use dredger for both Jellingham and Auckland Bar where the tidal window, draft restriction and sailing period is less.
6. For shore disposal scheme, dredging firms like DCI, Jan de Nal, Van Oord , International sea port dredging and Dharti dredging were contacted. Underwater / submerged pipeline for shore disposal was a preferred option over elevated pipeline disposal by the dredging firms.
7. M/s RITES has recommended to implement the shore disposal scheme on Turnkey basis with the dredging firms. The construction of Dykes will be done by KoPT.
8. M/s RITES has proposed 5.6 m draft dredger for this disposal scheme, exclusively to be engaged for Jellingham Channel. The anticipated cost of dredging will be approx Rs. 403 per m³ of dredged material.
9. It has been recommended to use the dredge and shore disposal material for land reclamation as the dredge material mostly comprises sand, silt and clay. The



reclaimed land can be used for irrigation and farming purpose. About 1770 acre, 926 acre, 922 acre and 1113 acres of land can be reclaimed in Phase 1, phase 2, phase 3 and phase 4 respectively.

10. Chemical analysis of sediment quality was carried out by KoPT which does not indicate contamination and toxicity and hence any adverse affect on the area is not foreseen.
11. It is estimated that 3660 tons (considering sand is 40% of total dredged material) of sand per day will be disposed on Nayachara island alone during phase 1. This corresponds to a revenue generation of approx Rs. 2.9 lakhs per day. The work of sand extraction from dredged material can be outsourced and made a business generating venture.
12. Based on the study, M/s RITES has suggested to hire minimum 3 TSHD dredgers- 1 each exclusively for Auckland and Jellingham and third on sharing basis between Auckland, Jellingham and any other critical shoal areas as and when required.
13. The shore disposal operation may be immediately started at Jellingham location and disposed to Nayachara island on priority. The shore disposal at Auckland and disposal to Rasulpur area can be taken up when the shore disposal scheme at Sagar island takes place.

2.9 Deliverable v/s Outcome of the Project

The outcomes of the R&D project have been listed against the deliverables as follows:

S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
1	In depth study of ground reality, dredging methods including methodology of disposal of dredged materials	<ul style="list-style-type: none"> • Study undertaken with respect to hydrography of the estuary, depths along navigation channels, cross sectional profiles of islands/ channels, wave patterns etc. • Detailed study of focus area i.e Auckland and Jellingham channel has been carried out including the currents during flood & ebb flow, surface, mid depth & bottom level based on current measurements provided by KoPT at various locations of both



S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
		<p>channels; suspended silt has also been recorded at the location where current measurements were recorded and grain size analysis, soil profile study has been done for the dredged material.</p> <ul style="list-style-type: none"> • Review of the outcomes of river regulatory measures (RRM) study undertaken by KoPT through Lanka Hydraulic Research Institute and CWPRS has been carried out. • The current method of disposal of dredging at Hooghly estuary has been studied and new alternate method has been proposed after reviewing 4-5 alternate disposal techniques.
2	Testing and analysis of dredged materials to assess suitability of the same in agriculture, brick manufacturing, road construction, land filling, land reclamation etc. and other field work	<ul style="list-style-type: none"> • The analysis of dredged material is provided based on chemical analysis of 5 samples (4 samples from Auckland and 1 from Jelligham). The results of the analysis have been provided by KoPT. • The chemical analysis indicates high level of heavy metal and mineral concentration in all 5 samples. However, no statement has been provided with respect to acceptable standards (national / international) of heavy metal/ minerals in dredged material. More Samples need to be taken and in different seasons to confirm the quality of the dredged material. • The suitability of heavy metals bearing dredged material for brick manufacturing, road construction, land filling, land reclamation etc. is not provided. Even the suitability of Dredged material for any of the stated Reuse have not been mentioned nor looked into.



S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
		<ul style="list-style-type: none"> • Soil and ground sample analysis was undertaken previously by KoPT and based on that analysis it has been mentioned in the report that the proposed dredged material in the navigation channel is mostly sand & silt and this deposition carried by streams / channels flowing from upland onto low and plain area results in formation of alluvial plain which is very fertile and hence can be used for vegetation, filling of low lying areas, any other construction etc. This statement needs to be qualified with more number of sample analysing and interpretation. • Based on the earlier studies undertaken by KoPT, e.g RRM study it has been concluded that there is no adverse environment impact of dredging; phytoplankton/ zooplankton levels are within natural levels of estuarine system, before and after dredging; there is negligible impact on fish stock; marine biological environment is not affected. No detailed reports or analysis available to substantiate the statements.
3	Identifying probable locations adjoining the shipping channel namely Jellingham and Auckland for utilization and disposal of dredged materials in keeping with the present available depth, tidal window and type of dredgers being used during maintenance dredging considering techno-economic and environmental aspects in addition to the identified locations	<ul style="list-style-type: none"> • Four locations were identified by KoPT for shore disposal: <ul style="list-style-type: none"> ➤ South west portion of Nayachara Island ➤ Right Bank of Jellingham area (Nandigram) ➤ South west Fringe of Sagar Island ➤ Mudflalt and fore shore of Rasulpur <p>Out of the above four options, Nayachara island is near by to the Jellighum channel and the capacity of the dyke proposed are adequate for shore disposal upto 10 years and hence this area is selected as the best</p>



S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
		<p>suitable option.</p> <ul style="list-style-type: none"> • Shore disposal of Auckland channel and disposal of material into Rasalpur is not considered in present shore disposal scheme and shall be taken up later when shore disposal scheme at Sagar Island will take place. • Nandi gram location has also been ruled out as the land is not under the ownership of KoPT. <p>The area availability, land use pattern, mangrove coverage, aqua habitation etc. at Nayachara island has been looked in to. Earthwork excavation has been proposed in south –west portion of Nayachara island for dumping of dredged material.</p> <p>Detailed Land Use pattern needs to be made in the present conditions; giving the habitation/ population, cattle, trees, land area under that is barren, grasslands, mangroves etc. Ground water, aquifers, its direction of flow, its analysis etc</p> <p>The Environmental impacts of the disposal of the Dredged Material on the shore (both positive and the negative) should be studied and presented in the report.</p>
4	To indicate the method and modality of transfer of dredged material from river to shore, dimensions of dykes, details of specification of pipeline and other accessories including installation methodology, pontoons etc	The current method of dredging being executed in Hooghly estuary by Dredging Corporation of India (DCI) for KoPT has been reviewed. The dredged material is currently disposed in an identified location about 9 Km off the Sagar Island. 3 dredgers are being used by DCI of hopper capacities 4500 me x 2 (draft 5.5 m) and 7400 m3 x 1 (draft 8.5 m); The concerns involved in current practice pertaining to long distance voyage, long turnaround time, decreased efficiency of dredgers,



S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
		<p>leakages, residual material etc. has been identified.</p> <p>Alternate options for disposal of dredged material have been studied including:</p> <ul style="list-style-type: none"> ➤ Underwater pipeline ➤ Elevated pipeline ➤ Floating pipeline ➤ Rainbow disposal and ➤ Open water disposal by barges <p>The advantages and disadvantages of all the five options have been detailed out and based on the overall analysis underwater / submerged pipeline method has been suggested for the shore disposal of dredged material owing to its advantages of improved efficiency, traffic reduction, fuel savings, turbidity reduction and no draft concerns.</p> <p>In underwater pipeline mode of shore disposal, the modality of transfer of dredged material is through underwater flexible pipeline laid in the river bed. One end of pipeline connects to the dredger and other end enters the dykes (constructed by geo-tubes/ sheet piles of sufficient width with weirs) at appropriate locations. Dredger operates in the navigation channel and dredged material is disposed to dykes at the identified locations.</p> <p>The specifications and dimensions of the dykes, pipeline, geo-textile tubes has been provided in the Bill of quantities (BOQ) available in the report.</p>
5	Comparison of conventional dredge cycle with suggested dredged cycle of dredgers considering shore	The present dredge cycle and cost of operation has been worked out for the 3 dredgers currently used by DCI . In the



S. No	Deliverable of the project	Outcome of the project as per the Study Report available with NPC
	disposal	<p>current practice of dredge disposal up to 3 cycles are being done in a day which costs upto Rs. 606 per m³ of dredged material or higher in case the number of cycle is less than 3.</p> <p>As per the new proposed shore disposal method of DCI, by using 5.6 m draft TSHD dredger, exclusively for Jellingham, the approx cycle time is around 3.5 hours and approximately 5980 m³ per day can be disposed. The no. Of cycles can be improved upto 7 in a day and costing shall come to Rs. 403 per m³ of dredged material.</p> <p>The dredging proposals of M/s Jan De Nul, M/s Van Oord, M/s International Sea Port Dredging and M/s Dharti Dredging in terms of dredge cycle and cost per m³ of dredged material has also been reflected in the report. However, the conclusive comparison of all prospective proposals is not presented in the report.</p> <p>The comparison should be more on “apple to apple” basis. Some more loose ends can be fixed. The cost of the dykes construction, cost of Land, cost of corrective actions of Environmental impacts of the dumping on the shore etc needs to be worked out and then compared with the conventional dumping to the shore dumping.</p>

2.10 NPC's Observations on the report of R&D project

The following observations have been found in the report:

1. The report is mostly based on secondary data review and records made available by KoPT or RRM study, e.g record of current velocities, lab test results



of silt content, grain size analysis, sieve analysis of surface soil etc. Ideally a R&D study should focus on primary data analysis.

- The chemical analysis of dredged material has been done by taking 4 samples from Auckland and 1 sample from Jellingham. The chemical and metal concentration analysis of dredged material has been provided by KoPT. There is no inference derived from the analysis results in the report.
- The heavy metal analysis report reflects the presence of several heavy metals and minerals in very high concentration in the dredged material. The analysis report is placed below for reference:

No	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5
Al ₂ O ₃ (%)	17.87	15.68	15.91	17.90	21.87
Fe ₂ O ₃ (%)	5.90	4.80	5.00	6.20	8.70
MgO(%)	1.20	1.12	1.20	1.50	1.90
CaO(%)	1.65	1.30	2.17	1.96	2.10
MnO(%)	0.11	0.07	0.05	0.05	0.06
Na ₂ O(%)	1.30	1.25	1.20	1.40	1.30
K ₂ O (%)	2.10	2.57	2.28	2.14	1.80
TiO ₂ (%)	0.38	0.47	0.35	0.36	0.44
P ₂ O ₅ (%)	.14	.16	.09	.09	.11
Cu (ppm)	10	15	10	15	20
Pb (ppm)	20	15	15	20	30
Zn (ppm)	120	100	80	110	120
Ni (ppm)	15	20	15	15	15
Co (ppm)	15	10	15	15	25
Cd (ppm)	<5	<5	<5	<5	<5
Ba (ppm)	460	430	400	410	490
Sr (ppm)	5	10	10	15	20
Cr (ppm)	25	30	15	20	50
V (ppm)	60	50	40	50	45
Mo (ppm)	10	10	15	10	20

Note:
Sampleno.1to 4....Auckland
Sampleno.5.....Jellingham

Auckland *Jellingham*

Figure 2.2: Chemical and Metal Concentration Analysis Results of Dredged Material



4. The methodology used for analyzing the concentration of heavy metal is not mentioned in the report. In case, the analysis is based on leachable concentration limits, then as per **schedule II of Hazardous and other waste (Management and Transboundary movement) Rules 2016**, the dredged material will fall under the category of hazardous waste considering the concentrations of Lead, Chromium, Vanadium, Barium etc.
5. Though it is mentioned in the report that the dredge material does not have any adverse impact on the environment, the suitability of heavy metal bearing dredged material for agriculture or vegetation needs to be concluded only on the basis of analysis of toxicity of the material.
6. The report states that 92% of the total dredging in Hooghly estuary is done from Auckland and Jellingham channel. Out of this 78% material is dredged at Auckland and 22% at Jellingham. However, the shore disposal scheme is being taken up only for Jellingham channel as a priority. Hence the major portion of the problem of siltation in the navigation channel is not addressed completely.
7. There is no mention of the type of monitoring of the depths. The data given by the KoPT has been used extensively. Surveying methods used and the requirement of such huge quantities of dredging could have been investigated. Then the dredging techniques could have been further analysed.
8. The dredged volumes and its calculation and see if it matches with the estimated siltation is one way of ensuring the Dredging quantities is true. Else the method of calculation used for the dredged material should be relooked into.

2.11 Usefulness of the R&D project for Port Sector

While it is appreciated for the effort having been put by the Consultant in arriving at the conclusions and recommendations, we find that there are some concern areas that still need to be tied up.



As the title of the Report suggests “Effective Utilization and Disposal of Dredged Material during Maintenance Dredging in the Hooghly Estuary” we could not find any suggestions of effective utilization for the dredged Material except suggestion for shore disposal. Even to arrive at the conclusion for shore disposal the consultant could have concentrated on the study of Environmental impacts of shore disposal and arrived at palpable results.

Experiments on the Reuse of the dredged Material at various usage points such as the Brick making, Road making, Land filling/ Land Reclamation etc as mentioned in the Deliverable of the Study could have been carried out. Means and methods for addressing the heavy metals contamination and then options for reuse could have been described. As such no R&D on this subject could be evidenced from the given study report. This report may be relevant to the KoPT. As such no Reuse options have been given and there is nothing substantial to share with the other Ports for replication.

While the report has analysed dredging methods and techniques, the cycle time cost per m³ of dredged material etc, from various dredging firms, these cannot be put to use directly in the other ports as the siltation problems vary from Port to Port and conditions. No two ports or the conditions especially the silting issues will be the same. Siltation is dependent on many conditions and the subject is complex basket of variables. The R&D project is relevant to the port sector, however only the idea or the outcome of one study can be replicated across various other ports in the country. The results cannot be implemented in totality in other Ports as the nature, hydrography, topography, tidal windows etc vary.

The report has analyzed the dredging methods and techniques from various expert dredging firms (national and international). The dredge cycle time and cost per m³ of dredged material has also been estimated. Based on these estimates, the dredger requirement for other ports facing similar siltation issue in the navigation channel can be addressed. The quality of the dredged material may vary from port to port. Hence to assess the possible variation in the composition and characteristic, this R&D study can be taken up for a different location (e.g Chennai/ Vishakhapatnam/ cochin etc.) and the outcomes can be correlated. The scope of the R&D project should also include certain aspects of primary data analysis.

Chapter – 3

ASSESSMENT OF R&D PROJECT-2: “Implementation of Pilot Project in connection with Short-Term and Long Term Measures for Improvement of Draft in the Hooghly Estuary”



Chapter 3

ASSESSMENT OF R&D PROJECT-2:

“Implementation of Pilot Project in connection with Short-Term and Long Term Measures for Improvement of Draft in the Hooghly Estuary”

3.1 Short Term Measures for the Improvement in Jellingham and Auckland Navigation Channel Leading to Haldia Dock System

3.1.1 Background of the R&D Project

Maintenance Dredging is a periodical activity in Port of Haldia that is undertaken to maintain a clear and safe channel for navigation. It is a crucial process, but it involves a huge expenditure of approximately **Rs. 400 crores** per annum out of which a major part is spent in maintaining Auckland bar and Jellingham shoal. KoPT entrusted the consortium headed by WAPCOS to resolve the complexities pertaining to hydro-dynamical and morphological behaviour. This was followed by seeking relevant recommendations from a **third-party** expert involving HR Wallingford. In order to reduce the dredging burden, they devised a modified dredging strategy and alternative dredging route via two measures viz. – Short Term and Long Term. Hydraulic Trail Dredging and Simultaneous rainbow dredging were the methods that were adopted using a bow-mounted dredge.

M/s HR Wallingford, **in the short term project**, opted to go for site trial at different locations in Hooghly estuary applying the method of overflowing/spreading/side casting the dredged material without loading the hopper of the **dredger** so that with minimum available draft the dredger could be deployed for a **longer** time over the bar and continue dredging over critical spots.

For Short Term Measures, a combination of conventional dredging with side-casting using rain-bowing was adopted for which DCI dredgers came into use. Certain parameters were assessed using the results from pre-dredge and post-dredge surveys which helped to set the limitations like **the size of the dredged area** or maximum distance from which the material can be discharged. **This assessment concluded that**



side-casting dredging is the most efficient and effective for the area with a 20m width along the channel edges.

However, with the help of monitoring using hydro-graphic surveys, it was observed that side-casting caused shoaling and spread the disposed material. This could not be done during ebb-tide. Thus, using the mathematical model simulations and monitoring, deposition, dispersion, and spread were known. Over a year, it came to light that monitoring and control of modified dredging were found to be more intensive as well as responsive in terms of adaptive management. Throughout the trial dredging, it was noted that the adaptive mechanism was enhanced corresponding to the varying tidal conditions and ensuring minimization of time loss. There was a significant increase in production and improvements in depth. For instance, the navigational draft for Jellingham improved from 3.5m to 4m and from 4.1m to 4.4m for Auckland Bar with the reduced quantum of dredging yielding a cost advantage to KoPT along with operational benefits.

With the help of an action plan, which entails a detailed analysis based on results from the Field Trial Dredging, helped to examine and identify the necessary operational input, area for dredging, and time requirement. Four dredgers, equipped with advanced instrumentation, were deployed for this project.

3.1.2 Objectives of the Short-Term Improvement Measures

Before undertaking the Field Trial Dredging (FTD), certain objectives were defined to understand the tidal conditions and how could the dredged material be possibly managed in and around the shoal. Improving the productivity of dredging was the primary objective so that it minimizes the time lost and increases vessel utilization. It was also crucial to underline the movement and time required for the material to resettle on the riverbed after side-casting. Considering the tidal conditions, it was aimed to make a note of the spread of the material in the water and to devise & execute dredging techniques over different tidal conditions to assess the productivity of the dredger. Disposal of material at the designated location is important to prevent the dredged material from returning to the shoal. Through the FTD, it was aimed to enquire about the stability of the dredge footprint pre as well as post-dredging.



The **primary** aim of the FTD was to identify how the dredged material **could** be managed, by understanding how it behaves in the river environment in and around the shoal, for example:

- Can TSHD productivity be improved (i.e., increased infill material removed from the channel within a given time period) by minimizing time lost to sailing and thereby increasing vessel utilization;
- How quickly the material drops out of the water column and re-settles on the river bed after side casting;
- How far the material migrates in the water column over various tidal cycles and water flow volumes;
- TSHD productivity using specific dredging techniques over different tidal windows;
- How far away material needs to be placed **to** not return to the shoal area;
- How stable the dredge **footprint** is **before** and post dredging.

3.1.3 Deliverables of the **Short-Term Improvement Measures**

1. Examination of field status on board DCI dredgers in association with International dredging experts
2. Analysis and investigations by the dredging experts with feedback from the field
3. Understand the present dredging **practice**, including sailing to the disposal site
4. Examination of existing dredging contract with DCI and advice for refinement / improvement
5. Field trials involving over spilling, side casting etc.
6. Model investigation by CWPRS
7. Monitoring the impact of new dredging techniques, including analysis of hydrological data, coordination with experts etc.
8. Bathymetric measurements and analysis to see how effective the revised procedure is.

3.1.4 Timeline of **Short-Term Improvement Measure Project**

The total timeline for short-term as well as long-term was for two years. For the short-term Measures, the project **lasted** from April 2014 to March 2015.



3.1.5 Findings of the Short-Term Improvement Measures

1. The report signifies the performance of the new methodology of **FTD along** with conventional dredging with a view **to improve the** productivity of the maintenance dredging and improvement of draft and **cubic** capacity of the maintenance of critical dredging areas of Hooghly estuary, **i.e.**, Upper Jellingham shoal and Lower Auckland Bar.
2. The report covers various aspects for improvement of navigational draft **through adoption of the** new methodology of the dredging, the fate of disposed dredged sediments by side casting, survey details, dredged volume, improvement of cubic capacity, deposition and spread of dredged sediments, selection of conventional dumping ground both offshore and onshore.
3. The new method adopted for **Field Test Dredging(FTD)** is **combination of** conventional dredging followed by side cast of material through modified **bow-mounted** rainbow installation, using TSHD of DCI (Dredge 19, 20 and 21) is novel – both in its use on the Hooghly River and for DCI.
4. Based on the FTD carried out for 12 months, **it achieved navigation depth improvement of around 0.5 m at Upper Jellingham Shoal (UJS) and 0.3 m at Lower Auckland Bar (LAB). The improvement in navigation depth in Jellingham went from 3.5 m to 4 m whereas the same in Auckland rose from 4.1 m to 4.4 m.**
5. The FTD concluded that **the** maximum distance the DCI dredge 19 **could** side cast using its **bow-mounted** rainbow installation is within 90 m, measured from the center line of the vessel, which means **the** landing zone of dredging material falls close to the area of dredging operation
6. As per the report, side casting is most effective in an area **approximately 20 m** width along the channel edges. By repeated side casting, it is possible to move material from within the central portion of the channel to outside the channel. Ideally, this will require more than one trailing suction hopper dredger (TSHD) configured for side casting to expedite the material removal.



7. The deposition of dredged sediments by side casting within UJS has mainly spread over and caused shoaling to the north of UJS – predominantly at the confluence of the Haldia River and OIL jetty area and further downstream and in between the spurs. Shoaling has also been observed within the Eden Channel area. Side cast sediments discharged at LAB are dispersed and deposited at the lower end of the Sagar Island and Bakhali areas.
8. The report recommends KoPT to take appropriate action in developing infrastructure to facilitate shore dumping of sediment dredge at designated shore dumping sites.
9. The report recommended to undertake frequent and timely hydrographic surveys with dedicated survey vessel equipped with modern facilities for data processing and online communication with the dredgers to quickly respond during critical and adverse developments etc.
10. The report provides the analysis of quantum of disposable dredged material by shore dumping. However, the same doesn't recommend shore disposal owing to the non-availability of required infrastructure for the shore disposal during the period of the study.
11. The report suggests employing minimum 3 and ideally 4 TSHD for dredging in UJB and LAB as per the prescribed methodology of conventional dredging coupled with side casting.
12. The report found that Hooghly estuary is complex and poses challenge due to highly variable environment. Therefore, it recommends a 5-year plan undertaking FTD continually until the implementation of Long-term studies for achieving overall dredger efficiency, improvement in navigational depths etc. Improvement in navigational depths would lead to revision in dredging and focus on new areas.
13. The report reveals significant reduction in unproductive operational time when adaptive (side cast) methodology is adopted. Efficient and effective working has



reduced the cost making the maintenance of current depths tenable. A continued increase in navigational depths can be achieved in the same cost being currently incurred.

14. The report demarcates necessity for constant review and monitoring of whole dredging operation by competent personnel experienced in dredging operations in tidal estuaries with bathymetric support of survey vessels, multi-beam etc. All the figures of dredging quantity, navigation depth etc. is not sacrosanct and will require to be reviewed as dredging requirement will vary in accordance with behavior of river and sediment load in it.
15. At least one dredger quipped with nozzle both to starboard and port side has been recommended for side casting and as a contingency measure, another dredger may also be fitted likewise.
16. It has been proposed that a suitable contingency plan be made operational in case of emergencies, including modifications in dredging schedules, O&M, emergency dumping of dredge at site not identified in the plan etc./ by KoPT.
17. The report provides calculation for the project cost implications as follows:
- a) 2 New Dredgers x Rs.40.0L/- x 300 days (82%) = Rs.240.0 Cr
 - b) 1 Old dredger (Dr.XIV) x Rs.23.0 Lakh x 300days= Rs.69.0 Cr
 - Sub-Total = Rs.309.0 Cr
 - c) Estimated side-casting (UJS+LAB) 130hrs. x 12 months =1560 hrs.
 - = 65 days x 30 % of Rs. 40 lacs
 - = Rs.7.8.0 Cr
- Total (Approx.) = Rs.316.0 Cr {Kolkata Short Term Report Pg. no. 140}.
- That is the expected expenditure for implementing Short-Term measure stands at Rs. 316 Crs.
18. As per the report, the current dredging expenditure is to the tune of Rs. 400 Crs. per annum in Upper Jellingham Shoal and Lower Auckland Bar. Hence, if the short-term measure is implemented, which envisages the expenditure of Rs. 316 cr annually, there shall be saving of more than 20 %.



3.1.6 Deliverable V/s Outcome of the R&D project

Sr. No.	Deliverable of Project	Outcome of Project
1.	Examination of field status on board DCI dredgers in association with International dredging experts	<p>The main element of the Short-Term Measures project is the undertaking of Field Trial Dredging (FTD) to try out new dredging methods aimed at improving the productivity of the present maintenance dredging campaign being undertaken by DCI for KoPT on the Hooghly River.</p> <p>Taken in association with international dredging experts by establishing FTD objectives and std methodology including trial options for:-</p> <ul style="list-style-type: none"> • Rainbowing (side casting) • Automatic Light Mixture Overboard system modification • Overflow installation • Installation of additional pipe work to discharge immediately overboard. <p>Prelim studies were undertaken in selected areas of the Jhellingham channel using the side cast dredging technique which required modification to the available DCI dredger like fitting of the nozzle with certain configurations.</p> <p>Site visits were undertaken by HR Wallingford experts, covering dredging aspects and bathymetric survey aspects. Dredging experts from WAPCOS was present during the execution of FTD for understanding the procedures of dredging undertaken and for further guidance in future after the outcome of Short - Term studies</p>
2.	Analysis and investigations by the dredging experts with feedback from the field	<p>Analysis and investigation were undertaken and initial results of the field trial of pre-dredge and post-dredge surveys, limitations of side casting were observed especially the size of the dredged area that can be easily managed and worked during side casting operations.</p> <p>The Possible impact of side cast dredging on environmental and channel prism were studied using</p>



Sr. No.	Deliverable of Project	Outcome of Project
		<p>analytical method and mathematical modeling. Variation of concentration of dispersed sediment along longitudinal transverse as well as the lateral spread of dispersed sediments has been studied and furnished in the report.</p> <p>As part of confidence-building measures, additional mathematical model simulations were also undertaken by CWPRS, Pune using 2D MIKE21 HD and ST model of the estuary.</p>
3.	Understand the present dredging practice , including sailing to the disposal site	While adaption of the side cast dredging technique has been elaborated in the report, the details of conventional dredging technique is limited in the report. The detailed analysis of side cast dredging substantiates that the evaluation of the conventional dredging technique has been undertaken by the consultant. However, that aspect has not been comprehensively addressed in the report.
4.	Examination of existing dredging contract with DCI and advice for refinement / improvement	<p>The existing dredging contract with DCI has been examined and HR Wallingford has advised regarding Future Maintenance Dredging Contract and Tender Considerations. The contradictions in the tender pertaining to charter contract, lump-sum contract or unit rate contract have been compared and addressed. The Incorporation of a bathymetric survey within the contract has been suggested. It is recommended to clarify the following points in any future contracts:-</p> <ul style="list-style-type: none"> - Offshore disposal ground location - Location of 'short dumping' disposal grounds within the Estuary - Possible side casting -Reporting and mitigation protocols for side casting - A minimal depth must be achieved and maintained. - Clear method statement from all tender parties. - minimal quality standard of survey - Reporting criteria <p>HR Wallingford has also recommended numerous</p>



Sr. No.	Deliverable of Project	Outcome of Project
		<p>other points that should be clarified in any future maintenance dredging contract; including contract terms, contractor's method and reporting of his works and quality of bathymetric survey.</p>
5.	Field trials involving over spilling, side casting etc.	<p>The modified dredging method comprising side casting combined with conventional dredging was carried out for one year (April 2014 to April 2015). The monitoring and control of side cast dredging were many times more intense than that currently required for conventional dredging. This was used to deploy a rapid response adaptive management approach to the overall activities of the trial dredgers.</p> <p>Detailed analysis of survey records during the whole period has been furnished to KoPT along with the summary of improvement in the draft, cubic capacities and dredge volume as well as dredging response. The net result being the improvement of the navigational draft from the original critical level of 3.5 m at Jellingham to about 4 m and in the Auckland Bar the improvement is from 4.1 m to 4.4 m.</p> <p>This has been achieved with reduced quantum of dredging and saving of operational time of dredgers with considerable cost advantage to KoPT.</p>
6.	Model investigation by CWPRS	<p>To justify the desk study using analytical methods by taking inputs from FTD undertaken by M/s WAPCOS, mathematical model simulations were undertaken by M/s CWPRS to assess the sediment transport aspect for the new dredging and disposal methods. The mathematical model was used to get indicative and qualitative information on the likely trajectory and spread (fate) of the fine sediments moving as a suspended load.</p> <p>The simulation plots gave a qualitative indication about the trend of movement of sediment and deposition.</p>



Sr. No.	Deliverable of Project	Outcome of Project
		<p>Simulation shows with actual data of sediment characteristics i.e. size and fall velocity, silt concentration, sediment does not get accumulated at the point of discharge. The tidal velocity particularly during spring tide is strong enough to keep sediments in suspension and move it to distance placed away from channel.</p> <p>The simulations were, also carried out for the freshet period; however, the results are more or less similar to those for the lean period.</p>
7.	Monitoring the impact of new dredging techniques, including analysis of hydrological data, coordination with experts etc.	<p>The result of the possible impact of the side casting of dredge sediments on the environment and channel prism has been studied in the report by following Analytical and Mathematical modeling.</p> <p>The trial of new technique i.e., side cast dredging has largely been successful due to the careful adaptation and close management/ monitoring of dredging technique.</p> <p>The role of bathymetric in monitoring dredging operations has been emphasized after observing the effectiveness of the bathymetric surveys during the FTD.</p> <p>Detailed analysis for preparation of an action plan for the dredge spoil management during the next five years starting from 2016 to 2021 (when it is expected the Long Term</p> <p>Measure of Alternative Navigation Channel across Nayachara Island will be in place) has been prepared based on the results and experience gained from the present Field Trial Dredging. To implement the plan the infrastructural facilities that need to be put in place specially for shore dumping, the requirement of dredgers and survey vessel and monitoring facility have been closely examined based on the identification of dumping ground and</p>



Sr. No.	Deliverable of Project	Outcome of Project
		<p>detailed calculations of tidal windows available for dredge operations, number of hopper loads required and the time requirement to travel, dump and return to operation area.</p> <p>The report recommends the necessity to carry out close monitoring by undertaking the frequent and timely hydrographic surveys with a dedicated survey vessel equipped with the modern facilities for data processing, preparation of survey chart and online communication with the dredgers so as to have quick response during the critical and adverse developments.</p>
8.	Bathymetric measurements and analysis to see how effective the revised procedure is	<p>The effectiveness of the bathymetric surveys proved during this Pilot Project for ascertaining the stability of the dredged track prior to and post dredging, how far the side-casted sediments migrates in the water column over various tidal cycles and water flow volumes, at what distances the sediments would need to be placed in order to gain improved depths within the channel.</p> <p>The report provides an insight of the morphological stability analysis of the existing and proposed shipping route to Haldia Dock Complex (Long Term Measures) along with the detailed examination of the issues related to Eden channels stability and suitability for navigation. The morphological study basically deals with short, medium and long-term changes expected in the estuary mouth, based on past behavior of the movement of sand flats, the disintegration and reformation of Bedford group of sands following a certain cyclic period.</p>



3.1.7. Usefulness of R&D Project for Port Sector

- The methodology of side casting / rain bowing of dredged material was experimented in the actual river, which was never tried before, in different tidal conditions. Based on the findings of the said experiment, side casting / rain bowing of dredged material along with Conventional dredging was recommended and has been implemented.
- Due to implementation of **Short-Term** Measure, the productivity of the dredging has improved and contributed for the improvement of navigable depth in the shipping channel leading to Haldia. It was mentioned that with lesser quantity of dredging (Dredge material in Mm^3) the required navigational draft could be maintained. More light can be thrown on this aspect as it is commonly known that navigational depth is achieved more or less by virtue of the dredged quantity material. It has to be acknowledged that this method has however saved operational time which is a positive impact on the cost to KoPT.
- Disposal of dredged materials in a far away designated location in the river coupled with the new methodology of side casting jointly contribute towards maintenance & improvement of navigable depth in the shipping channel.
- The project report addresses the overall objective envisaged for this R&D project. Aspects related to improving the productivity of TSHD within a given time frame by minimizing the time loss, increasing vessel utilization, assessing the distance dredging material migrates in the water column over various tidal cycles and flow volume; TSHD productivity using specific dredging techniques and placement of dredged material so as to avoid their return to the shoal has been dealt with. It is felt that the net result of the above savings may also be due to the close monitoring of the Bathymetry and dredging **in highly** controlled and monitored conditions based on the **real-time** bathymetry studies.
- It has been proven through the trials that the Side Casting dredging is most efficient in an area of approximately 20 m width along channel edges in order to place the material sufficiently outside the channel **footprint**. Though the study and its results on this aspect cannot be used in the other Ports directly the principle can be adopted with further study of that specific channel conditions.
- Owing to the **above-mentioned** benefits, the study appears to be useful to ports sector. The results of the short-term measures are based on the pilot study



undertaken for **one-year** time span. For more sustainable solutions and comprehensive conclusions, the R&D project may be extended for a longer time span.

- Besides the longer time span for sustainable solutions the consultant can further explain the reasons for achieving the navigational depth with lesser quantity of dredging. As this explanation might bring out the root cause of the siltation in the channel in a new perspective.
- It is pertinent to mention here that it is assumed that the Port authorities have adequately taken measures with regards to the requirements of the marine biology in terms of the monitoring marine life before and after the trials and the necessary statutory requirements met in terms of disposing the dredge material at various locations in the river/ shore/ offshore. This is an important requirement for both short and **long-term** Environmental implications in the Estuary.
- While it has been rightly recommended to use Multi Beam Echo Sounder with approximately 10 m line spacing as it will give **quicker** and higher resolution Bathymetry surveys compared to the Single Echo Sounder with approximately 100 m line spacing. It is understood that the Surveying techniques **are** the backbone for the dredging activity control and this is an important take-away from this study.
- The Tendering Contract for the Dredging has been adequately addressed in this study report and is also an important output which can be tried out I the other Ports with adequate modifications to cater to their conditions.
- **A** Very elaborate Morphological Stability analysis has been carried out and reported for the existing sailing route and the proposed new route. It is very important to mention here that this is very specific to the Hooghly estuary and cannot be replicated. This is a topic **that** is to be addressed by different ports based on their specific issues and their morphology. No two ports will have **the** same Morphology. Stability Analysis studies are highly specific to the location.
- Dredge Management Plan has been amply explained, criteria made and Plan developed based on the criteria and the Field Trials. This too is specific to the Estuary, the Navigational Depth needs, Siltation issues during various seasons, given Bathymetry, disposal locations (On Shore, Off Shore, Side Cast disposal)and the available dredgers and the techniques to be followed. This too



is highly specific and cannot be implemented in other Ports directly. The idea and the principle can be adopted.

- It can be strongly concluded that this study can be a guiding document for other Ports to develop **their dredging** strategy for their maintenance dredging/ Capital dredging and cannot be implemented in toto. Some of the dredging techniques (Side Cast) discussed for this Port can be looked into studied and tried before attempting implementation in their Ports. The Side Cast dredge disposal too has its **Pros** and **Cons**.
- As it is supposedly **an** R&D project, true to its title it has done necessary trials and arrived at results worth implementation, which are however specific to the Hooghly estuary. The outcomes cannot be replicated but methodology can be tried in other Ports.



3.2. Long Term Measures for the Improvement of Draft in Hooghly Estuary

3.2.1 Background of the R&D Project

The annual maintenance dredging at Haldia Dock Complex has been a concerning issue to the Haldia Port as the amount of dredging is one of the highest among the major ports in India. Despite the long navigational channel of about 145 kms from Sagar Island to Kolkata, there has been a gradual decrease in navigational depths due to morphological changes in Hooghly Estuary. Large spatial dimensions of the estuary and the sediment transport make it difficult to plan as well as execute the River Regulatory Measures (RRM) meant to improve the drafts in **the** navigational channel.

The study of Long-Term Measures was undertaken to explore the possibility of establishing a new shipping route that would cut across Nayachara Island to Haldia Dock Complex. The study comprises of developing a reliable mathematical model that would facilitate predicting the behaviour of Hooghly Estuary. This required **study of** hydrodynamic and morphological aspects like bathymetry survey and field data at different locations for bed-load and suspended samples on **an** extensive level. Using the model, various hydrodynamic and morphological features were examined at various alternative channels cutting across Nayachara Island.

Eight alignments were modelled for which the simulations were examined considering various parameters like CRZ regulations, size of vessels, siltation etc. Following this, Alignment number VIII was selected for the shipping route across Nayachara. After deliberations between consortium parties, it also helped conclude that two-way navigation is possible requiring a channel base width of 600m. Necessary protective measures were designed for the dykes (from wave action in **the** Rangfalla side) and navigation channel side bank. Since Nayachara Island is newly formed, its seismic and dynamic conditions were analysed. Based on the standard stability analysis criteria and FEM analysis, the designs have been found stable.

3.2.2 Objective of the Study

The objectives for **the** Long Term Measures that are identified by KoPT are as follows:-

1. To avoid the existing inconvenient routes of Auckland and Jellingham channel that have a likelihood to suffer from high rates of sedimentation.



2. To investigate the potential for opening a new channel that connects Haldia Dock with Rangafalla (eastern side of Hooghly estuary). This study would comprise of hydrodynamic modelling, ship navigation studies, siltation studies and desk studies.
3. To open and operationalise a single channel between Haldia and Kolkata that constitutes recommended measures with less maintenance dredging and improved depth.

3.2.3 Timeline of the Study

The project meant to determine the location of **the** navigational channel had set certain tasks to be accomplished during the course of the project over a span of one year.

They are as follows:-

- I. Field investigation in order to acquire data pertaining to bathymetry, hydraulic and geo-technical aspects.
- II. Determining hydrodynamic modelling to achieve precision (approx zero value to minimize through flows) between two ends of the channel.
- III. In order to determine the hydraulic alignment, the project involves studying the land use pattern and setting up the design of the channel.
- IV. Navigational study considering the entry/exit of the channel.
- V. Determining the design of channel **based on the** operation mode, ship size, one/two-way transportation.
- VI. Sediment Transportation Modelling to analyse the siltation and to determine infill rate at different stretches of **the** channel.
- VII. Designing measures for bank and dykes protection at both ends of the channel as well as for dredging and its disposal.
- VIII. Projecting the estimated cost of the project.



3.2.4 Deliverables

In order to successfully achieve the project objectives, certain deliverables are outlined as follows:-

- I) A comprehensive review of all data available and an appraisal of the reports prepared by LHI and HR Wallingford on RRM.
- II) Extracting the needful information from the data/reports to generate a conceptual “model” of the estuary. This helps in understanding the critical behavior of the estuary to operationalize and sustain the scheme.
- III) Considering all the possible solutions to determine the most feasible channel cut through the mathematical model.
- IV) Seeking experts’ advice from HR Wallingford to ensure that any proposed solutions are viable for smooth navigation.
- V) Assessing the sediment and siltation transportation to Haldia Oil Jetties and entry/exits etc.
- VI) Determining the requirement of capital and maintenance dredging in the channel over Nayachara Island.
- VII) Determining the requirement for maintenance dredging to maintain a suitable channel depth to Haldia through Nayachara Island and Kolkata.
- VIII) Assessment of Geo-Technical stability of the recommended channel, dykes/ training measures on entry and exit in Rangafala / Haldia side.
- IX) Preparing a Detail Project Report (DPR) outlining the implementation schedule and the estimated cost of the project.
- X) Indicating the approach opted for the Long-Term Measures and advantages associated with it as against multiple/possible scenarios for the vessel leading to Haldia and Kolkata.

3.2.5 Findings from the Report

Based on the analysis for Long-Term Measures for the Improvement of Draft in Hooghly Estuary, following are the findings that have been derived from the report:-

- As per various investigations undertaken by the consortium parties, it has been concluded that the most suitable (natural) alternative shipping channel route is



through the Rangafalla channel where almost 80 to 85 percent of the flood discharge are passing through as per the latest observation by KoPT.

- Calibration of the Hydrodynamic model MIKE -21 is a part of the main study since it is with respect to real-time data of tidal elevation, currents and its orientation, suspended sediment load at the selected location and their appropriate simulation in the model post the quality assessment carried out primarily by HR Wallingford.
- Following the criteria proposed by HR Wallingford with negligible head loss for the tidal flow within the channel cut and investigating to find out feasible alignment, the hydrodynamic studies indicated that a substantial amount of flow will be diverted through the channel cut across Nayachara to Haldia channel.
- The report concludes that the cut no. VIII is the most suitable of all channel cuts. This conclusion was reached after thorough examination of various parameters such as approach angle, physical and topographical condition, tidal prism volume exchange, duration of peak discharge, deposition within the channel etc. The investigation was carried out through hydrodynamic model.
- The report expounds detailed analysis comprising of navigational channel design on criteria like bed width, depth and side slope. The report also substantiates stability analysis of the channel embankment after the completion of the structural design of the channel where the soil characteristics have been under due consideration. Soil characteristics have been investigated through borehole samples taken along the navigational channel route profile.
- Theoretical analysis to assess the bank stability was carried out. It constituted conventional as well as sophisticated Finite Element Method (FEM) analysis for both static and dynamic consideration. Analysis pertaining to Settlement and liquefaction has also been carried out to be incorporated in the design of the embankment. The result from this suggests that under various flow conditions, the dyke and channel sections are stable both in un-drained and drained conditions.
- Taking into the consideration, maximum possible wave height and breaking on the slope, bank protection of the dyke section has accordingly been provided. Examination of the channel side slope has been done and geo-textile cover with geo-bags filled with sand over the clay layer has been provided.



- Report lays down the max vessel size that would be operated in the channel along with channel bathymetry. This was established with the help of navigation simulation studies through hydrodynamic model data (current, orientation, spring tidal range).
- The report on the basis of the data furnished by CWPRS, Pune and after necessary simulation studies by HR Wallingford suggests that only one-way traffic movement is possible for a channel having bed width of 350m and for a two-way simulation, the width of the channel needs to be of the order of 600m.
- Based on the sedimentation studied by CWPRS of the new navigation channel route the total quantum of maintenance dredging that will be required will be of the order of 12Mm^3 . The breakdown is follows:
 - Channel portion – 4.229Mm^3
 - Haldia side approach- 2.762Mm^3
 - Auckland to Rangafalla – 4.985Mm^3
- The report indicates the feasibility of two-way navigation with the proposed channel with 600m base width and various operating conditions. In an unlikely situation, it was not made known to WAPOCOS and HR Wallingford that KoPT wants a two-way shipping channel for the project to be a viable alternative against the existing route. Through deliberations, an additional two-way simulation involving channel bed width of 600m has been agreed to be carried out by HR Wallingford despite an additional cost burden to WAPCOS.
- On the basis of final channel dimension of 600m base width and associated measurements, the total project cost including civil construction and other ancillary works has been estimated to be of the order of Rs. 3480 Crore, including contingency, PMC etc. charges.
- The exchange of a substantial tidal prism volume both flood and ebb across the channel from Rangafalla to Haldia side and vice versa is a significant finding of the investigation.
- The report suggests a precautionary investigation into the expected morphological changes that are most likely to occur in the Hooghly estuary as a result of the implementation of the present project.
- It is recommended to undertake a physical model study of the flow exchange to the channel cut in Haldia and Rangafalla side.



- The report mentions the tentative quantum of the maintenance dredging. The report suggests to carry out appropriate hydrological survey of the new channel once it come into operation to assess actual siltation.
- The provision of the proposed channel through Nayachara is likely to bring down the annual maintenance dredging quantity to 12 Mm³ as against the present annual maintenance dredging of 18Mm³ for the route through Auckland and Jellingham.
- With regard to the timeline envisaged for implementation of long term measure, the report states that the construction of the new channel would entail two and a half years and additional 6 months for commissioning of channel trial.

3.2.6 Deliverable v/s Outcome

S. No.	Deliverables	Outcomes
1.	A comprehensive review of all data available and an appraisal of the reports prepared by LHI and HR Wallingford on RRM	<p>The appraisal of the reports prepared by LHI concluded that the implementation of research outcome based on the suggestions is possible only with consent of the concerned port trust. It is suggested to have a task-force committee to oversee such a research outcome is at least tested at pilot-scale project level for its success.</p> <p>Subsequently, HR Wallingford suggested short-term and long-term measures for implementation by KoPT after proper studies.</p>
2.	Extracting the needful information from the data/reports to generate a conceptual “model” of the estuary.	<p>The data base pertaining to topographic survey, bathymetric survey, tide data and current etc. were qualitatively analyzed in the report. A conceptual model for estuary to be able to explore feasible alignment of the channel.</p> <p>The mathematical model studies in connection with the Long-Term Measures for the improvement of draft in the Hooghly estuary were undertaken by CWPRS. For</p>



S. No.	Deliverables	Outcomes
		<p>most feasible alignment, the proposed cut across Nayachara Island was proposed to be taken based on the 2D hydrodynamic model simulations initially. The 2D mathematical model was setup to adequately cover the area of interest and utilizing the field data after careful quality assessment. On the advice of M/s HR Wallingford the model calibration was also undertaken to the best possible extent along with statistical analysis of the quality of match between the observed and computed water levels and currents for some locations inside the model domain.</p>
3.	<p>Considering all the possible solutions so as to determine the most feasible channel cut through mathematical model.</p>	<p>Three alternative alignments were chosen for the initial hypothesis for deciding the alignment of cut to achieve minimal currents in the proposed channel to have reduced siltation and maintenance dredging.</p> <p>The results of 2D hydrodynamic model simulations for the above three alternatives were presented to the TAC. After detailed discussions, it was opined by KoPT that pilotage of ships across the proposed cuts especially at the entry and exit points needs to be aligned with proper angle with the flood and ebb flow conditions in the Rangafalla and Jellingham Channels. Therefore, it was recommended that all the proposed cuts selected by WAPCOS - HR Wallingford – CWPRS for testing in the mathematical model must proceed with the concurrence of the Director, Marine Department (DMD) of KoPT.</p>
4.	<p>Seeking for experts' advice from HR Wallingford to ensure that any proposed solutions are viable for smooth navigation.</p>	<p>The experts from HR Wallingford were engaged and involved during the entire span of project during the execution of Long-Term Measures.</p>
5.	<p>Assessment of siltation and sediment transport in the channel</p>	<p>A preliminary simulation of the sediment transport model was initially carried out for both the Cuts V and VIII to assess the</p>



S. No.	Deliverables	Outcomes
	including entry, exit and approach channel leading to Haldia Oil Jetties, lock entrance etc.	relative merit of these cuts in terms of likely siltation and maintenance dredging requirement. Since adequate data were not available for calibration of the model this was used to relatively assess the potential shoaling rates for the two alternative cuts. The simulations indicated that the Cut VIII will have 20% more siltation compared to Cut V. The HD simulation data of Cut VIII was forwarded to HR Wallingford for carrying out the Ship Simulation Studies.
6.	Requirement of capital and maintenance dredging in the channel over Nayachara Island including approach.	The quantity of capital and maintenance dredging in the Nayachara Island has been specified in the report. The total capital dredging will be about 57.5 million m ³ . And maintenance dredging will be about 12 million m ³ . The methodology for dredging has also been elaborated using large cutter suction dredger (CSD)
7.	Assessment of overall requirement of maintenance dredging in KoPT for maintaining shipping channel depth leading to Haldia through Nayachara Island (as per long term measures) and Kolkata.	
8.	Assessment of Geo-Technical stability of the recommended channel, dykes/ training measures on entry and exit in Rangafala / Haldia side.	A separate detailed report on the stability test of dyke embankment through the proposed navigational channel across Nayachara Island has been provided. This stability study has been executed by the Indian Institute of Engineering Science and Technology, Shibpur. The report includes seismicity of the project site, liquefaction analysis, lateral spreading, slope stability analysis, settlement, uplift and quality monitoring scheme based on the data made available to the institute.
9.	Preparing a Detail Project Report (DPR) outlining the implementation schedule, estimated cost of the project.	The DPR has been prepared specifying the dredging plan, capital and maintenance dredging quantity, dredging methodology, choice of dredgers and project cost estimate including estimation of dredging and



S. No.	Deliverables	Outcomes
		<p>reclamation, dyke, embankment, utilities, navigational aids etc. The project implementation schedule has also been laid down in the report highlighting the main construction elements to be implemented.</p> <p>This report also clearly indicates the advantage of the implementation of Long-Term Measures analyzing multiple scenarios as may be possible for maneuvering of vessels leading to Haldia and Kolkata.</p>

3.2.7. Usefulness of R&D Project for Port Sector

- True to the title of this study report “Measures for improvement of Draft in the Hooghly Estuary” Long Term measures; the objectives have been met. It is pertinent to mention that this study report is exclusive to the Hooghly Estuary and the outcome cannot be used for any other Port. Any Port which needs to carry on with their business will have to carry out capital dredging, start Port operations and carry out maintenance dredging as per the need in that location. The Port will have to carry out the necessary Hydro morphology Studies, Siltation/ Sedimentation issues, bathymetry studies and the dredging techniques to be adopted.
- It is important to mention here that the KoPT will carry out the Marine Environment Impact Assessment and get the necessary statutory approval. It will accordingly have an Environment Management Plan in place to address the environmental issues especially with regards to the marine environment.
- This study report and its conclusions cannot be used in toto for any other Port.
- The project on Short-term as well as Long-Term Measures has given insight into the method of side-casting and also useful in reducing the quantum of dredging due to effective dredging technology. It is also noted that the morphology of the river bed has undergone changes.
- However, it is worth mentioning that ideas and principles beneath the studies carried out could be studied by other Port authorities.

Chapter – 4

ASSESSMENT OF R&D PROJECT-3: “Studies on Siltation and Optimal Ameliorative Measures at Cochin Port”



Chapter 4

ASSESSMENT OF R&D PROJECT-3:

Studies on Siltation and Optimal Ameliorative Measures at Cochin Port

4.1 Background of the R&D project

Cochin Port's plan to carry out a nautical depth study aimed at reducing the recurring dredging expenses has received the Shipping Ministry's approval. The Ministry has approved a grant of ₹10 crore s for studies on siltation and optimal ameliorative measures in which it will bear 50 per cent and the balance by the port.

It is for the first time that a major Indian port is going ahead with a nautical depth dredging, a concept that is in use in most of the Riverine ports in Europe like Netherlands, Belgium, Germany etc. A senior port official said that the new study would help the port to implement this new concept. Once implemented, it would reduce the depth to be dredged alongside cutting down maintenance dredging costs to about 30 per cent.

According to the report, Cochin port has a muddy bottom, unlike most other Indian ports that have a hard one. The Indian National Hydrographic Organization had prescribed 10 per cent under keel clearance for dredging, which was increasing the dredging quantity as well as expenditure incurred on it.

However, most of the European ports with muddy bottoms are carrying out shipping operations under keel clearance based on a study to fix the navigable density of fluid mud. It helped reducing dredging quantities and expenditure. As per the existing standards, Cochin Port has to dredge 10 per cent more than the draft of the ship to ensure proper clearance without hitting the bottom. In riverine ports like Kochi, the channel bottom is made up of either loose clay or sand. Therefore, dredging was required only five per cent more than the draft of the ship. The water injection method used in riverine ports required for dredging wherein water is pumped at high pressure to the bottom of the channel. The clay and sand at the bottom get stirred up in the process enabling vessels to sail through the suspended particles without getting stuck.



If the port is successful in curtailing the dredging expenses, the official pointed out that it would be a big achievement and beneficial in the long run. **The high and recurring dredging expense is denting port's revenue coercing the management to doll out ₹170 crores last year, especially with the commissioning of the Vallarpadam container terminal.**

The project on siltation and optimal ameliorative was sanctioned by Ministry at a cost of Rs. 10.75 crores with 50% sharing with Cochin Port Trust (CPT) on 01.12.2014. **It was for the first time that a major Indian port is going ahead with a nautical depth dredging.**

4.2 Objective of the R&D Project

The main objective of this study was to find ways and means to reduce and manage the high siltation in the navigation channels at Cochin port **and** recommend parameters for **the** implementation of a nautical depth concept.

The major components of the study were:

- Comprehensive field data collection.
- Conduct numerical hydrodynamic model studies.
- Set up and validate a nautical simulation model.
- Determination of a nautical depth criterion, establishing a monitoring method and recommend a dredging strategy.

The **scope** of the **assignment included but was not** limited to the following:

- i) Hydrodynamics - studies on **the** tide, wave and current.
- ii) Estimation of maintenance dredging quantity through Mathematical modelling.
- iii) Mathematical model studies for siltation pattern and measures for minimizing siltation.
- iv) Rheological studies on mud silt accumulated in the channel.
- v) Establishing **the** feasibility of adopting nautical depth concept for navigation in the Port channels and deriving instrumentation to monitor the density suitable **for safe navigation. Taking the length of navigation, vessel size and type expected to call at the Port into consideration.**
- vi) Duration of dredging and optimising dredging quantity.



- vii) Suitability of providing silt trap at selected locations for reducing siltation.
- viii) **Possibility** of beneficial use of dredged material (Beach nourishment! reclaiming the areas/other applications).
- ix) Possibilities of using water injection method or other advanced technology in maintenance dredging in the Port Channels.

4.3. Timeline

The project timeline proposed is **18 months** from the start of work.

4.4. Deliverables

The detailed study covered under the different heads of above shall generally be as below.

- i) Hydrodynamics: **To conduct study for wave and tide effects, sediment characteristics, sediment transport studies and estimation of siltation in the channels leading to measures for reduction in siltation.**
- ii) Estimation of maintenance dredging quantity through Mathematical modelling: **Finding out morphological changes in the channels through Mathematical modelling leading to estimation of maintenance dredging quantity.**
- iii) Mathematical model studies for siltation pattern and measures for minimizing siltation: **Undertaking study of siltation to ascertain its causes and ways to reduce it.**
- iv) Rheological studies on mud silt accumulated in the channel: **To measure rheological parameters, shear strength and viscosity in order to account for environmental and local conditions defining the true Nautical Depth and navigability.**
- v) Establishing **the** feasibility of adopting **the** nautical depth concept for navigation in Cochin Port Channels: **To establish the acceptable frequency of theecho sounder to be used for implementing Nautical depth for navigation in Cochin Port Channels.**
- vi) Period of dredging and Optimizing dredging quantity: **Cost optimization through operational controls and mobilisation of additional dredger capacity on case to case basis.**
- vii) Suitability of providing silt trap at selected locations for reducing siltation: **Studying impact of silt traps in arresting siltation.**
- viii) Possibility of beneficial use of dredged material: **To find the possibility of beneficial use of dredged material available from the maintenance dredging along with assessing environmental impact and suggesting mitigation measures for the same.**



- ix) Possibilities of using water Injection or other advanced technology in maintenance dredging in Cochin Port Channels: **Assessing the dredging effectiveness using WID dredging subjected to maintain the turbidity at acceptable pre-specified levels.**

4.5. Finding of the R&D Project

- i) Project conclusively recommends on ameliorative measures for optimizing the dredging cost at Cochin Port.
- ii) Alternate dredge disposal site has been suggested.
- iii) The findings of the project give a nod to the implementation of nautical Depth Concept. This approach takes the rheological properties of the fluid mud into account and their effects on safe navigation. At present, port accessibility is determined by echo sounding, which is an unsuitable methodology in case of fluid mud conditions. This is because with echosounding only the presence and thickness of fluid mud layers can be determined.
- iv) The siltation in the Cochin harbour is coming from sea-side. At least sea contributes 95 % of the siltation quantities at the Cochin Port. One of the causes of siltation in the channel/berth basin is the formation of eddies and subsequent deposition of the sediment. At the onset of monsoon, the siltation starts in outer channel and then it is also occurring in the inner harbour, especially in the ICTT. In the Ernakulam and Mattancherry channels, the siltation is significantly lower than the other harbour zones.
- v) The report discovers that siltation is mainly confined to the monsoon. Siltation processes were analyzed in detail by means of dredging volumes, bathymetry and SILAS profiles in combination with rheological monitoring.
- vi) The report recommends to adopt Tonnage Dry Matter Formula instead of the one that is in current practice. In Cochin dredging volume is reported at the overestimation of 400%. The quantity of maintenance dredging has been estimated through mathematical modelling.
- vii) Field survey, laboratory tests, simulation studies are suggested for determining dredging needs.
- viii) Based on the findings of the nautical simulations, the nautical depth criterion for Cochin can be defined as the most shallow depth of the following safety limits: 1. Maximum penetration of the mud-water interface with 12% of the ship's draft; 2. Minimal under keel clearance of 10% of the ship's draft above the solid bottom. and



3. Density of the fluid mud lower than 1170 kg/m³ (corresponding to acceptable level of mud yield strength)
- ix) The report states that the dredging quantities should be same as the siltation quantities. As per the report, the siltation volume of 23 million m³ was occurred in Cochin Port during the duration of the project.
- x) The project suggests employing methods to arrest siltation which may include construction of entrance structures to reduce water exchange and change in flow pattern etc.
- xi) The TELEMAC-MASCARET suite was used for the numerical modeling of the wave, hydrodynamics and sediment transport processes in the area of Port Cochin. Three components of the suit were used for the simulations, i.e. TELEMAC2D, TOMAWAC and SISYPHE, which were coupled in order to reproduce the physical processes associated to the siltation process in the study area.
- xii) EBP system, Dual frequency 200/24 kHz transducers, Silas Software, Acquisition and Processing density and RheoTune are recommended to fix the nautical bottom.
- xiii) The project suggests measures which could be opted for optimizing the dredging cost at Cochin Port.
- xiv) It makes recommendations to adopt nautical depth concept, the implementation schedule for the suggested measures and financial implications etc.
- xv) The report does not reflect on the possible usage of dredged material.
- xvi) The report suggests the rheological monitoring of different harbours in Cochin overtime. The rheological acquisition and data interpretation are needed to study the potential shift to higher densities for dedicated harbour areas and period of the year.
- xvii) The findings delineate required echo sounder characteristics and settings.
- xviii) Better suited locations and/or tide dependant disposal strategies has been suggested.

4.6 Outcomes vs Deliverable

S.No	Deliverables	Outcomes
1.	Hydrodynamics: Studies on tide, wave, current etc. of Cochin Port, entrance channel and Cochin backwaters for wave and tide effects, SSC, sediment transport studies, estimation of siltation in	The report substantiates extensive monitoring campaign that was undertaken w.r.t. to the following: Wave and current data at two offshore locations by means of bottom mount ADCPs.



S.No	Deliverables	Outcomes
	the channels and remedial measures for reducing siltation.	<ul style="list-style-type: none"> • Current data at Cochin Gut by means of horizontal ADCPs. • Current data at upstream river branches by means of bottom mount ADCPs. • Discharge data at Cochin Gut and upstream river branches by means of mobile vessel mount ADCP measurements over full neap and spring tidal cycles that can be correlated to the current measurements. • Water quality data (salinity, temperature, turbidity, sediment concentration) at multiple locations and three depths for all tidal phases and seasons. • Wind data for onshore and offshore location. • Tide data. • Monthly bathymetric surveys. • Monthly beach profiles North and South of Cochin. • Seismic bottom profiling (SILAS) of the fluid mud layers combined with Rheotune measurements of its rheological properties over the different seasons. • Bed samples before and after Monsoon for grain size analysis. • Monsoon discharge at 10 locations along the backwater system. • Ad hoc measurements (e.g. high frequent suspended sediment sampling) needed for siltation analysis. • Monthly dredging volumes for different harbour zones. • Information on design vessels and typical ship maneuvers in Cochin port. <p>Siltation processes were analyzed in detail by means of dredging volumes, bathymetry and SILAS profiles in combination with rheological monitoring. Siltation is mainly confined to the Monsoon season.</p>
2.	Estimation of maintenance	The quantity of maintenance dredging has



S.No	Deliverables	Outcomes
	dredging quantity through Mathematical modeling to find out morphological changes occurred in the channels	been estimated through mathematical modeling. As per the report, currently an improper dredging formula is applied in Cochin causing an overestimation of the current dredging volumes up to 400%, depending on the in-situ porosity shifting to the Total Dry Matter formula in the silty conditions of Cochin port has been recommended. The report states more than 20 million m ³ of material is dredged in the Cochin harbour.
3.	Mathematical model studies for siltation pattern and measures for minimizing silt	<p>The TELEMAC-MASCARET suite was used for the numerical modeling of the wave, hydrodynamics and sediment transport processes in the area of Port Cochin. Three components of the suit were used for the simulations, i.e. TELEMAC2D, TOMAWAC and SISYPHE, which were coupled in order to reproduce the physical processes associated to the siltation process in the study area.</p> <p>Wave modeling was executed in two main steps: the simulation of a Regional Wave Model (200x500km) and the simulation of a Local Wave Model (25km radius). The results of the regional model served as boundary conditions for the local model. Wave modeling was able to reproduce, qualitatively and quantitatively, the observed wave activity in the area of Port Cochin.</p> <p>The model developed qualitatively reproduced the observed sedimentation patterns. In quantitative terms, the calculated sedimentation is acceptable, reaching values of about the same order of magnitude of the observed sedimentation.</p>
4.	Rheological studies on mud silt accumulated in the channel, its	The report states that current surveying strategies do not into take account



S.No	Deliverables	Outcomes
	<p>parameters, shear strength, viscosity and yield strength values that are capable of accurately defining the true Nautical Depth, a different dredging strategy for the handling of maintenance dredging works.</p>	<p>rheological properties (mud strength). Thorough rheological monitoring of the different harbour zones over time of Cochin Port is suggested in the report. As per the report, the rheological acquisition and data interpretation is needed to study the potential shift to higher densities, for dedicated harbour areas and periods of the year.</p> <p>During this research project a portable RheoTunewas used for this purpose which measures the density and yield stress. It is lowered in the fluid mud and gives an accurate reading on the location where the device is lowered. The usage of RheoTune led to:-</p> <ul style="list-style-type: none"> • More accurate detection of the fluid mud package (both top and bottom). • Recording the full signal gives possibility for data and quality control and gives indication of the nature of the fluid mud. • Rheological information on the fluid mud (density and yield stress) within the area. • Detect problem areas before ships may encounter difficulties.
5.	<p>Establishing feasibility of adopting nautical depth concept for navigation in Cochin Port Channels.</p>	<p>Nautical simulations were performed at the Flanders Hydraulics Research facilities in Belgium to determine nautical depth criteria for Cochin Port. More than 50 simulations were performed in different mud conditions and level of mud penetrations. The feasibility of each scenario was evaluated by the feedback of the pilots and with objective criteria such as required tug assistance, engine and rudder application, etc. According to the information available from nautical simulations, the densities larger than 1170 kg/m³ the mud strength</p>



S.No	Deliverables	Outcomes
		<p>is too large to guarantee safe ship navigation.</p> <p>The implementation of Nautical Depth Criteria was backed by a significant amount of scientific research including monitoring campaigns, data processing and interpretation, numerical modeling and nautical modeling.</p> <p>To summarize, the nautical depth criterion for Cochin can be defined as the mostshallow depth of the following safety limits:</p> <ul style="list-style-type: none"> i) Maximum penetration of the mud-water interface with 12% of the ship's draft. ii) Minimal under keel clearance of 10% of the ship's draft above the solid bottom. iii) Density of the fluid mud lower than 1170 kg/mm³ (corresponding to acceptable level of mud yield strength).
6.	<p>Period of dredging and Optimizing dredging quantity, managing increased siltation, mobilization of additional dredger capacity on case to case basis.</p>	<p>The report details on the aspects of :-</p> <ul style="list-style-type: none"> i) Siltation phenomena in the Cochin Harbour. ii) Estimating the silt transport capacity parameter and quantity of silt iii) Maintenance dredging to be carried: a) during the monsoon period; b) post monsoon period after consolidation of silt and; c) dredging throughout the year. iv) Capacity of Dredger to be deployed for maintaining the channels to -, the required depth: <ul style="list-style-type: none"> a) during the monsoon period; b) post monsoon period after consolidation of silt and; c) dredging throughout the year. <p>The report states that the dredging quantities should are same as the siltation quantities. As per the report, the siltation volume of 23 million m³ was occurred in Cochin Port during the duration of the project, which implies that dredging over the span of one year was 23 million m³.</p>



S.No	Deliverables	Outcomes
		<p>With regard to management of siltation, the report suggests the following engineering solutions:-</p> <p>Methods to keep sediment out (KSO)</p> <ul style="list-style-type: none"> • Methods to keep sediment moving (KSM) • Methods to keep sediment navigable (KSN). • Methods to remove sediment after it has deposited in the port (RS). <p>These engineering solutions are specific to each port and cannot be prescribed without a systematic study along with pilot tests because the amount/pattern of siltation in a harbor is affected by the physical and environmental conditions.</p>
7.	Suitability of providing silt trap at selected locations for reducing siltation	<p>Siltation processes were analyzed in detail by means of dredging volumes, bathymetry and SILAS profiles in combination with rheological monitoring. The report states that in the Ernakulam and Mattancherry channels, the siltation is significantly lower than the other harbour zones.</p> <p>The outer channel, especially the near-shore part with shallow surrounding coastal area, as well as the LNG and ICTT basins act as effective sediment traps. Due to continuous dredging to remove the siltation in these zones, attempting to maintain necessary depths for navigation, their high sediment trapping efficiency is maintained. These sediment traps limit the sediment influx from upstream in the harbour. Only the fine sand is able to reach the port because the current velocities are very high there and settling of these very fine particles is most likely limited. The report suggests the measure of creating sediment trap upstream i.e., catching sediment before it reaches the sensitive area for</p>



S.No	Deliverables	Outcomes
		<p>reducing shoaling in harbours and navigational channel and also preventing sediment deposition.</p> <p>The implementation of a sediment trap in Cochin was considered in this study. When a river is the main source of sediment in a harbour, installing a sediment trap upstream can be an efficient measure against siltation. Sediment traps can also be a strategic choice: by focusing siltation in the trap area, the other zones are not only less subject to siltation, but also the interference of dredgers with the commercial ship traffic is reduced. The sediment trap can be installed by means of capital dredging.</p>
8.	Possibility of beneficial use of dredged material	While the report comprehensively addresses the aspects of dredging strategies, techniques, practices, types etc. The deliberation regarding the possible use of dredged material has not been reflected in the report.
9.	Possibilities of using water Injection or other advanced technology in maintenance dredging in Cochin Port Channels	The report discusses various agitation dredging, plough or sweep beam dredging, auger dredging, air injection dredging and water injection dredging etc. for maintenance dredging. WID is a dredging technique that concerns transport of sediment from one placeto another through the creation of a density current near the bottom by water jetting the mud. Application of WID to remove the deposited sediment from the port of Cochin is restricted by specific conditions and topography of the harbour. The report highlights that WID technique would probably not be successful in removing sediments from the inner harbour. towards the outer channel and subsequently open-sea.



S.No	Deliverables	Outcomes

4.7 Contribution by the Project

This study is a starting point, a benchmark for the port of Cochin. Safe nautical depth criteria have been determined, can be monitored and dredging strategies can be adjusted to maintain nautical depths that are sufficient for the drafts of ships accessing the harbour zones. Implementation is strongly recommended but needs to be performed with care, i.e., extensive monitoring and evaluation. Multiple options are already revealed for further optimization of the nautical depth criteria. New findings and experiences will lead to further ideas and potential improvement. This study is a scientific base and well-founded starting point. There is an interesting and challenging road ahead. Experiences in North-West European ports have shown significant safety and economic benefits after decades of dedicated research efforts.

4.8 Usefulness of the R&D project in the Port Sector

Research will lead to both safety and economic benefits to CoPT. The current study should thus be seen as a starting point from which optimization research/experiments strive towards economic benefits while safe navigation remains the top priority.

This Research & Development Project has tried out a new concept called **Nautical Depth** criteria and Draft of Ships entering the Port which is a new concept in Indian Ports.

Nautical Depth is the depth of soft mud below the water level of density 1.025 t/m³, which can be used for safe Navigation of Vessels. Although Cochin Port has been using Nautical depth concept for Navigation of Vessels based on extensive field knowledge and practical experience of Pilots, this practice was going on without any scientific studies. Thus, the practice followed by the Port in carrying out the dredging has been scientifically established through this study. Now based on the recommendations of the study, action has been taken to partially adopt the concept on trial basis in the outer channel from the chainage 2000m to 13150m by reducing the depth to be maintained from 16.70m to 15.90 and from 17.40m to 15.90m. and expected saving of dredging quantity on this account is about 5 M. Cum.



As per the report, the estimated annual maintenance dredging is 18 Mm³ and an amount of Rs. 150 crs. per annum is borne on it which stands at 32 % of the total operational cost.

CoPT reports that after the implementation of Nautical Dredging Concept, the maintenance dredging quantity would reduce by 5 Mm³ i.e., annually the maintenance dredging quantity that CoPT would have to dredge shall reduce to 13 Mm³.

Considering 150 crores is currently being incurred for dredging 18 Mm³, a reduction in dredging volume by 5 Mm³ may lead to substantial saving of more than 25 %.

Nautical Dredging Concept has however been tried and tested and in practice in some North West European Ports. This could be achieved after sustained research and trials. This method cannot be implemented directly in other Ports as the Siltation quality/ sediment properties differ from Port to Port. Acquisition of proper monitoring equipment for monitoring of the Nautical Depth and establishing the **same is required**. Dredging needs to be done depending on the Nautical **Depth** and the Draft of the Ships which call on the Cochin Port. A very detailed study **along** the same lines as this research study needs to be carried out before taking a call on this concept of Nautical Depth Criteria. It was suggested that Cochin Port Trust should abandon using the sand in-situ volume calculation method and shift to the Tonnage Dry Matter (TDM) matter which is the proper formula for cohesive sediment. This way, important overestimations of the dredging volumes are avoided. A TDM-based payment method could be applied in dredging contracts. This option may be tried in other Ports after due studies ascertaining the siltation/ sedimentation and discussions with the Dredging contractors.

The principle and the basic knowledge that has been gained from this research study can be utilized for other Ports, especially the sediment particle and its characteristics. The learning from this study includes the Nautical Depth criteria and its applicability for the respective ports, the Rheological Sampling and the Bathymetry Surveying using more advanced Technology.

4.9 Outcome of the R&D Project

The need for dredging will need to be determined based on the nautical depth criteria via the suggested monitoring methods. As compared to dredging the port with the current dredging techniques, i.e. conventional TSHD, to maintain a nautical depth



sufficient for the design vessels, the application above will most probably result in a reduction of dredging requirements and costs. This can be explained by the combination of mud conditioning, which is a relatively cheap method, and sediment removal with higher dredging densities near the solid bottom. It is impossible to predict the benefits of the proposed techniques at this stage.

It is worth noting that the density of the fluid mud is not the same, i.e. lower, than the density of the dredged material. Therefore, siltation volumes would be underestimated if set equal to dredging volumes. The current formula in use is only suitable for the calculation of dredged volume of sand. In fluid mud conditions (fine, silty material), such as Cochin, the formula above is not applicable. In silty environment it is not the dredged volume that is determined, but the Tonnage Dry Matter, TDM (ton). The dredging volumes in Cochin are currently being overestimated with a factor 1.7 to 4.

As discussed above, COPT should abandon using the sand in-situ volume calculation method and shift to the Tonnage Dry Matter (TDM) matter which is the proper formula for cohesive sediment. This way, important overestimations of the dredging volumes are avoided.

A TDM-based payment method could be applied in dredging contracts, while the requirement should be the maintenance of the nautical depth to allow ships with design drafts.

As reported by CoPT, the project has been implemented in Cochin Port channels especially at outer channel from the chainage 2000m to 13150m by reducing the depth to be maintained from 16.70m to 15.90m and from 17.40m to 15.90m.

Adoption of nautical depth concept as per the study carried out would, in the short term, require investments in acquisition of the survey equipment and additional expenditure in dredging to meet the conditions required for nautical depth.

Given the financial condition of the Port, it was not possible to take on additional expenditure for dredging and it was decided to continue the existing practice for a period of time till the financial situation of the Port improves sufficiently to be able to spend more on account of dredging.

NTCPWC, i.e. IIT Madras, the Technological arm of MoPS&W, has been entrusted with monitoring of maintenance dredging in the Port channels and basins in the years 2018-19, 2019-20 and 2020-21. Monitoring for successful implementation of recommendations of Nautical depth study as well as further optimisation is also being done through IIT Madras.

Chapter – 5

ASSESSMENT OF R&D PROJECT-4: “Comprehensive Analysis of Siltation Behaviour: Kandla Port”



Chapter 5

ASSESSMENT OF R&D PROJECT-4:

Comprehensive Analysis of Siltation Behaviour: Kandla Port

5.1 Background

The Port of Kandla (lately renamed as Deendayal Port) is situated in the Gulf of Kutch on the north-western coast of the Indian subcontinent. It was the first port to have been developed soon after Independence in order to ease the volume of trade on Mumbai Port. Considering the volume of trade and the vessel movements, Kandla Port witnesses an extreme amount of sediment accumulation. This poses a great concern for the harbour authorities to put together a solution that reduces the siltation and simultaneously eases the expenditure incurred for the same.

The project had been outlined to analyse the siltation behaviour and devise strategies to reduce the quantity of maintenance dredging in the channel. These strategies helped in identifying appropriate engineered solutions to reduce the siltation and the cost for it. A three-way approach was outlined to undertake this comprehensive study. This included initial field visits to observe certain parameters, combinations of numerical modelling and remote sensing analysis using satellite imageries. Initial field visits to the site were undertaken so as to gather engineering parameters pertaining to hydro-morpho-dynamics of the region. Besides the volume of data collected over past decades by DPT, vital information like Pre- and Post-Monsoon seasonal and tidal conditions were observed and Suspended Sediment Concentration (SSC) was enumerated at various locations during the analysis. Followed by this, a numerical model was designed using Delft3D, a software tool. The validation of the estimates from numerical simulations was checked if in accordance with the siltation indices from DPT. Once a high confidence interval was established from the analysis, porous barriers (acting like silt curtain) were placed along the side of the navigational channel and proven to have reduced the siltation by 46-56 percent in the Kandla Port. These barriers have global credibility to act as an effective siltation stopper.



5.2 Objective of the Study

The Comprehensive Analysis of the Siltation Behaviour has primarily been commenced to analyse the environmental conditions that are naturally directed to influence the siltation behaviour at the Kandla Port and suggest appropriate solutions to reduce the maintenance dredging and the cost associated with it. This study calls for investigating engineered solutions after analysing the hydrodynamic and morphological information from the region. The observations are intended to be incorporated in the numerical modelling which will help in designing a suitable management system. Through numerical modelling and remote sensing techniques, maintenance dredging at the Kandla Port is intended to be minimised.

5.3 Timeline of the Study

Comprehensive Analysis of the Siltation Behaviour for Kandla Port was sanctioned with the designated cost of Rs. 90.77 lac on 13.04.2017 and the project completed in November, 2019.

5.4 Deliverables

The deliverables of the project are as follows:

1. In-situ field measurements of tides, currents and waves near approach channel and Suspended Sediment Concentration (SSC) at various locations.
2. Development of port specific numerical model for the estimation of hydrodynamics and siltation dynamics.
3. Finding the characteristics of suspended sediment concentration and bed load sediment.
4. Calibration and validation of numerical model results of tidal hydrodynamics using the field measured data.
5. Calibration and validation of numerical model results of siltation behaviour, using Deendayal Port supplied bathymetry data.
6. Develop an algorithm for Remote Sensing to estimate SSC, validate the same using in-situ measurements and prepare maps for the temporal and spatial distribution of SSC.



7. Based on above **the** analysis, recommend suitable sediment management system for Deendayal Port.

5.5 Findings from the Report

Through the comprehensive study that is conducted to analyse the siltation pattern in the navigational channel of Kandla Port, a few predominant findings have been enlisted in the following section. The study has been titled as comprehensive for its cohesive 3-way approach comprising field visits to the site, devising a numerical model and remote sensing analysis through satellite imageries.

- i) The Gulf of Kutch is characterised **by** high tidal range and currents where the elevation has peaked to a maximum of 6.6m. As has been recorded from the field measurements and modelling, the maximum current velocity **is** 1.2m/s (inside creek) and 1.6m/s (outside creek).
- ii) The sediment characteristics have been found, from SSC contour maps, to vary with time as well as place. The maximum SSC measures at three different locations have been found as:-
 - 340 mg/l for bottom
 - 440 mg/l for middle
 - 390 mg/l for surface
- iii) From the SSC contour findings, it has been recorded that throughout the water column, SSC values are high and uniform. **So**, the recommended turbidity curtain should extend from **the** water surface to the seabed to protect the entire water column.
- iv) Having observed the turbulent eddies at the mouth of Kandla Creek which are responsible to cause erosion and deposition, it has been found that the suspended particles settle down after a certain distance that depends entirely on the tidal currents. This settling down after a range causes siltation in the navigational channel.



- v) It has been observed that the morphological changes predicted by the model were sensitive to the two most significant transport parameters that have been incorporated in the model viz- bed-load (f_{bed}) and suspended load (f_{sus}).
- vi) Long-term morphological changes are significantly determined by the grain size. Grain size analysis facilitates obtaining accurate D_{50} values for different regions before implementing engineered solutions. For example, an increase in the value of D_{50} from 100 μm to 200 μm led to a reduction in the rate of siltation.
- vii) In the navigational channel, sensitivity has been identified especially Zone 1 and maximum deposition has been predicted upto 1.4m by the model.
- viii) As has been estimated from the developed numerical model, changing the alignment of the navigational channel does not give a favourable solution to the siltation issue.
- ix) Use of silt/ turbidity curtains (porous plate) placed on the adjacent sides of the navigational channel for the given alignment has been found to have reduced the siltation by approximately 46-56 percent.
- x) The practical and effective solution so far has been the (porous) silt curtains which are made of the permeable screen allowing water and current movements with minimal sediment passage.
- xi) The report suggests that the use of silt curtains can arrest siltation by 50 %.

5.6 Deliverables Vs Outcomes

S. No.	Deliverables	Outcomes
1.	In-situ field measurements	Surface samples of the water were collected through in-situ measurements. For this Gooch filtration method was adopted. Observed values of TSM found to lie between 100-500mg/l. On a particular day i.e 19.12.18, TSM values were higher between 400-800mg/l. From the images, it could be seen that there was a gradual decrease in TSM from west to east.



S. No.	Deliverables	Outcomes
2.	Development of numerical model for the estimation of hydrodynamics and siltation dynamics.	Numerical modelling was carried out using Delft3D model. For modelling of hydrodynamics, the Delft3D-Flow Model was utilized, which is a multi-dimensional (2D or 3D) hydrodynamic program which calculates non-steady flow that results from tidal and meteorological forces.
3.	Characteristics of Suspended Sediment Concentration (SSC)	<ul style="list-style-type: none"> • SSC is generally transported at the same velocity as the surrounding fluid. The stronger the flow and finer the sediment, the greater the amount of sediment that can be suspended by turbulence. • Only the finer fraction (silt/clay) of SSC can be continuously maintained in suspension by the flow turbulence, known as wash-load Its concentration is usually related to sediment supply and is difficult to determine theoretically. • Bed-material load are the ones that are not continuously suspended but are continuously settled through the fluid and may return to bed. • Analysis of SSC using OCM and model simulation shows entire northern region exhibits higher SSC as compared to southern during months of March, April, November, December. • In central part, SSC comes in suspension because of high tidal current.
4.	Validation of numerical model results: field data	(PG 133 OF REPORT : 3 VALIDATION figures) The figures shown in the report depict sedimentation pattern as predicted by the model for February, May, September and December. Maximum deposition upto 1.4m and maximum erosion upto 2.8m in September. Through these four months, volume of deposition has been recorded and compared in the report.
5.	Validation of numerical model results : bathymetric data	(PG 126 OF REPORT : 3 VALIDATION figures) The developed model has been simulated for 31 days from 01/12/18 to 31/12/18. The estimated water levels, velocity and directions were extracted at three locations from model output.



S. No.	Deliverables	Outcomes																				
6.	Algorithm for Remote Sensing to estimate SSC, validate the same using in-situ measurements and prepare maps.	<p>(PG 123 OF REPORT : 4 maps)</p> <p>Using the Niskin water sampler, surface samples of water were collected throughout the in-situ measurement campaign. For analyzing the collected water samples for SSC, Gooch filtration method was adopted which is a standardized methodology. The results obtained from linear model were compared with algorithm proposed by Miller and McKee (2004) :-</p> <p>TSM= -1.91 + 1140.25* (MODIS band 1 Reflectance)</p> <table border="1"> <thead> <tr> <th>Date</th> <th>No. of Valid depth points</th> <th>Linear Algorithm based RMSE (mg/l)</th> <th>Miller and McKee algorithm RMSE (mg/l)</th> </tr> </thead> <tbody> <tr> <td>18.12.18</td> <td>21</td> <td>57.85</td> <td>117.9</td> </tr> <tr> <td>19.12.18</td> <td>7</td> <td>201.6</td> <td>119</td> </tr> <tr> <td>20.12.18</td> <td>5</td> <td>82.99</td> <td>112.3</td> </tr> <tr> <td>25.12.18</td> <td>36</td> <td>84.03</td> <td>215.5</td> </tr> </tbody> </table>	Date	No. of Valid depth points	Linear Algorithm based RMSE (mg/l)	Miller and McKee algorithm RMSE (mg/l)	18.12.18	21	57.85	117.9	19.12.18	7	201.6	119	20.12.18	5	82.99	112.3	25.12.18	36	84.03	215.5
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7.	Recommend suitable sediment management system for Deendayal Port.	<p>Since this is a comprehensive analysis, the effective solution to mitigate the problem is by using a silt curtain along a navigational channel with the alignment. Silt/Turbidity curtains are permeable vertical barriers that extend from water surface to a specified depth or till seabed to minimize the movement of silt. A flexible silt curtain consisting of hypalon was used in one of the naval basins along Mare Island Strait and reportedly reduced the siltation rate by 70 percent.</p>																				

5.7 NPC Observations on the R&D report

- The project has completed all the research components through a systematic and comprehensive analysis of the physical condition and an optimised engineering solution of providing silt-curtain is also proposed for minimizing the siltation and thereby cost of maintenance dredging in Kandla port navigational channel. The implementation of any pilot-scale testing of the proposal is in its nascent stage.
- Under the R&D project, the executing agency has:-
 - Collected the measured bathymetries for numerical model development and to assess the siltation quantities.



- Collected field data of tidal levels, currents and SSC for pre- as well as post-monsoon.
 - Studied mesh generation, calibration & validation and estimation of hydrodynamics.
 - Developed algorithm for extraction of SSC from satellite imageries.
 - Tested variety of silt-curtain options and a final solution to minimize the siltation by more than 50 percent is suggested.
- Upon interacting with the executing agency, it came to notice that certain logistical, natural and time challenges were faced by them. The challenges were curbed after receiving good logistical support by DPT (providing boats/vessels etc) ; proper planning of field measurements campaigns to avoid any equipment or data loss and by adopting appropriate project management team.
- Implementation of research outcome based suggestions is possible only with consent of concerned port trust. It is suggested to have a task-force committee to oversee such a research outcome is at least tested at pilot-scale project level for its success.
- Sediments Characteristics vary from place to place and also varies with time. In this case study the SSC values were high and equivalent throughout the water column. After extensive modelling for numerous alignments and different structures, the use of silt curtain (Porous Plate) on the adjacent sides of the navigation channel was found to be effective leading to reduced siltation by approximately 46 to 54%. While this seems to have worked for these conditions in the Navigation Channel, the results cannot be adopted in the other Ports. This study has however opened up the opportunities for other Ports to follow suit by carrying out the various studies as done in this Port/ Navigation Channel. This outcome is a trial of numerous combinations of situations for the given Navigation Channel Alignment, Tides, Currents, Wave characteristics, Sediment Characteristics and the other marine conditions.
- It may be noted that this is a physical obstruction adjacent to the Navigational Channel and will have objections from the fishermen community in the locality as this may hinder their movement. It is not known from the given study report if



the fish mobility and its implications has been studied. The implications on the Marine Diversity too is not evidenced in the study report.

- It is desirable that the study be shared with the Coastal Zone Authority and further studies on the Marine Environment be carried out if found essential by the CRZ.

5.8 Usefulness of R&D Project for Port Sector

This R&D project is a very unique research study for the port sector which has been accomplished by virtue of field studies as well as usage of advanced numerical models like Delft3D. Such studies widen the horizon of R&D as it involves creative, meticulous and diligent approach to execute the task. The following three achievements of this R&D project can be categorically utilized by port sector for forthcoming port projects.

- **Development of numerical model, validated with field measurements:**

The hydro-morpho-dynamics of the entire region of Gulf of Kutch with special emphasis to Kandla creek is captured, which will be great use for any future development port & harbor infrastructure

- **Development of algorithm for Satellite imageries, validated with comprehensive field data collection of SSC:**

In future, mapping of SSC in the entire Kandla creek region can easily be obtained from satellite imagery snap-shots.

- **Engineering Solution to minimize siltation quantity along the Navigational Channel:**

Use of silt curtains to minimize siltation quantity shall subsequently reduce the cost of maintenance dredging activities in Kandla port.

Chapter – 6

R&D PROJECTS IN-PROGRESS



Chapter 6

R&D Projects in-Progress

6.1 Preparation of Guidelines for the use of Geo-Synthetics in Ports

6.1.1 Background

Special measures are required to control the water and enhance the resistance against hydraulic effects in order to preserve the beneficial uses irrigation and navigation. The special measures need designing of suitable materials and reliable execution in accordance. In many such cases, a combined use of geo-synthetics can support as well as improve the functionality to attain the desired results. Geo-synthetics are equipped to provide strength, flexibility, robustness and durability of the controlled measures. Considering the advantages of geo-synthetics in Ports, Coasts and Waterways, MoSPW has entrusted Indian Institute of Technology Madras to prepare guidelines that shall prove to be useful to academia, research and companies from manufacturing sector.

6.1.2 Scope of Work

- To prepare guidelines for the use of geo-synthetics in the construction of marine embankments and road in ports, geo-tube containment structures for disposed materials from dredging, offshore submerged reef using geo-tubes and gabions and erosion control structures in coasts and waterways.
- The guidelines shall be useful to the academia, port engineers, port consultants, construction companies and members from manufacturing companies.

6.1.3 Deliverables

The deliverables which have been given by JSW are as follows:-

- Review the geo-synthetics projects executed in India and abroad and to also document the details.



- Prepare guidelines for the pavements, shore protection, submerged reef and retaining wall for berths.
- Prepare construction methodology

6.1.4 Timelines

The period of contract was **two months** starting 24.01.2019 onwards.

6.2 Utility Of High Strength Self-Compacting Alkali Activated Slag Concrete (Hs-Sc-Aasc) Filled Steel Tubes In Enhancement Of Strength And Durability In Ports, Harbour And Offshore Structures

6.2.1 Background

All across the world, construction industry has adopted for Ordinary Portland Cement (OPC) as the primary constituent for the reinforced concrete. This has been used for marine as well as normal construction. However, due to chemical actions of the sulphate and chloride ions in water, it poses detrimental effect to the concrete structure. Consequently, with the passage of time, performance and strength of concrete reduces substantially. Considering these shortcomings, High Strength Self-Compacting Alkali Activated Slag Concrete (HS-SC-AASC) had been planned to enhance the strength and durability of structures. Alkali Activated Slag Concrete are known to give superior durability than OPC concrete. Aim of this research project is experimental and analytical study of structural and damage behavior of High Strength Self-Compacting Alkali Activated Slag Concrete (HS-SC-AASC) filled steel tubular columns subjected to compressive loading. The different materials planned to be used in this study are product and waste product of steel industry. The products are Steel tubes and plates and waste products are Ground Granulated Blast Furnace Slag (GGBFS), Blast Furnace Slag (BFS) sand and Electric Arc Furnace (EAF) Slag.

Through the study of the project, experimental and numerical investigations were undertaken. As proposed, analytical investigation was carried out by using a Finite Element model using ABAQUS software. Proper frictional coefficient and proper meshing technique were proposed so as to avoid errors in the analysis. The proposed



model and results obtained from it to be verified by comparing its results with the experimental results.

6.2.2 Objectives of the R&D Project

The research work planned for Utility Of High Strength Self-Compacting Alkali Activated Slag Concrete would be helpful in finding solutions for the following:

- Disposal of blast furnace slag and electric arc furnace slag from the steel industry which is an environmental issue.
- By using the steel industry waste products in the concrete, we can reduce 60-80 percent CO₂ emission in to the atmosphere.
- Replacing the natural materials (e.g. fine and coarse aggregate) by using the waste product of steel industries in the concrete can save natural aggregates.
- By using the steel tubes filled concrete at the place of concrete elements, increase the concrete confinement, so concrete members are able to take more loads along with the improvement in durability in marine region.
- Concrete filled steel tubular members will be useful in construction as compression member in port and jetties with improved durability.
- Outcomes of the present research work can be shared with the constructional firms for use of steel industry waste product in concrete in construction of different structure in Ports, Harbours and marine environment

6.2.3 Deliverables of the R&D Project

- Development of High Strength, Self-Compacting, Alkali Activated Slag Concrete (HS-SC-AASC) Mixes with different constituent parameters suitable for marine construction.
- Micro structural study of alkali activated slag hydration and the experimental investigation of mechanical properties of Alkali Activated Slag Concrete (AASC) at micro scale.
- Study of Mechanical properties and durability behavior of HS-SC-AASC Mixes suitable for marine construction.
- Study the behavior of HS-SC-AASC filled steel tubes subjected to compressive loading suitable for port construction.



- Finite Element Analysis of HS-SC-AASC filled steel tubes with compressive loading to verify the experimental test results.

6.2.4 Timelines

The duration of the project is **two years** starting October, 2020 onwards which is divided over 6 phases in terms of execution.

- Phase I involves literature survey of AASC filled steel tubes structural member subjected to impact loading and preparation of mix design by trials-and-error method will be adopted to develop HS-SC-AASC mixes with the different combinations of parameters at many levels.
- Phase II includes procurement of materials, cutting, finishing of steel tubes and plates, testing for properties of raw materials that is used in the research work including the micro structural analysis of raw materials.
- Phase III is mixing and casting of concrete filled steel tube specimens for all the mixes will be performed in this phase. Tests for fresh concrete properties and mechanical properties of hardened concrete including durability of HS-SC-AASC mixes.
- Phase IV includes testing trials for HS-SC-AASC filled steel tube specimens, with and without stiffeners, subjected to different types of loading.
- Phase V is modifying and scaling up, if results are not coming as expected.
- Phase VI includes numerical simulation by using 3D-FEM in ABAQUS after which all the results will be analyzed and final report shall be prepared.

6.3 Observations

While the reports/any information pertaining to the ongoing R&D projects were not available with NPC, the thematic areas considered seem to be very relevant and possibly useful for the port sector. The proposal and terms of reference for both the ongoing R&D projects, i.e “guidelines for usage of geosynthetics in Ports, Coasts & waterways” and “Utility of high strength self-compacting Alkali activated slag concrete filled steel tubes in enhancement of strength & durability of ports, harbours and offshore structures” are very comprehensive and methodology proposed is potentially appropriate. The outcomes of these projects will enable the port sector with robust infrastructure and other requirements.

Chapter – 7

COMPOSITE OBSERVATIONS AND RECOMMENDATIONS



Chapter 7

Composite Observations and Recommendations

7.1 Prelude

The Research & Development Scheme for Port Sector that has been initiated to develop infrastructure for Port Sector with the objective to carry out Research in the Port and Harbour Sector to find solution for field problems in formulation, design and execution of Harbour Projects. Consequent to the evaluation of the scheme carried out by NPC on the basis of R&D projects submitted by project proponents and feedback from stakeholders, the composite observations in terms of outcome of the implementation of the scheme and recommendations thereof have been enumerated in the following paragraphs.

7.2 Use of Dredged Material during Maintenance Dredging in the Hooghly Estuary in Kolkata Port Trust. Study by M/s RITES

While it is appreciated for the effort having been put by the consultant in arriving at the conclusions and recommendations, there are some concern areas that needs to be tied up for effective utilization of dredged material, i.e. using the dredged material in brick making, road making, land filling/ land reclamation etc. Further, the environmental impacts of such usages too need to be included in the study.

7.3 Implementation of Pilot Project in connection with Short-Term and Long Term measures for improvement of draft in the Hooghly estuary by WAPCOS Ltd. in association with HR Walling Ford, UK and CWPRS, Pune in Kolkata Port Trust.

7.3.1 Short Term Measures

- This R&D project, true to its title has done necessary trials and arrived at results worth implementation, which are however specific to the Hooghly Estuary and



cannot be replicated in other Ports. It has study outcomes which are commendable and with little adaptation can be tried in other Ports.

- It can be strongly concluded that this study can be a guiding document for other Ports to develop their own dredging strategy for their maintenance dredging/capital dredging. Some of the dredging techniques (Side Cast) discussed for this Port can be looked into, studied and tried before attempting implementation in other Ports.
- It has been recommended to use Multi Beam Echo Sounder with approximately 10m line spacing as it will give more quicker and higher resolution Bathymetry surveys compared to the Single Echo Sounder with approximately 100m line spacing. It is understood that the Surveying techniques is the backbone for the dredging activity control and this is an important takeaway from this study.
- Dredge Management Plan has been amply explained and Plan has been developed based on the criteria and the Field Trials. The Navigational Depth needs, Siltation issues during various seasons, given Bathymetry, disposal locations (On Shore, Off Shore, Side Cast disposal) and the available dredgers and the techniques to be followed are highly specific to Hooghly estuary and cannot be implemented in other Ports directly. The idea and the principle can be adopted for other ports.

7.3.2 Long Term Measures

- The objectives of Long term Measures have been met as the report substantiates the necessary way forward for making an alternate channel for navigation, the dredging Plan, Dredge Disposal and weighing the pros and cons of the new Channel after having studied various options.

7.4 Studies on siltation and optimal ameliorative measures at Cochin Port

- This Research & Development Project has tried out a new Concept called as Nautical Depth criteria and Draft of Ships entering the Port which is a new concept in Indian Ports. This has however been tried and tested and in practice in some North West European Ports. This could be achieved after sustained research and trials. This concept can be a good start for the Indian Ports to



adopt and carry out necessary studies with respect to their sediment characteristics etc. to adopt this concept.

- The report suggests that Cochin Port Trust should abandon using the sand in-situ volume calculation method and shift to the Tonnage Dry Matter (TDM) which is the proper formula for cohesive sediment. This way, important overestimations of the dredging volumes are avoided. A TDM-based payment method could be applied in dredging contracts. This is a very innovative suggestion and will lead to substantial savings on the Dredging cost.
- The suggestion of a more technologically advanced sampling and surveying is a good suggestion an important takeaway from this study.

7.5 Comprehensive Analysis of Siltation Behaviour for the Deendayal Port Trust

- The report exhibits extensive modelling and trial of numerous alignments, use of Silt Curtains (Porous Plate) was proposed on the adjacent sides of the navigation channel. It was found to be effective leading to reduced siltation by approximately 46 to 54 percent.
- This is a good lead and other Ports can consider this option for trials and to reduce the issue of Siltation.

7.6 Way Forward

While evaluating the six R&D reports of Port sector, it was observed that each report is significant in its own unique way and is beneficial to the Port in particular and with further studies and adaptation measures can be useful to the other Ports. Such R&D projects should be taken up regularly. While approving the R&D Projects it is suggested that a component of Environment Impact Assessment too be included as these exercises will have a direct impact on the Marine Bio Diversity/ Terrestrial Environment. Few of the suggested domains for new R&D projects or extension of the above Projects is given below.

1. **Dredged material and its reuse;** though the toxicity/ chemical analysis of the material will vary slightly, atleast the outcomes will give an idea for the other Ports to follow suit.



2. **Methodology of measuring dredging material** and paying the dredging contractor for the dredging material disposal accordingly (Cochin Port Trust Study). The scope of Cochin Port Trust study can be stretched to a more general mode (by carrying out the same monitoring exercise in one or two more Ports) and shared with the other Ports. The other Ports can adapt the outcome to their conditions.
3. **Methodology of measuring the Navigational Depths and the development of Low cost Instrumentation or alternate methods.**
4. **Fast and accurate Bathymetry studies** have added to the efficiency of Dredging (Short Term measures, KoPT study report). This may be tried in one or two more Ports and shared with other Ports for their adoption.
5. **A study to arrive at General Measures for forestalling siltation/ sedimentation** as this is a common issue with all the Ports. However it may be noted that the conditions are different in each and every Port.
6. **Pilot studies for Sand Washing of dredged soil from SMP Kolkata Shipping Channels:** This study may benefit in terms of re-use of dredged material for filling in the low-lying areas and for other construction purposes. Further, the 100% removal of dredged materials permanently from the system may lead to reduction of annual dredging volume in the long-run.
7. **Comprehensive assessment of siltation of other major ports that spends sizable funds towards maintenance dredging:** The minimization of expenditure incurred towards maintenance dredging could subsequently be used for infrastructural development.
8. **Conditional assessment of port/marine/ harbour infrastructure:** As most of the ports' infrastructures are decades old, comprehensive conditional assessment could assist informed decision-making by the government for any up-gradation of retro-fitting required based on understanding of the actual site-conditions.



- 9. Adaptation of Life-cycle management of port structures:** This may be carried out through technically sound maintenance/strategies, performance grading through frequent inspections, comprehensive analysis and implementation of any counter measurements. This scheme maybe implemented for all major ports infrastructure through institutional programs.
- 10. Proposed Silt Curtains (adjacent to Kandla Port Navigation Channel).** In continuation to this a study to ensure that these silt curtains do not disturb the Marine Bi Diversity and to ameliorate the same.
- 11. R&D in the Ports to develop alternate sources of Energy using their infrastructure/ space such as the Break waters etc.**
- 12. Ports must transform their operations to make their activities more sustainable.** Strategies to increase energy efficiencies, reduce carbon footprint, reduce water footprint and manage their wastes prudently (including dredge material). A study can be approved on these lines in one Port and a guideline document produced for the other Ports to follow suit. Baseline studies on these lines should be initiated with targets to be met in the long run.
- 13. A study on those Ports which are under performing or are not in a position to expand.** In such cases new Ports where the challenges being faced now can be addressed can be designed and relocated. A balance between the costs incurred now and the cost of establishing a new Port can be worked out.
- 14. A study on providing Shore side Power and its Expansion to provide for all the ship sizes.** With this the Ships main and auxiliary Power is turned off. This will help in reducing the carbon emissions and noise pollution. (This is practiced in some Airports for the Aircrafts)
- 15. Integrate the marine side research so as to arrive at solutions which will enrich the Marine Bio Diversity including Fish production while aiming to improve the efficiencies of the Port Operations on the Marine front.**



7.7 Conclusions

In view of the evaluation study conducted by NPC, and in consideration of the reports and information shared by the project proponents/Ministry during discussion and through questionnaire survey it is indicative that the R&D projects are finding solution for field problems in formulation, design and execution of harbour projects.

The conclusions in the reports have been reached after thorough implementation of field trials and backed by different modelling algorithms, tools and estimation. The underlying methods, latest tools and techniques of estimations, algorithms and methodologies employed in the studies undertaken could be further adopted as a reference for future studies and the standardisation of these latest techniques should be brought under consideration.

Furthermore, it is noteworthy that the aspects of the research should be broadened in order to address environmental and ecological impacts along with siltation and dredging disposal problem that has been primarily taken up in these studies.

After the perusal of the above conclusions, it is notable that the “Research and Development Scheme for Ports Sector” is achieving its outlined objective to a considerable extent. The scheme may therefore be continued for implementation with adequate measures in line with the improvements suggested.

7.8 Recommendations

In the light of above conclusions and evaluation undertaken, National Productivity Council makes the following recommendations:

- Considering the unique takeaways, it is prudent and recommended to undertake more of such research studies and come out with effective as



well as creative solutions for common problems being faced by port sector.

- It is recommended that Ministry may consider constituting a panel of R&D experts (national as well as international) for carrying out such studies from which the Port can select their consultants for the study, on competitive bidding process.
- Being mindful of toxicity being a major aspect with regard to usage of dredged material; it is imperative and thus recommended to immediately undertake R&D study for this.
- It is extremely important that the outcomes of various R&D studies are shared for flow of information. In order to materialize the same, it is recommended that separate dash board may be developed.
- The stakeholders are recommended to lay down the procedure and guidelines for selection of researchers / executing agencies of the most efficient agency for the work under consideration.
- It is imperative and thus recommended that the research should be peer reviewed by the experts in the field so that outcomes could be better implemented.
- While these studies are of R&D nature, it is seen that that the studies are carried out for long duration such as even 12 to 24 months and some of the activities are of irreversible nature. It is therefore recommended that Marine Impacts be considered and necessary ameliorative actions be included in the study. The recommendation of the R&D study should necessary list the likely Environmental impacts and importance of management of the same.



ANNEXURE

Annexure - 1

QUESTIONNAIRE



QUESTIONNAIRE

National Productivity Council (NPC) under DPIIT, Ministry of Commerce & Industry, Government of India, is undertaking “**Evaluation of Central Sector Scheme on R&D Scheme for Port Sector**” implemented by the **Ministry of Ports, Shipping & Waterways, Government of India**. The evaluation study would focus on the outcome of the scheme vis-à-vis the objective outlined in the research project, specific areas/components where the project has been successfully implemented and the opportunities for improvement, the targets set and achievements against the backdrop of the plan of operations and the base line status at inception of the project, contribution made by the research work and usefulness for the ports sector for continuation of the scheme. Based on your feedback/suggestions, NPC would recommend necessary improvements/modifications for effective implementation of the R&D projects.

The information/data provided would be kept as confidential and would be utilized solely for the study purposes only.

A.	GENERAL INFORMATION			
	Name of the Institution / Organisation	:		
	Address of communication	:		
	Telephone & Mobile No.	:		
	E-mail ID	:		
	Contact Person	:		
	Mobile No.	:		
	E-mail ID	:		
B.	R&D PROJECT INFORMATION			
	Name of the project	:		
	Approved Project Location	:		
	Duration of the project	:		
	Commencement Date	:		
	Completion Date	:		
	If not completed, project status as on date	:		
C.	PROJECT DELIVERABLES			
	Project's Deliverables/ Set Targets`	Timeline	Achievements	Whether timely delivered (Yes/No)? If no, reasons thereof



D.	PROJECT'S USEFULNESS/BENEFITS	
	Usefulness/Benefits	Scale of benefit and impact
E.	CHALLENGES FACED IN IMPLEMENTATION OF THE R&D PROJECT	
	Types of Challenges	Technique to overcome
F.	Please suggests what kind of projects should be undertaken in the near future?	
	Types of Project	Expected Benefit
		Suggested interventions from Government
G.	Challenges including the social challenges being faced in implementation of the project.	
H.	Specific suggestions/feedback on improvement of existing implementation procedures.	
I.	Please share specific areas/components where the project has been successfully implemented.	

Thank you!!

If you have any clarifications, please contact the person below:

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