Guidelines for Preparation Of Coastal Engineering Hydraulic Study And Impact Evaluation

(For Hydraulic Studies Using Numerical Models)

Fifth Edition
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Jabatan Pengairan dan Saliran
Malaysia

Foreword

This publication is intended to assist the consultant and the developer in carrying out a thorough coastal hydraulic study and impact assessment. The proper assessment of impacts will contribute towards 'informed decision making' that will in the long term negate the necessity for expensive mitigation measures to overcome any adverse impacts.

These guidelines will also be used as a basis in evaluating the hydraulic reports that are submitted to DID in accordance with *Garispanduan JPS 1/97* and *Surat Pekeliling Am Bil. 5 Tahun 1987* (General Administrative Circular No 5 of 1987), as well as EIA reports on coastal development projects that are referred to DID by the Department of Environment. Apart from providing broad guidelines for hydraulic studies and impact assessment, this publication is also intended to promote greater transparency on the needs of the Department, so that it will be possible for the consultants and developers to expedite the preparation of the relevant reports according to the requirements.

These guidelines have been produced with the collective effort from various Government Departments, Universities, Institutes and Consultants. I would like to take this opportunity to thank and congratulate all those involved in the production of this document.

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Preface

Coastal hydraulic studies need to be carried out by consultants / developers who are proposing to carry out development works in the coastal area that could cause environmental impacts, as outlined in '*Garispanduan JPS 1/97 – Garispanduan Kawalan Hakisan Berikutan Dari Pembangunan Di Kawasan Pantai*'. In addition, the coastal hydraulic studies for coastal development works that require mandatory preparation of Environmental Impact Assessment (EIA) under the Environment Quality Act 1987, shall form part of the EIA.

These guidelines have been prepared by the Coastal Engineering Division (CED), Department of Irrigation and Drainage Malaysia (DID) in order to serve as a guide for all the consultants / developers who are carrying out coastal hydraulic studies using numerical models to fulfill the abovementioned requirements. These guidelines are also intended to assist the hydraulic modeler in determining the various technical aspects that need to be included or assessed in the hydraulic study. This is to promote greater transparency on the needs and requirements of the Department in relation to coastal hydraulic modeling. However, these guidelines should be perceived solely as a ***guide***. Therefore the user may use their discretion and engineering judgment to differ from the recommendations of these guidelines for particular cases, giving the relevant justifications for their choice subject to the agreement of the DID.

This is the fifth edition of the guidelines that was first prepared in 1997. This revised edition shall supercede all the earlier editions issued in and before May 1999. The main changes that are incorporated in this edition are related to the following :

a) Requirements for using software other than the established models
b) Additional information on data input
c) Scenarios and conditions for simulation of the various modules
d) Types of impacts and their assessments
e) Presentation of results

With these additions, it is hoped that the hydraulic study shall be conducted in a more comprehensive manner, covering all the possible scenarios so that the model predictions are more representative of the actual conditions.

Acknowledgements

These guidelines were prepared with the cooperation of various *Government Departments / Agencies, Universities,* and *Consultants* who are involved in coastal engineering as well as in the assessment of coastal impacts.

Feedback on the preparation of the guidelines were received through written comments, informal discussions and from formal meetings. Two formal meetings were held to discuss in detail the various issues, i.e. in February and July 2001 at the DID Office in Kuala Lumpur.

These guidelines were finalised in September 2001 after due consideration to all the comments received from the various parties. In this regard, the DID would like to acknowledge the various *Government Departments / Agencies, Universities*, and *Consultants* for their valuable contributions and cooperation in the preparation of these guidelines.

Contents

1. Introduction

Hydraulic studies need to be carried out for various types of development projects in the coastal zone in order to assess their potential impacts to the environment and to formulate mitigative measures to overcome these impacts. The types of development projects in the coastal zone, which require hydraulic studies to be carried out, are as outlined in '*Garispanduan JPS 1/97 – Garispanduan Kawalan Hakisan Berikutan Dari Pembangunan Di Kawasan Pantai*'. The present guidelines are to complement the above-mentioned guidelines on the use of numerical models for coastal hydraulic studies. The intention is to set up general criteria and standards so as to streamline the coastal studies carried out by various consultants.

2. Components of a Coastal Hydraulic Model

Usually the coastal hydraulic model consists of a suite of modules, each of which is used to simulate particular coastal processes. The common modules that are widely used in assessing the impacts of a particular development are:

a) Nearshore Wave Module

   This module is used to transform deepsea waves to the nearshore waves considering the various transformation processes such as refraction, shoaling and wave breaking.

b) Hydrodynamic Module

   This module is used to simulate the water level variations and current velocities induced by a variety of forcing functions such as tides, waves and wind. This module forms the basis for carrying out other coastal processes such as advection/dispersion and mud/sand transport.

c) Advection / Dispersion and/or Water Quality Module

   This module simulates the spreading of suspended material, dispersion of thermal effluent and other pollutants. This will indicate the extent and intensity of the impacts.

d) Mud/Sand Transport Module

   This module simulates the erosion or sedimentation pattern in the affected areas. By comparing the 'before' and 'after' project cases it will be possible to identify areas with increased erosion or siltation.

e) Sediment Budget and Shoreline Evolution Module

This module computes the shoreline budget and simulates the shoreline evolution. This can be used to identify shoreline areas with potential erosion and simulate the potential shoreline evolution.

3. Selection of Model

The coastal hydraulic computer model to be used must be carefully selected. The chosen model shall be of a type that has been well proven and tested.

If a relatively new or generally unrecognised software is proposed, then sufficient information pertaining to the organisation which developed the software, records of actual applications in other studies, theoretical equations used in the model as well as the mathematical techniques used in the solution shall be furnished for evaluation. The new model shall also be tested against other more established models, and the results submitted for evaluation. The decision on the acceptance of the new model will be decided by DID based on the evaluation of all the information that has been supplied.

4. Model Set Up

Most modeling works are carried out using two levels (or sometimes three levels) of models i.e., coarse grid model and fine grid model. The coarse grid model uses a large grid spacing (in the order of 1 km depending on the size of the area to be modelled). The grid spacing in the fine grid model is very important because it determines the accuracy of the output. The fine grid spacing shall generally be less than 50 m.[1]

If there are any estuaries, which need to be modelled, the fine grid spacing shall not be more than ¼ of the width of the river mouth. For modeling the impacts due to coastal structures, the grid size shall also not be more than ¼ of the length of the structure.

For the fine grid model the outer boundary of the model shall be sufficiently far away from the project area so that they will not introduce any inaccuracies in the project area. The area of interest shall generally be at least 50-grid spacing away from the model boundary. Another condition is that the boundary shall not fall on or be adjacent to river mouth areas as this will introduce inaccuracies unless detailed information regarding current and sediment flow from the river is available. The coordinates of the selected model boundaries together with the location of the project shall be submitted to DID in MRSO coordinates.

[1] If there are any particular reasons for adopting a higher grid spacing, the modeler is invited to have a prior discussion with the DID.

5. Data Requirements

Data requirements differ with the type of modules used. Therefore it is necessary to initially identify the various modules that will be utilized in a particular hydraulic study and to subsequently identify all the data required in the simulations using these modules. The required data may be obtained from primary or secondary sources. The following sections briefly describe the data requirements for some of the modules.

5.1 Types of Data Required For Various Modules

5.1.1 Data For Nearshore Wave Module

The data required for this module are the deepwater wave characteristics and the bathymetry of the area.

a) WAVE DATA

The deepwater wave characteristics for this module can be obtained from established databases, hindcasting techniques or other reliable sources such as satellite data or wave atlas. If the data is in the form of raw data then these data may be processed as follows :

i) Carry out a statistical analysis of all the incident deepwater waves from all the possible directions to determine the deepwater wave characteristics in the area. The results of this analysis shall be presented in the form of annual and seasonal wind rose diagrams and/or in the form of tables
ii) Carry out wave transformations of the deepwater waves to determine the nearshore wave characteristics

Whereas if a hindcasting technique is used, then the following analysis may be carried out : -

i) Obtain offshore wind rose diagram
ii) Determine the critical fetch lengths
iii) Employ suitable hindcasting techniques to determine the deepwater wave characteristics
iv) Carry out wave transformations to determine the nearshore wave characteristics.

b) *BATHYMETRY DATA*

The bathymetry for the modelling works is normally obtained from the Admiralty Charts for the deep-sea areas while a bathymetry survey is carried out for the nearshore areas (fine grid model area). The grid spacing of the bathymetry survey for the fine grid area shall not exceed twice the fine grid size. The survey data shall be processed in MRSO coordinates and reduced to Land Survey Datum. The bathymetry data that has been tabulated under the relevant fields such as Northing, Easting and Depth shall be prepared in digital form in plain ASCII format and submitted to the DID.

5.1.2 Data For Hydrodynamic Module

The basic data required for the hydrodynamic module are tides, waves, wind and bathymetry. The same bathymetry data that was used for the Nearshore wave module can be used for this module. The output from the Nearshore wave module which is in the form of nearshore wave field can be used as the input for this module The tidal and wind data for this module can be obtained from the following sources :-

a) *TIDAL DATA*

The tidal data to be used as input to the model may be in the form of tidal constituents. These data are obtained either from tide tables published by the Royal Malaysian Navy (or other reputable sources) or by carrying out actual measurements at predetermined locations and carrying out the relevant analysis to determine the tidal constituents.

If the tide data is obtained by measurements, then these measurements shall be carried out for at least two weeks to include the spring and neap tides. The following data shall be clearly shown:-

i) Location / Coordinates of Tidal Stations (in MRSO coordinates)
ii) Type of tide gauge used
ii) Time series observation of tide levels
iii) The computed tidal constituents

b) *WIND DATA*

Wind Data may be obtained from the Meteorological Department or from other reliable sources such as satellite data.

5.1.3 Data For Model Calibration and Verification

Data collection for water level and current velocity need to be carried out for calibration and verification of the hydrodynamic module. Separate measurements need to be carried out at the calibration and verification stations.

a) Water Level Measurements

The water level measurements shall be carried out for at least two weeks to include the spring and neap tides.

b) Current Measurements

The velocity measurements shall be carried out for at least 3 days each during the spring and neap tides. For calibrating 2-D models, the measurements can be made at the appropriate depth of the water column to obtain the representative velocity. However, if the measuring instrument is set at the appropriate depth at, say, the low tide, then the same setting will not be the appropriate depth for the high tide. The necessary corrections must be made to these values so as to obtain the representative velocity.

For 3-D models it is necessary to obtain a profile of the velocity in the vertical direction.

The following data shall be clearly shown: -

i) Location / Coordinates of calibration stations (in MRSO coordinates)
ii) Types of measuring equipments used

5.1.4 Data For The Advection/Dispersion and Water Quality Module

The main input to this module will be the current flow pattern from the hydrodynamic module, nearshore wave pattern from the nearshore wave module, wind, the pollutant source concentration and duration of discharge. The pollutant source discharge, concentration and the duration of discharge need to be estimated as accurately as possible as it greatly influences the results. The baseline conditions, such as the existing suspended sediment concentration at selected locations also need to be measured for proper assessment of the possible impacts.

a) *SOURCE CONCENTRATION OF SUSPENDED SEDIMENT FROM SAND SOURCE AREAS*

For modeling of the suspended sediment plume from sand source areas, the sea bed material has to be analysed to determine the percentage of fine material content. If the material is to be pumped directly to the required location, then the source concentration at the pumping location is determined by the mixer which churns up the bed material and the intake pipe which sucks in the slurry. But if the pumping is carried out using modern equipments that has a more environmental friendly design, the spread of the suspended sediment plume can be minimized. However, even with the latest equipments, the amount of suspended sediments released at the source shall be taken as at least 2 % of the fine material content. If the transportation is by barges or other dredgers, where overflow is allowed, then the amount of suspended sediments released at the source shall be assumed as 20 % of the fine material content. Generally, the use of a rehandling pit is not recommended. However, in particular cases, where rehandling pit is allowed, the amount of suspended sediments released at the the rehandling pit during dumping shall be taken as at least 50 % of the fine material content. The actual amount of suspended sediment released shall be computed based on the production rate of the dredgers, the percentage of fine material content, the estimated percentage of fine material released, and the density of the sea bed material. This parameter shall be introduced into the module using an appropriate concentration and discharge.

b) *SOURCE CONCENTRATION OF SUSPENDED SEDIMENT FROM RECLAMATION AREAS*

For modeling of the suspended sediment plume from reclamation areas, the source concentration of the outflow need to be estimated as accurately as possible. The concentration of suspended sediment at the outflow varies with the amount of fine material content, adequacy of containment structures, effectiveness of settlement ponds, etc. However, the source concentration of suspended sediment at the outflow shall not be taken as less than 1000 mg/l., even with the provision of proper containment structures and settlement ponds and minimal fine material content in the sand, unless it can be proven that a lesser concentration can be obtained. The flow rate of this discharge shall be obtained by deducting the solid material content from the incoming slurry.

For reclamation works utilising the ‘rainbow’ method, the amount of suspended sediments released shall be assumed as 100 % of the fine material content.

c) *DURATION OF SAND MINING OPERATION*

The duration of the discharge also need to be estimated as accurately as possible based on the proposed equipments and operation mechanism. Some examples of the duration of discharge is as follows :

i) Continuous operation with a few hours of downtime for repair and maintenance
ii) Daytime operation only
iii) Sand mining operation carried out at a reduced pace to minimise impacts

5.1.5 Data For Mud/Sand Transport Module

The main input to this module will be the bathymetry, the current flow pattern from the hydrodynamic module, nearshore wave pattern from the nearshore wave module, wind and sea bed sediment characteristics. Proper soil tests need to be carried out at selected locations to establish the sea bed sediment characteristics.

5.1.6 Data For Sediment Budget Analysis and Shoreline Evolution Module[2]

The main input to this module will be the nearshore wave pattern, shoreline sediment characteristics and shore profile. The nearshore wave pattern is available from the nearshore wave module, while the shoreline sediment characteristics will have to be established by carrying out soil sample analysis. Proper soil tests need to be carried out at selected locations to establish the shoreline sediment characteristics.

5.1.7 Data For Assessment of River Mouth Effects

The main data required for the assessment of the effects to the river mouth area are the flow characteristics, river cross sections and tidal characteristics at the river mouth.

5.2 Data Analysis

In order to ensure that the model properly simulates the various scenarios that shall be considered, it is pertinent that the input to the model consists of quality data. As such it is important that a critical analysis of the data be carried out before they are used in the model. For the case where in-situ data collection is carried out, some of the important aspects that need to be checked are as follows :-

5.2.1 Location of Measurements

The measurement locations for the current, tide levels, salinity, etc. are often selected with care so that the data obtained can be used for the desired task. However, during the actual site measurements, the locations could have shifted due to various reasons such as site problems, misinterpretation of the instructions, etc. Therefore it is important to check the records of the surveyors or the data collection team so as to verify and determine the exact location of the data collected.

5.2.2 Bathymetry Data

During the site measurement exercise for the tides, current, etc., it is also necessary to measure the bathymetry of that location so as to check the consistency of bathymetric data already obtained from other sources

[2] This module is applied to sandy coastline only

such as Malaysian Navy Bathymetric Charts, British Admiralty Charts, and hydrographic surveys. If there are pronounced differences, it is necessary to analyse the bathymetric data in order to identify the sources of errors if any and to make logical decisions on the most appropriate values to be used.

5.2.3 Tidal Measurements

Tide level measurements, are usually carried out at two or more stations that are located within the model boundary. As such the results from these stations can be compared with one another to check if there are large differences between levels as well as in their phase. If there are pronounced differences that is not coherent with their relative positions, then it is necessary to analyse the data in order to identify any sources error such as local interferences, equipment setting errors, etc. and to make the necessary corrections if possible. Otherwise, the unreliable data sets have to be identified and discarded.

5.2.4 Current Measurements

Current measurement are carried out at two or more stations that are located within the model boundary. Current measurements should ideally be carried out using fixed-position recording instruments as it reduces interferences due to handling, boat movement, etc. The current measurement shall be compared by checking the phase of the currents and tide levels (at approximately the same location). It is normal for slack conditions (low velocity) to occur during the high and low tides, whereas the flow will be the fastest during the mid ebb and mid flood tide conditions. If there is a large phase shift in the current and tides or if there is no clear pattern of phase correlation then the data need to be checked for its validity before it can be used.

6. Model Calibration

The model calibration is normally carried out by comparing the predicted water levels and current velocities at spring and neap tides with the measured values and making the necessary adjustments to the various model parameters so that these two sets of data match as closely as possible. The following information shall be submitted for evaluation :

i) Values of all the model parameters that have been adjusted (eg. Roughness coefficient, eddy viscosity etc.,)
ii) Water level difference diagram (showing the comparison of the water levels for the predicted and measured values)
iii) Velocity difference diagram (showing the comparison of the speed and direction for predicted and measured values)

7. Model Verification

The verification of the model is carried out by comparing the predicted water levels and current velocities to actual measured values. The verification stations shall be located at different locations from that of the calibration stations. The verification stations shall be close to the points of interest (areas where the impacts would probably occur) in the study. The calibration points shall be sufficient in numbers commensurate with the size of the model/project area. The following information shall be submitted for evaluation :

a) Water level difference diagram (showing the comparison of the water levels for the predicted and measured values)
b) Velocity difference diagram (showing the comparison of the speed and direction for predicted and measured values)
c) Average differences in the comparison for water levels, current speed and direction

The average differences in speed and direction shall not be more than 30 % and 45^0 respectively. The average difference in water level shall not be more than 10 %. The general pattern of speed and direction shall be similar.

The differences between the predicted and measured values shall be treated as absolute values and these values shall be averaged over the duration of comparison. The time interval between each consecutive value shall be less than 60 minutes.

8. Simulation of Impacts and Presentation of Results

The simulations shall be carried out for the ‘before project’ and ‘after project’ cases. If alternative proposals are to be considered, then the model shall be simulated for each of the proposed alternatives. In general the study shall focus on the worst case/dominant case scenarios depending on the purpose of the study. In order to arrive at more realistic values (e.g. when assessing yearly erosion or siltation rates) a combination of the dominant cases (mild, moderate and extreme events) according to their percentage of occurrence shall be considered. In general it is recommended that the modeling works be simulated for the following scenarios :-

a) North east monsoon season
b) South west monsoon season
c) Inter monsoon seasons

The wave, wind and tide data used in these simulations shall be representative of the respective seasons.

Siltation and erosion rates shall be presented in terms of annual rates, while the spread of suspended sediment plume, thermal discharge or pollutants shall be presented in the form of seasonal or annual percentage exceedence plots. In order to carry out these assessments it is necessary to establish the percentage of occurrence of each of these seasons in a year.

It is important that the results of each module that is simulated shall be presented in a suitable manner such as plots, diagram, tables, etc., so as to allow easy inference of the results and assessment of impacts. Suitable colour schemes shall also be utilised to ensure clarity of the presentations.

8.1 *Nearshore Wave Module*

This module transforms the deepwater waves to nearshore waves. The results of the wave transformation module may consist of nearshore wave height and direction for both the ‘before project’ and ‘after project’ cases. For the after project cases, any wave reflection caused by the development may also be included.

The current velocity, rate of bed sediment movement and rate of coastline erosion or siltation vary throughout the year depending on the wave climate, tides and other factors. During periods of high wave activity the turbulence at wave breaking is very high and causes most of the sediment transport in the littoral zone because the bottom velocities and turbulence at breaking suspend more bottom sediment. This suspended sediment can then be transported by currents in the surf zone whose velocities are normally too low to move the sediment at rest on the bottom. Therefore, in order to arrive at a realistic assessment of the current velocity and sediment transport, wave breaking shall be considered in addition to the other driving forces. The surf zone shall be resolved by approximately 5 or more grid points in both the wave and hydrodynamic modules if wave driven currents are to be included.

During the low tides, the waves may break away from the coastline, while during the high tide, the waves may break closer to the shore. Ideally, this module shall use a varying water level that depends on the tides. However, if this is not possible, then, in order to assess the worst conditions, the MHWS level shall be used as input for the water level in this module.

The results shall be presented in such a manner so as to facilitate easy inference of the changes in the wave pattern. For cases where the wave pattern is not affected by the development project, it would be sufficient to provide the wave pattern diagrams for the existing case only. However, if the wave pattern is affected by the development works, then it is necessary to provide wave pattern diagrams for the ‘before’ and ‘after’ the project cases. The diagrams may consist of the following :

a) Wave patterns diagrams in plan view for the 'before' and 'after' project cases together with difference diagrams,
b) sectional transects showing wave height variation before and after projects, etc.

8.2 *Hydrodynamic Module*

This module predicts the current flow pattern due to the natural forces such as tides, waves and wind. The results of the hydrodynamic module consist of current velocity pattern for the various tidal conditions at different seasons of the year.

Generally this module shall consider the forces due to tides, waves, wind and regional forcing. However if it can be verified that the location of the study is a very sheltered area where the wave climate is very mild all year round and do not contribute significantly to the current and sediment movement, then this module can be executed considering the effects of tides and wind only.

The current velocity during a tidal cycle is higher during spring tides than during the neap tides. As the high spring tide level varies throughout the year, the maximum current velocity during a tidal cycle also varies accordingly. In order to obtain representative current speed values, it is recommended that the high water level of the tides reached in this simulation shall be at least equal to the MHWS. If this module is carried out to represent particular seasons, then the tide used shall be representative of the tides within that season.

The results of this module shall be presented in such a manner so as to facilitate easy inference of the changes in the current velocity pattern before and after the project implementation. This may be achieved by producing diagrams showing current velocity patterns before and after project for each season together with difference diagrams or other suitable means.

8.3 *Advection/Dispersion and Water Quality Module*

This module may be used to determine the dispersion pattern of suspended sediment plume[3], thermal effluents or other pollutants. The results of this module consist of the pattern and intensity of the distribution of the pollutant during a tidal cycle.

In some cases, where the effluent discharge is high, it may not be fully dispersed during the neap tides, resulting in a build up of the concentration. This build up may then be subsequently flushed during the stronger spring tides. But in order to ensure that the effluent is completely dispersed during a tidal cycle, and that there is no build up over successive tidal cycles, it is necessary that the module be carried out for a longer period of time.

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[3] The suspended sediment plume may also be simulated using the mud transport module

8.3.1 THERMAL EFFLUENTS AND OTHER POLLUTANTS

For the thermal effluents and other pollutants, the concentration or thermal increase in the nearby waters need to be kept below the levels specified by the relevant authorities. For this purpose, the module shall be carried out for the worst case, which is pure tides only with no waves and wind effects. However if there are sensitive ecosystems or habitats in the vicinity, then it is also necessary to include the effects of waves and wind during the various seasons in order to ascertain the reach and intensity of the impacts.

In order to ensure that there is no build up of concentration over time, it is recommended that the module be carried out continuously for one month. This shall be carried out for a single simulation considering pure tides only. The high water level of the tides used for this purpose shall be ***lower*** than the MHWS. However if it can be shown that the thermal effluent or pollutant is in such a small quantity that it can effectively be dispersed even during the neap tides, then it is not necessary to carry out this simulation.

8.3.2 SUSPENDED SEDIMENT TRANSPORT

For the suspended sediment plume dispersion, it is necessary to consider waves and wind in addition to the tides, as it will cause a wider spread of the plume, thereby increasing the area of impact. This module shall be simulated for the various seasons of the year so as to establish the limits of the spread and intensity of the suspended sediment plume throughout the year.

For suspended sediment plume caused from sand mining, the center of the sand mining area is usually used as the source of the suspended sediment plume. But in certain cases, where the sand mining area is very large and/or there are sensitive areas in the vicinity, it may be necessary to select several critical points in the sand mining area as the source of the suspended sediment plume and simulate the module for each case. If it is foreseen that two or more dredgers will be used in the sand mining operation, then the corresponding number of source points shall be incorporated in the module.

In order to ensure that there no build up of concentration over time, it is recommended that this module be carried out continuously for one complete spring-neap tidal cycle. This shall be carried out for a single simulation for the worst case conditions. However if it can be shown that the suspended sediment plume is in such a small quantity that it can effectively be dispersed even during the neap tides, then it is not necessary to carry out this simulation.

The results of this module shall be presented in such a manner so as to facilitate easy assessment of the potential impacts caused by the spread of the plume. This may be achieved by several methods, such as :

a) Diagrams showing the spread of the plume and its intensity during various tidal conditions at different seasons. These diagrams must be overlaid with the diagram showing the location of sensitive marine habitat or important socio economic activities.
b) Diagrams showing contours of the seasonal and annual percentage exceedence for several levels of pollution. These diagrams must also be overlaid with the diagram showing the location of sensitive marine habitat or important socio economic activities.
c) Continuous plots showing the variation of the intensity at several selected locations. These plots must be overlaid with the tide levels and must cover at least one neap and one spring tide.

8.4 *Mud / Sand Transport Module*

The mud / sand transport module can be used to study the transportation, sedimentation and erosion of sediments due to changes in the current flow patterns as well as to estimate the siltation from the suspended sediment plume generated by the project.

This module shall be simulated for the various seasons of the year. These results shall then be combined to produce annual siltation or erosion rates based on the percentage occurrence of each of the seasons.

The results of this module shall be presented in such a manner so as to facilitate easy assessment of the potential impacts caused by the erosion or siltation. This may be presented as follows :

a) Annual erosion/siltation diagrams for the before and after project cases together with difference diagrams. These diagrams must be overlaid with the diagram showing the location of sensitive marine habitat or important socio economic activities.
b) Siltation rates caused by the spread of the suspended sediment plume. These diagrams must be overlaid with the diagram showing the location of sensitive marine habitat or important socio economic activities.

8.5 *Sediment Budget Analysis and Shoreline Evolution Module*[4]

This module may be used to assess the sediment budget along the coastline and to predict the shoreline morphology in the vicinity of the project area.

[4] This module is applicable for sandy shoreline only. Appropriate modules for muddy shoreline shall be used when available.

8.5.1 SEDIMENT BUDGET ANALYSIS

In general, the sediment budget analysis shall be assessed along the shoreline at locations where there are :

a) changes in the orientation of the shoreline,
b) existence or introduction of physical features which cause changes to the quantum of sediment transport
c) existence of natural coastal features that effect sediment transport (e.g. river mouth, coral reefs, etc.)
d) changes in the wave pattern

Along straight coastlines devoid of any features, it is recommended that the sediment budget analysis be carried out at regular intervals of about 5 km intervals

The results of this module shall be presented in such a manner so as to facilitate easy assessment of the potential impacts caused by the project. This may be presented in the form of diagrams showing the sediment transport (using arrows to indicate direction and indicating the magnitude) for both the 'before' and 'after' project cases

8.5.2 SHORELINE EVOLUTION

This module may be used to simulate the evolution of the shoreline affected by the development works. In general, the assessment of the evolution of the affected shoreline shall be carried out for cases of 1 year, 2 years, 5 years and 10 years after the project implementation.

The results of the shoreline evolution assessment shall be presented in suitable diagrams showing the existing shoreline and the future predicted shoreline movement.

8.6 *Assessment of Effects to the River Mouth*

The river mouth area is easily affected by the physical changes in the nearby areas that are caused by coastal developments. All the necessary analysis shall be carried out to check for the following effects :

a) Drainage problems and upstream flooding
b) Changes to the tidal prism and salinity pattern/concentrations in the estuarine area
c) Deterioration in the flushing capacity in the estuarine area.
d) Navigation problems at river mouth

8.6.1 Drainage Problems and Upstream Flooding

This may be analysed by carrying out backwater analysis along the affected rivers and streams. The appropriate design flood flow shall be used in this analysis (the appropriate return period should be obtained from the state DID). This analysis should cater for the :

a) increased water levels along the river (at MHWS) due to decrease in velocity at river mouth (immediate effect)
b) increased water levels along the river due to increased siltation at river mouth areas (long term effect)

The backwater curve analysis should be carried out to incorporate the long term effects of increased siltation at the river mouth (e.g. after 3 years and 5 years). The computed water levels should then be compared with the existing bank levels to check if there will be any increased upstream flooding.

The results of this analysis shall be presented in suitable diagrams such as :

a) backwater curve and river bank levels for existing case
b) backwater curve and river bank levels for the case immediately after project implementation (no consideration of river mouth siltation)
c) backwater curve and river bank levels for for the case of 3 and 5 years after project implementation (considering river mouth siltation)

8.6.2 Changes to the tidal prism and salinity pattern/concentrations in the estuarine area

The simulation for the salinity concentrations shall be carried out for a complete spring-neap tidal cycle for the 'before' and 'after' project cases. If there are profound differences between the two cases, then the relevant modifications need to be made to the configuration so that the salinity concentration /pattern are similar in both cases. The tidal prism shall also be established for the 'before' and 'after' project cases.

The results of this analysis shall be presented in suitable diagrams such as salinity concentration diagrams for the 'before' and 'after' project cases for different tidal conditions.

8.6.3 Deterioration in the flushing capacity in the estuarine area

The flushing capacity may be assessed by introducing a conservative pollutant source in the area of interest and simulating the module for a complete spring-neap tidal cycle. This simulation shall be carried out for the ‘before’ and ‘after’ project cases. If there are profound differences between the two cases, then the relevant modifications need to be made to the configuration so that the flushing capacity are similar in both cases.

The results of this analysis shall be presented in suitable diagrams such as concentration levels of the pollutant at various time intervals after its introduction for the ‘before’ and ‘after’ project cases

8.6.4 Navigation problems at river mouth

An assessment of the annual siltation rate at the river mouth shall be carried out for the ‘before’ and ‘after’ project cases.

The results of this analysis shall be presented in suitable diagrams so as to clearly indicate the increases in river mouth siltation (if any).

9. Types of Impacts

Development works in the coastal area could cause various types of adverse impacts to the adjacent areas, such as :

a) Coastal erosion
b) Adverse impacts to the river mouth area
c) Increase in suspended sediment concentration

9.1 *Coastal Erosion*

Erosion usually occurs when development works interfere with the natural sediment transport and cause a deficit in the sediment supply or when the incoming wave pattern is altered to create areas where there is a convergence of waves.

It is necessary to assess the existing conditions at the coastline and determine if the shoreline is stable, eroding or accreting. This shall then be compared with the new shoreline conditions that are predicted to occur as a consequence of the coastal development works. If it is established that the accreting or stable areas will now face erosion, then the developer shall be fully responsible to propose suitable measures to overcome the new erosion problem and to bear the full cost of implementing the selected mitigation measures. However, the final selection of the most appropriate measure to overcome erosion in a particular area shall be subject to the acceptance of the relevant authorities such as DID, with due consideration of the land use, coastal resources, and other needs.

9.2 *Adverse impacts to the river mouth area*

River mouths areas or drainage outlets are very sensitive to changes caused by coastal development works. These may lead to several adverse impacts to the environment, such as:

a) Drainage problems and upstream flooding
b) Navigation problems at the river mouth
c) Changes to the tidal prism and salinity concentrations in the estuarine area
d) Reduced flushing capacity

9.2.1 Drainage Problems and Upstream Flooding

Alteration in flow hydrodynamics of the estuarine area may lead to a reduction in the flow capacity at the river mouth which may eventually cause drainage problems and upstream flooding during the rainy season. Some of the causes of this impact are as follows :

- Increased tide levels at the river mouth that occurs as a consequence of the development works may retard the existing flow pattern.
- Reduced velocity pattern at the river mouth may also encourage siltation. This leads to a reduction in the flow capacity at the river mouth.
- Lengthening of the river mouth (e.g. due to land reclamation) alters the hydraulic gradient and may cause upstream flooding

If it is suspected that drainage problems and upstream flooding could occur due to the development works, then the developer will be fully responsible to propose suitable mitigation measures to overcome these problems and to bear the full cost of implementing the selected mitigation measures. However, the final selection of the most appropriate measure to overcome the drainage and flooding problem in a particular area shall be subject to the acceptance of the relevant authorities such as DID.

9.2.2 Navigation Problems at River Mouth

Siltation at the river mouth area may occur due to reduced flow velocities that induce settlement of the sediment load. This can create navigation and berthing problems especially to the fishing boats. The consultant will have to assess the amount of siltation that could occur at the river mouth as well as the draft requirements of the vessels in the locality. If it can be established that the coastal development project will cause navigation and berthing problems, then the developer shall be responsible to propose appropriate mitigation measure as well as to bear the full cost of its implementation. However, the final selection of the most appropriate measure to overcome the siltation problem shall be subject to the acceptance of the relevant authorities such as DID and LKIM.

9.2.3 Changes To The Tidal Prism And Salinity Concentrations In The Estuarine Area

Another problem that could occur due to alteration of the flow hydrodynamics of the estuarine area is the changes to the tidal prism and salinity pattern in the estuarine area. This could lead to environmental degradation that may endanger the existing habitat such as mangroves, sea grass, etc. In order to avoid these impacts the project proponent will have to propose and carry out remedial measures (such as periodic widening and deepening of the river mouth) so that the existing tidal prism and salinity pattern are maintained.

If it is suspected that the problems associated to the changes in the tidal prism and salinity concentrations could occur due to the development works, then the developer will be fully responsible to propose suitable mitigation measures to overcome these problems and to bear the full cost of implementing the selected mitigation measures. However, the final selection of the most appropriate measure to overcome these problems in a particular area shall be subject to the acceptance of the relevant authorities.

9.2.4 Reduced Flushing Capacity

The reduction in the flow capacity at the river mouth also leads to a decrease in the exchange of the riverine and tidal waters. This may cause a reduction in the flushing capacity and result in an increase in the concentration of pollutants within the estuarine areas.

If it is suspected that flushing problems could occur due to the development works, then the developer will be fully responsible to propose suitable mitigation measures to overcome these problems and to bear the full cost of implementing the selected mitigation measures. However, the final selection of the most appropriate measure to overcome the flushing problem in a particular area shall be subject to the acceptance of the relevant authorities.

9.3 *Increase In Suspended Sediment Concentration.*

Suspended sediment plume is usually generated during sand mining or land reclamation activities. As the plume dispersion is sensitive to wind and waves, its pattern varies from season to season. It is thus recommended that this analysis should in general consider tides, waves and wind and should be carried out for the various scenarios as described in Section 8.1 and 8.4.

The wave, wind and tide data used in these simulations shall be representative of the respective seasons.

In cases where the sand source and the land reclamation areas are not very far apart, the module should consider the combined effects of the sand mining and the land reclamation activities.

Usually the suspended sediment plume is a temporary form of pollution that occurs during the construction phase. In order to ensure that the suspended sediment concentrations do not exceed the critical threshold values, and cause adverse impacts, it may be necessary to carry out real time monitoring of the relevant parameters and to make adjustments to the construction schedule or procedures.

10. Assessment of Impacts

Coastal development works such as land reclamation, sand mining, construction of shoreline structures, etc., can cause various negative impacts to the coastal area. Some examples of such impacts are :-

a) destruction of coastal habitat, such as mangroves, coral reefs, sea grass, etc.,
b) disruption to fisheries and aquaculture activities,
c) disruption to tourism related activities and other socio economic activities in the coastal area, etc.

In order to carry out proper assessment of the impacts, and to propose measures to reduce these impacts, the consultant should carry out a thorough hydraulic study that covers the various seasons, taking into consideration the seasonal changes in waves, wind and tides.

10.1 *Impacts on coral reefs and sea grass*

These coastal habitat are extremely sensitive to changes to their surrounding environment, such as suspended sediment concentration, salinity, temperature, etc. In order to minimise the impacts on these habitats it is important to minimise the changes to the existing environmental parameters. While the actual tolerance of these habitat to changes will be determined by marine biologists or other related experts, the hydraulic modeler will have to ensure that the environmental changes are within the safe limits. This may require modifications to the original proposed development, changes to the construction procedures and/or implementation of additional mitigation measures.

Among the more common impacts on coral reefs and sea grass are increased suspended sediment concentration and siltation arising from the settlement of the suspended particles. These impacts tend to block the penetration of sunlight and to smother the habitat respectively. In general it is recommended that the increase in suspended sediment concentration and total siltation be limited as follows, unless otherwise determined by marine biologists or other related experts :

i) Average increase in day time suspended sediment concentration over important habitat < 10 mg/l (whereby the standard deviation must be less or equal to 10 % of the average value)
ii) Average increase in night time suspended sediment concentration over important habitat < 25 mg/l (whereby the standard deviation must be less or equal to 10 % of the average value)
iii) Permissible siltation rate over very sensitive habitat < 2 mm / year

10.2 *Impacts on mangrove forest*

Mangrove forests survive along the coastal areas that are alternately subjected to saline and fresh water flows. These forests are sensitive to the tidal prism and to the salinity of the incoming tides. Quite often the coastal development works cause changes to the tidal flow along the shoreline as well as the estuaries. These cause changes to the tidal prism and the existing salinity pattern, which may adversely impact the mangrove forests.

In order to ensure that the mangrove forests in the estuarine areas are not seriously affected by the coastal development, it is necessary that the existing tidal prism and the salinity pattern during the various phases of the tides is maintained. The hydraulic modeler will have to simulate the necessary modules and show that the tidal prism and salinity pattern for the 'before' and 'after' project cases are similar.

10.3 *Impact on Public Beaches*

One of the main attractions of coastal resorts, hotels and public beaches are the clear seawater conditions along the shoreline. However, coastal development works can generate suspended sediment plume that may pollute the coastal waters adjacent to important tourist areas. This will cause visual pollution and impact the tourism industry.

In order to minimize this impact, it is recommended that the absolute suspended sediment concentration at these areas be maintained at less than 20 mg/l[5]. If the existing suspended sediment concentration at these locations already exceeds this value then the increase in the day time suspended sediment concentration due to the development works should be limited to 5 mg/l.

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[5] This does not apply to mud coasts

10.4 *Impact on fishing and aquaculture areas*

Fishing and aquaculture areas are very sensitive to various environmental parameters such as salinity, suspended sediment concentration, temperature, etc. The actual tolerance to increase in these parameters varies with species and will be determined by the experts in fisheries.

One of the most common impacts is due to suspended sediment plume. In the open sea, this may cause the fishes to migrate to other areas, whereas the fishes from the aquaculture will have to face the full impact. In order to reduce these impacts it is recommended that the absolute suspended sediment concentration at these locations should be kept at below 50 mg/l or as advised by the fisheries expert.

11. Identification of Impacts and Proposed Measures To Minimise These Impacts

All the potential impacts on the surrounding areas due to the proposed project shall be identified and presented in suitable diagrams. These impacts may include the following :-

a) Erosion or siltation (showing rates and extent of area involved),
b) River mouth siltation and the associated problems of drainage, upstream flooding, changes to tidal prism and salinity,
c) Siltation of navigation channels.
d) Increased turbidity or other pollutants and its impact on other marine habitat and socio economic activities, such as mangroves, coral reefs, sea grass, tourist beaches, fishing activities, aquaculture, etc.

Proper measures shall be recommended to minimise the potential impacts that have been identified above. These may be in the form of new alternatives or incorporating modifications to the original proposal or layouts. These new alternatives will then have to be tested again using the various modules to determine the reduced impacts.

Proper mitigation measures shall also be recommended to minimise or overcome all the adverse impacts that have been identified.

12. Monitoring

In order to ensure that the impacts are within the limits as predicted by the model, all the necessary monitoring programs during and after the construction (for a period of three years after project completion or as otherwise stipulated) shall be outlined and carried out by the project proponent. These monitoring works for the physical environment may include the following :-

a) Shoreline monitoring,
b) Water level measurements along drainage outlets,
c) Monitoring of river mouth areas, navigation channels, berthing areas and other affected waterways or channels
d) Waves and tidal measurements,
e) Water Quality such as suspended sediment concentration, salinity, etc.

The monitoring data shall be processed using the appropriate tools to assess the validity of earlier model predictions with respect to the various impacts. In some cases it may also be necessary to carry out real time monitoring of certain parameters in order to decide on the pace of construction works so as ensure that the impacts do not exceed critical limits (e.g. in sensitive coral reef areas where the suspended sediment concentration should remain below the critical threshhold values). All the data collected during the monitoring program together with the analysis shall be submitted to the DID.

Regular audit of the monitoring works (at intervals of three months during construction and six months after construction, or as otherwise stipulated) shall also be carried out and the audit reports shall be submitted to the DID.

13. Preparation of Coastal Engineering Hydraulic Study Report

A report on the coastal engineering hydraulic study shall be submitted to the Coastal Engineering Division of the Department of Irrigation and Drainage (at State and / or Federal level). This report shall include the following :-

a) Project Proposal
b) Existing conditions at project site
c) Types of anticipated impacts and the selected model and modules used to assess these impacts
d) Data collection and analysis of measured data
e) Details of the hydraulic computer modelling as outlined in these guidelines
f) Potential impacts caused by the project
g) Proposed measures to minimise impacts
h) Monitoring program
i) Conclusion and recommendations

14. Technical Presentation of the Hydraulic Study

A technical presentation of the hydraulic study shall be conducted to the Coastal Engineering Division of the Department of Irrigation and Drainage (at State and / or Federal level). This technical presentation shall encompass all the relevant topics as mentioned in Section 13 with special emphasis on the details of the computer modelling works and compliance with the requirements of these guidelines.

15. Submission of Data & Report

15.1 Submission of Data

A copy of the following datasets in digital form shall be submitted to the Department of Irrigation and Drainage for reference :

a) All input data to the model (wave, tides, bathymetry, etc.,)
b) Calibration datasets (tide data, current velocities, etc.,)
c) Average differences in speed, direction and water levels at verification stage
d) All the model parameters after calibration
e) Verification datasets (tide data, current velocities, etc.,)
f) Soil / sediment investigation report

15.2 Submission of Report

Two copies of the hydraulic report (origial colour copy) shall be submitted to the DID. The cover of the report shall state clearly the following :

a) The Project Title
b) The name, address, telephone number and e-mail address of the Developer
c) The name, address, telephone number and e-mail address of the Consultant

The qualification and professional experience of the modeller and other professionals and specialists involved in carrying out the study shall be included as an appendix to the report.