Guidelines

Australian Government
Great Barrier Reef Marine Park Authority

The use of Hydrodynamic Numerical Modelling for Dredging Projects in the Great Barrier Reef Marine Park

August 2012

To provide guidance on the use of three-dimensional (3D) hydrodynamic numerical models in the Great Barrier Reef Marine Park. Deviations from these guidelines require prior written approval from GBRMPA.

General Principles

1. These guidelines, prepared by the Great Barrier Reef Marine Park Authority (GBRMPA), are used to inform proponents and interested stakeholders about the specific procedures, methodologies and frameworks associated with hydrodynamic modelling and dredge plume modelling that GBRMPA expects for projects in the Great Barrier Reef Marine Park (Marine Park).

2. Three-dimensional (3D) hydrodynamic numerical modelling of sediment plumes underpins the assessment of potential impacts from dredging and sediment disposal activities in the Marine Park.

3. Actions to avoid, mitigate, and/or offset and adaptively manage potential impacts from dredging and disposal activities will be based on the model outputs.

4. Modelling is used to predict the extent, intensity and persistence of dredge-generated sediment plumes and the extent, severity and duration of resultant indirect impacts to benthic habitats, which can range in severity and duration from irreversible to readily reversible.

5. The use of 3D hydrodynamic and sediment plume modelling is considered international best practice.

6. The hydrodynamic model should take into account the tides, the wind, the waves and the mean prevailing circulation (oceanic currents) and potential stratification from river discharges.

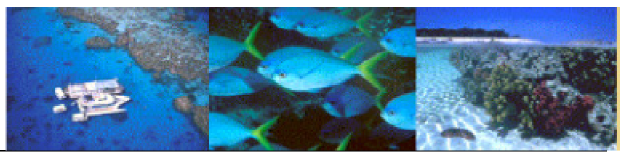
7. The model must be calibrated and validated against collected baseline information.

8. 3D modelling must include all types of potential re-suspension including current and wave-induced bottom shear stress and wave-induced mud fluidization.

9. GBRMPA supports the use of the Western Australia's Environmental Protection Authority 'Environmental Assessment Guideline for Marine Dredging Proposals'[1] and the use of a zonation scheme in describing impact predictions (i.e. zone of impact, zone of influence).

Baseline information

10. For dredging campaigns less than one month duration, a minimum of one month of baseline data collection is required. For wind data collection, 3 to 4 months of baseline data is required.



11. For dredging campaigns that are predicted to last longer than one month, then a minimum of twice the duration of the dredging campaign worth of baseline data is required to account for seasonal variation. For example, if the dredging campaign is 2 months, then at least 4 months of baseline data is required. For wind data collection, six to eight months of baseline data is required.

12. Baseline data must be measured in close proximity to the dredging and disposal sites and include metocean parameters such as tidal range, wave height, water current, wind direction and intensity and sediment dynamics.

Sediment transport

13. Sediment transport modelling must consider the a range of particle sizes. The size of the particle will determine its behaviour in the marine environment and thus how it is numerically modelled. For example:

    a. Sand is generally modelled as bed load;

    b. Silt is modelled using a fixed settling velocity. Due to the range of silt fractions a silt particle may behave similar to a sand particle or a mud particle;

    c. Mud (clay) is modelled with a settling velocity which is determined as a function of the suspended sediment concentration in order to take into account the process of flocculation.

Model resolution

14. Predictive modelling of dredge plumes must:

    a. Describe whether the model uses a z or σ coordinate in the mesh.

    b. Adequately resolve how the model deals with sudden changes in bathymetry. For example: a dredge channel or coral reef as percentage error in the prediction.

    c. It is recommended that the minimum resolution as a function of mesh size to pick up changes in hydrodynamic flow associated with a dredge channel is two cells within the width of a dredged channel.

    d. Describe the physical characteristics of the sediment being transported. These characteristics should be informed by sampling undertaken in accordance with the *National Assessment of Guidelines for Dredging 2009* (NAGD).

    e. Accurately represent the ambient conditions at the time of year in which the dredging occurs. If this is not known, then modelling should be undertaken for all seasons (i.e. summer conditions, winter conditions, transitional conditions) using the corresponding prevalent oceanographic conditions.

    f. Include additional dispersion and re-suspension from both dredging operations and dredge disposal activities. This must be completed for a range of probable hydrodynamic conditions, weather events and expected dredge equipment scenarios. The amount of material liberated by the dredging and dispersed in the environment around the dredge site must also be stated.

    g. Numerical modelling must be performed for a duration of time that is long enough to establish the re-suspension associated with different weather conditions that occurs after dumping and initial settling.

    h. If dredging is to occur near coral sand islands, modelling of particles must be undertaken using coralline sand characteristics. The use of sand particles in this scenario is not supported.

Model outputs

15. GBRMPA expects that direct, indirect and sublethal impacts of sediment plumes are considered.

16. Numerical models must use a spatially based scheme that provides for a clear and consistent way of describing and presenting the extent, severity and duration of predicted impacts of dredging and dredge disposal and must include likely "best case" and likely "worst case" scenarios.

17. The lethal and sublethal thresholds used for the ecological response modelling must be clearly indicated and supported by peer reviewed scientific published papers and compared against model outputs.

18. The output from the model should be overlaid upon maps of the sensitive habitats and ecological receptors in order to visualise and interpret what the impact of the sediment plume might be.

19. GBRMPA expects all modelling results (maps) to be provided in a suitable GIS compatible format (i.e. shapefiles in geographic coordinates and GDA94 datum) to GBRMPA.

20. Outputs should at a minimum requirement include maps showing the predicted maximum suspended solid concentration at mid-depth and near the seafloor, the predicted median suspended solid concentration at mid-depth and near the seafloor, and the predicted sedimentation rate (g/cm^2) over the duration of the project, as well as time-series predictions of these three parameters at key sites over the duration of the project.

21. GBRMPA encourages consistency when using sediment loading units (NTU's, mg/L or kg/m^3). Do not use the units interchangeably.

22. Selection of dredge disposal site (even if a historic site) must be fully justified and compared to other possible sites with a prediction for sediment re-suspension and possible direction and distance of the migration of the dredge material under different water current conditions.

23. If GBRMPA is uncertain about the methodology used in the modeling, then the methodology and the model outputs will be independently peer reviewed at the cost of the proponent.

Background

Justification

1. The Great Barrier Reef Marine Park (Marine Park) is widely recognised as one of the best managed marine areas in the world. It is a multiple-use Marine Park that supports a range of activities, industries, communities and businesses. However, it faces challenges from a range of threats including climate change, declining water quality, increased coastal development and the growth in ports and shipping activities.

2. The economy of Queensland continues to grow and some industries are developing rapidly, such as coal and mining, which is fuelling growth in ports in the Great Barrier Reef Region and increasing the number of ships travelling through Reef waters. This growth results in the construction of new shipping berths, dredging of shipping channels and the dumping of dredge material. All of these have the potential to impact on the marine environment.

3. The Great Barrier Reef Marine Park Authority (GBRMPA) is committed to protecting the Great Barrier Reef from the impacts of ports and shipping on the Marine Park through a range of management initiatives and partnerships with other government agencies.

4. Numerical models are used to quantify the predicted impact of dredging and disposal on marine ecosystems. The hydrodynamic model predicts the physics of water, sediment dynamics and oceanographic behaviour.

5. The Guidelines provide for a transparent and acceptable standard to assist in the development of predictive numerical models associated with dredge related sediment plumes in and adjacent to the Marine Park. They allow for the understanding of the fate of suspended sediments within the marine environment and potential for impacts to sensitive marine receptors.

Background

6. Dredging activities can have adverse effects on marine ecosystem (see figure 1). Dredging and dredge disposal at sea can result in environmental impacts such as:
    a. Increased concentrations of suspended sediments[2]
    b. Changes to hydrodynamics
    c. Smothering of benthic fauna and flora
    d. Introduction of contaminants
    e. Alteration of coastal processes
    f. Damage to marine wildlife
    g. Translocation of pest species
    h. Removal of habitat.

Increased concentrations of suspended sediments

7. Dredging involves the removal of sediments from the seafloor. This disturbance creates sediment plumes, which decreases water clarity and quality. The plume reduces light penetration to the seafloor; it affects fish behaviour and other benthic life[3]. Coarser-grain sediments such as sands will sink to the substrate quickly, but finer-grain sediments such as silt and clay will remain suspended in the water column for an extended period of time[4] because of the low settling velocity[5].

8. Sediment plumes can also liberate nutrients[6] and once the nutrients are dispersed into neighbouring areas by the effect of currents and waves, they have the potential to be detrimental to the surrounding marine life[7]. Sediments, once settled, can adversely affect the seagrasses, bottom-dwelling organisms and their eggs through smothering and burial[8].

9. The reduction in light also prevents pelagic and benthic organisms from seeing and sensing their food, preys, predators, mates and offspring. Suspended sediments can clog fish gills and reduce their resistance to disease[9].

Changes to Hydrodynamics

10. The creation of an artificial channel and reclamation of the seafloor causes a change in hydrodynamics which in turn causes turbulent flow. The water circulation pattern changes once currents are influenced by the structures. It is therefore imperative that 3D turbulent flow over the structures must be considered in the model in order to ascertain the momentum and intensity of the turbidity currents.

Smothering of benthic fauna and flora

11. The increase in turbidity can retard the growth of flora and fauna. It also suffocates the newly hatched larvae. The resettled sediments can cover the spaces between the rocks thus displacing the habitats of bottom-dwelling organisms[10].

3D Hydrodynamic Model as Best Practice

12. Hydrodynamic models are generated by computer softwares. A two-dimensional hydrodynamic model, though useful in many situations, is limited to its depth-averaged equations and thereby unable to resolve stratification or vertical gradients[11]. However, a three-dimensional model, though complex but made easy by the power of modern computers, can determine the vertical distribution of currents.[12] It provides the most complete solution for any hydrodynamic system[13] including the formulation for the effects of bottom shear stress and surface wind shear stress[14]. A 3D hydrodynamic model is highly recommended as best practice because it provides realistic simulation of the marine environment.

13. The World Heritage Report on the Great Barrier Reef highlighted that any developments or associated activities are to be carried out with the highest international standards of best practice commensurate with status of an iconic World Heritage Property[15].

Legislation governing dredging and dredge disposal

14. International protocols and Commonwealth legislation requires the protection and preservation of the marine environment from pollution related to spoil disposal at sea. The *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972,* which Australia is a party to, recognises ocean disposal as the least favoured method of dredge material disposal. The *Environment Protection (Sea Dumping) Act 1981* is the domestic legislation through which Australia regulates sea dumping and meets its international obligations under the protocol.

15. Dredge disposal in the Marine Park or in the World Heritage Area is subject to rigorous environmental assessment. Dumping in the Marine Park requires a permit under the *Great Barrier Reef Marine Park Act 1975;* and dumping in the World Heritage Area requires consideration against the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and approval under the *Environment Protection (Sea Dumping) Act 1981*.

16. For loading or dumping within the Marine Park, GBRMPA holds the delegation for the assessment and granting of Sea Dumping permits under the Sea Dumping Act, notwithstanding that one or more of the activities associated with the dumping, such as dredging, may occur outside the Marine Park.

17. Most ports are located outside the Marine Park, but are within the World Heritage Area. This means that the majority of a port's activities are outside of GBRMPA's direct jurisdiction and are mostly managed by the Federal Department of Sustainability, Environment, Water, Population and Communities.

18. The *Great Barrier Reef Marine Park Act 1975 (Marine Park Act 1975)*

    18.1. The main object of the Marine Park Act 1975 is to provide for the long term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region.

    18.2. Regulations may be made under the Marine Park Act 1975 to regulate or prohibit activities in the Marine Park (Section 66).

    18.3. Under section 38AA of the Marine Park Act 1975, it is an offence to carry out an operation for the recovery of minerals in the Marine Park, which may include some dredging operations. There is also the *Great Barrier Reef Region (Prohibition of Mining) Regulations 1999* which was gazetted on the 23 December 1999. These regulations identify 'mining operations' which include 'operations for the recovery of minerals' as a prohibited activity in the Great Barrier Reef Region, adjoining the Marine Park.

19. The *Great Barrier Reef Marine Park Regulations 1983*

    In deciding whether or not to grant an application, GBRMPA must consider matters outlined in Regulation 88Q (mandatory considerations) and may consider matters outlined in Regulation 88R (discretionary considerations). Mandatory considerations include: the potential impacts of the proposal on the environment and on the social, cultural and heritage values of the Marine Park; options for monitoring, managing and mitigating the potential impacts; the objectives of the Great Barrier Reef Marine Park zone in which the proposal will take place; whether the proposal requires an approval under the EPBC Act; written submissions from the public about the proposal; and matters relevant to the proper and orderly management of the Marine Park.

20. The *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*

    20.1. On 25 November 2009, legislative changes came into effect to better integrate the Marine Park Act 1975 with the national environment law – the EPBC Act, so that a single environmental impact assessment system applies to development proposals in the Marine Park. If a development proposal is referred under the EPBC Act, and the action or a component of that action requires a permission under the Marine Park Act 1975, the EPBC Act referral is deemed to be a Marine Park application.

    20.2. The legislative changes also established the Marine Park as a 'matter of national environmental significance' (known as a NES matter) under the EPBC Act. This means that development proposals outside the Marine Park that are likely to have a significant impact on the environment of the Marine Park, or other NES matters, must be assessed under the EPBC Act.

Relationship to other GBRMPA Policies or Position Statements

21. This Policy relates to the following GBRMPA Policies and Position Statements at the time of review:

    21.1. **Environmental Impact Management Policy** - sets the framework for assessment, mitigation and management of environmental impacts associated with development activities in the Marine Park and World Heritage Area.

    21.2. **Dredging and Spoil Disposal Policy** - sets out the guidelines as to what is to be done with contaminated dredge material, where to dispose the dredge material in the Marine Park, the limitation of maintenance dredging volume and the environmentally levy that may be charged.

    21.3. **Ports and Shipping Information Sheet** – describes the current dredging activities and the proposed port expansion in the Marine Park and World Heritage Area. Facts and figures are listed to show the magnitude of dredging and port expansion.

Definitions

22. ***Dredge Disposal***

The relocation of dredge material from the dredging site to a designated disposal site. Disposal sites may include marine or land based receiving facilities.

23. ***Wave-induced Bottom Shear Stress***

A wave-induced bottom shear stress is a stress that is generated by ocean waves as they propagate over the sea floor. It is an important parameter for understanding sediment dynamics and bottom properties[16] and for calculating erosion, storm surge, wave height attenuation and coastal structural stability[17]. In coastal zones where the ocean depths are shallower than 4 m, the bottom shear stresses are greater[18].

24. ***Mud Fluidisation***

Mud fluidisation is a process or condition in which the contact stresses between particles in the mud reduce to zero. The mud is thus converted from a solid-like state to a dynamic fluid-like state as the granular material loses its shear strength[19]. This process occurs as the fluid passes through mud particles. The waves could fluidise the mud, but they do not transport the sediment. As soon as the mud has been fluidised, the currents erode it away[20].

25. ***Flocculation***

Flocculation is the process of sediments forming naturally or by the addition of flocculants larger aggregates, agglomeration or clusters of sediment particles.

GREAT Barrier Reef Marine Park Authority (GBRMPA) Decision(s)

Approved by:	General Manager, Marine Park Management Branch, Great Barrier Reef Marine Park Authority 14 August 2012
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2 - 68 Flinders St PO Box 1379
Townsville Qld 4810 Australia

Phone + 61 7 4750 0700
Fax + 61 7 4772 6093

info@gbrmpa.gov.au
www.gbrmpa.gov.au

Further information

Contact the Ports and Shipping Team at GBRMPA

ports@gbrmpa.gov.au

Phone: (07) 4750 0700

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