DREDGING AND MATERIAL RELOCATION IN SENSITIVE CORAL ENVIRONMENTS

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ABSTRACT

Coral reefs are one of the richest and yet most sensitive elements of the marine environment. Coral reefs provide significant social, economic and resource related services and their continued health is essential for the sustainable development of many reef dependent communities.

Unless well managed, marine construction activities such as dredging and material relocation in and around coral reefs may impact coral reefs and other habitats. Management measures including planning, environmental impact assessment, avoidance, minimisation and compensation have been used with various measures of success. Some examples of impact management from a range of dredging and material relocation projects in Australia, Singapore and Indonesia are discussed.

While aspects of the impact of dredging and material relocation on coral reefs communities are complex, vectors such as sedimentation and turbidity provide effective candidates for monitoring and adaptive or feedback impact management. The application of integrated and rapid monitoring technologies such as satellite imagery and modelling are discussed.

In the context of movement towards "best practice", international initiatives such as PIANC Working Group 15 guidelines for “Dredging and Port Construction around Coral Reefs” are presented.

Keywords: Dredging, Coral, Environmental Impact Assessment, Monitoring, Management, PIANC

INTRODUCTION

Coral reefs are in global crisis due to natural and human impacts (Johannes and Hatcher, 1986; Nystrom et al., 2000; GBRMPA, 2006). Healthy coral reefs are estimated to provide benefits of up to US$375 billion on an annual basis (Côté and Reynolds, 2006), generated through a range of services, including supporting tourism, fisheries and extractive industries. This is particularly significant when two thirds of all countries with coral reefs are developing countries, of which, one quarter are considered “least developed” countries (UNDP, 2002).

Efforts are made to locate dredging and sediment placement activities away from coral environments (IHC, 2007; US Army Corps Engineers, 2007) but with one third of the worlds population inhabiting a coastal strip representing 4% of the land surface (UNEP, 2006), human impacts are increasing and coral reefs are continuing to decline. Over 20% of all coral reefs have been destroyed, with another 24% at imminent risk of collapse (Wilkinson, 2004). In Jordan, for example, port construction has replaced much of the coral reef area (Wilkinson, 1998).

Increased pressure resulting from population growth, increasing maritime trade and industry and limited available land is demonstrated throughout the tropics as having large impacts on corals in developed and developing countries (Nishihira, 1987; Al-Madany et al., 1991; Hoq and Swaminathan, 1997; AIMS 2000; Wolanski 2006). Even countries with large landmasses such as the United States of America and Australia are experiencing on going cumulative impacts (Laist, et al., 1986; Hunter and Evans, 1995; Voisey and Apelt, 2001). Individual dredging and material relocation projects may have direct and indirect impacts on coral at a range of scales from metres to up to 70kms (Morton, 1994; Telesnicki and Goldberg, 1995; Anthony, 1999; Larkombe et al., 2001; Brown et al; 2002; Stoddart and Stoddart, 2004; Smith et al., 2006) and months to centuries (Koloi et al, 2005). Aspects of the impact of dredging and material relocation on coral reef communities are complex and are illustrated in Figures 1 and 2.

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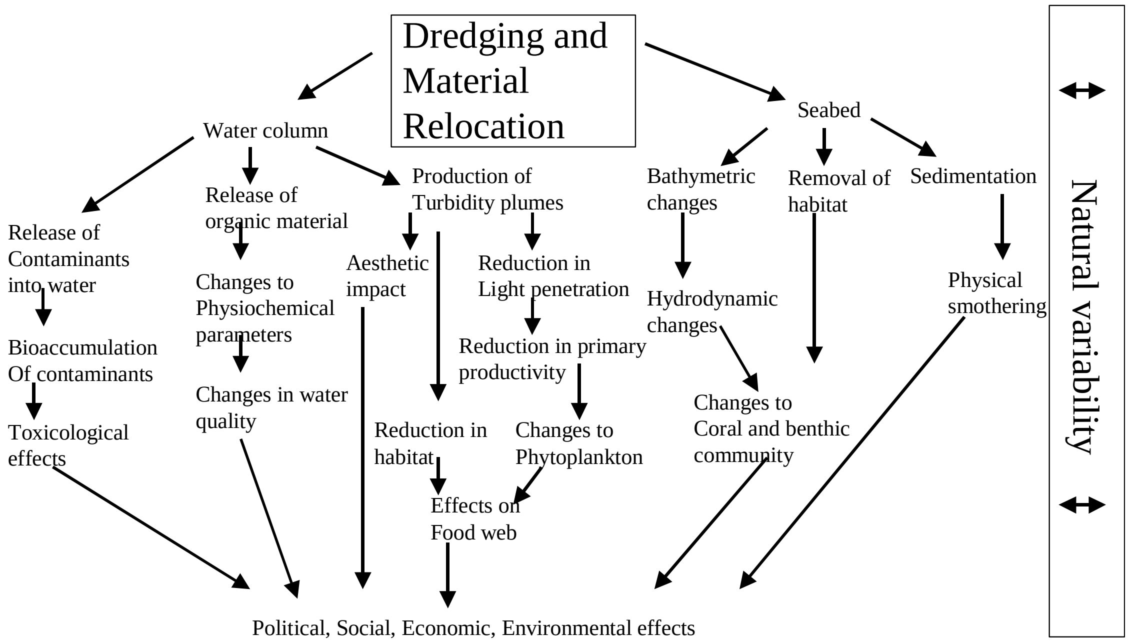

Figure 1. Conceptual impacts of dredging and material relocation on the environment (modified from Elliot and Hemingway 2002).

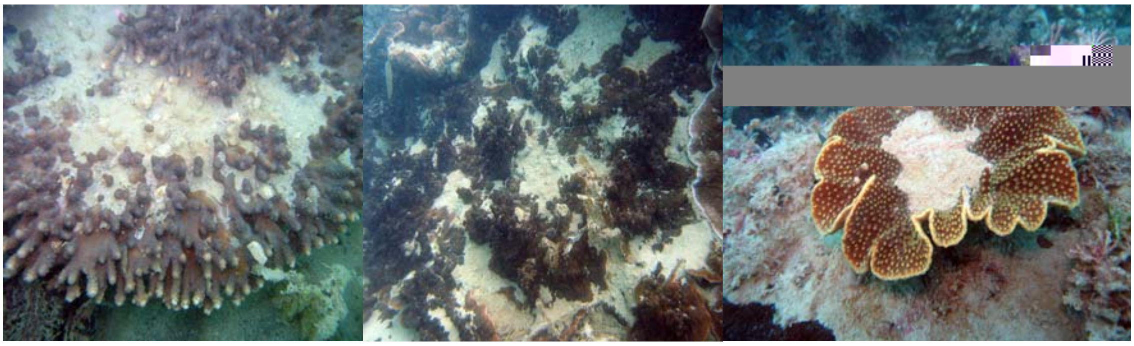

Figure 2. Several species of coral with partial coverage of sediment transported by plume and currents from dredging works approximately 6km away.

Marine construction activities, such as dredging in and around coral reefs and the temporary and permanent installation of structures, can have adverse impacts on coral reefs. These impacts may be directly due to construction and operation of the port or indirect due to other human impact stressors such as land-use, pollution and sedimentation or natural variability and stressors such as coral bleaching, weather, floods or disease (Figure 2).

Management impacts may be complex and include political, social, economic and environmental impacts (Figure 2).

Figure 3. Dredging a navigation channel to a marina using barge-mounted grab and silt curtains to minimise impacts to adjacent coral.

There is a body of experience in relation to the potential direct and indirect impacts of dredging and marine construction activities on coral reefs, and this enabled the objectives of PIANC Working Group 15 (PIANC 2007) to be established so as to:

- Collect available scientific and grey literature including case studies on dredging and port construction activities around coral reefs and their associated communities with an emphasis on shallow warm-water communities.
- Analyze the information in order to determine the effects of dredging and port construction activities on corals reefs and identify the methods/techniques used to minimise impacts, and
- Identify knowledge gaps, the environmental issues and practical constraints associated with implementation of the guidelines.

This paper is an initiative of PIANC Working Group 15 guidelines on "Dredging and Port Construction around Coral Reefs". A framework for best management practice that can be used as a guideline for projects by diverse stakeholders is proposed with planning, impact assessment, monitoring and management. Important components of each of these four processes are discussed with examples from developed and developing countries.

Scientific reviews of the environmental impacts of dredging in estuaries (Johnston, 1981) and seagrasses (Erftemeijer and Robin Lewis, 2006) will assist integrated management of adjacent non-coral communities.

PLANNING

A high level of strategic planning should be encouraged to place appropriate facilities at optimal locations but also ensure key ecosystem processes and corals are protected. Long-term planning and consideration of alternatives are essential to addressing environmental and other issues. Common planning processes prior to development of Environmental Impact Assessment (EIA) documents are Scoping and\or Risk Assessment meetings with all stakeholders to exchange information. At the early planning meetings there is always gaps in available information and often differences of opinion about relative importance of issues associated with dredging, material relocation and coral will arise. Extensive planning and consultation over several years are often required for obtaining the best environmental outcome and location in relation to capital dredging works associated with new port and marina locations, whilst several months of consultation may be adequate for routine maintenance dredging and material relocation operations.

Timing of dredging is a critical factor that can have considerable effects on the resulting environmental impact, environment, economics and the community. Planning the timing of projects to avoid periods of high risk (such as cyclone season) and critical or sensitive phases of the life cycle of corals (such as spawning) is generally accepted as best practice.

More recently, there has been a shift towards long-term planning for capital and maintenance dredging works on a 5 to 6 year basis rather than annual plans. This has benefits for the developer, contractor and the regulator and can lead to improved environmental outcomes.

ENVIRONMENTAL IMPACT ASSESSMENT

An EIA *is an assessment of the likely human environmental health impact, risk to ecological health, and changes to nature's services that a project may have. The purpose of the assessment is to ensure that decision-makers consider environmental impacts before deciding whether to proceed with new projects* (Wikipedia, 2007). While some form of EIA is mandatory in developed countries with coral reef habitats, there is no formal EIA process in some developing countries with reef habitats (GBRMPA, 2007).

Environmental Impact Management has evolved over the past 30 plus years (Wikipedia, 2007). The EIA processes have also changed as the field developed and also in response to shifts in key issues and technology. The historical approach which is still in use in some developing countries (Hoq and Swaminathan, 1997) has evolved and the current best practice is to have a framework of policy and guidelines, a risk based approach, longer-term simple permits, issue-based monitoring and a partnership approach (Table 1). PIANC (1999) has developed a best practise guideline on “Environmental Management Framework for Ports and Related Industries” with key components of Policy, Plan, Act, and Continual Improvement.

Table 1. Comparison of historical and best practice environmental impact management.

Historical	Best Practice
Case by case	1. Planning, policy and guidelines
EIS for small projects	2. Risk-based approach
Short term complicated permits - 1 year	3. Longer-term simple permits and EMP
Intensive, broad monitoring programs	4. Baseline and issue-based monitoring
Regulatory approach	5. Partnership approach with all stakeholders

Table 2 contains selected studies of the impacts of dredging on coral reefs. A summary of these individual studies indicates that dredging volumes ranged from 35,000 m^3 to 20 M m^3. A summary of the impacts of dredging on coral in Table 2 indicates they may be measured in different ways with percentage, area and, distance, and that a possible trend is that most impacts are detectable within 500m to 2km and up to 6km. The nature and scale of impacts of dredging and material relocation on tropical reefs are difficult to predict with satisfactory rigour, and in some cases are under or over-estimated by an order of magnitude (Table 2).

Table 2. Review of impacts of dredging and material relocation on coral reefs.

Country	Location	Year	Activity/Purpose	Scale of Impact/Damage	Impact Assessment/ Monitoring/Management	Reference
Thailand	Phuket	1986-1987	Dredging	30% loss cover & diversity	Recovery after 22 months	Brown et al (1990)
Australia	Hay Point	2006	Port, Capital Dredging 9M m^3	2-5% loss cover at 2 islands up to 6km away	Marine Park, BACI water quality and coral, Management Response Group	Smith et al. (2006)
Australia	Nelly Bay	2000-2004	Marina, Capital Dredging 35,000 m^3	18 ha construction area, no detectable impacts immediately outside construction area	Marine Park, reactive water quality and coral monitoring, transplantation *Porites*, Environmental Site Supervisor	Chin and Marshall, (2003); Koloi et al. (2005)
Australia	Dampier	2003-2004	Port, Capital Dredging 4.1M m^3	1 site 80% loss, within 1 km	BACI, 19 sites for 12 months	Stoddart and Stoddart (2004)
Singapore		2006	Reclamation 9 Mm^3	No detectable impacts 300m outside direct impact area	Detailed EIA and Feedback EMP. Construction activities controlled by spill budget	Doorn-Groen and Foster (2007)
Indonesia	Turtle Island	1997	Dredging and Reclamation 20 Mm^3	No detectable impacts 300m outside direct impact area	Detailed EIA and Feedback EMP. Construction activities controlled by spill budget	Driscoll (1997)
Malaysia	Bintulu	2005	Borrow dredging $4Mm^3$	No impacts detectable 2km from borrow area	Detailed EIA and Feedback EMP, Construction activities controlled by spill budget	Doorn-Groen and Foster (2007)
Malaysia	Kota Kinabalu	2004	Reclamation for port construction $2Mm^3$	No detectable impacts 500m outside direct impact area	Detailed EIA and EMP	Doorn-Groen and Foster (2007)

One of the key environmental impact assessment tools is risk assessment and this process should be undertaken early by all stakeholders and reviewed regularly throughout the life of the project, as more information is available. Some countries have formal risk assessment processes (Figure 4) and in this model, one of the un-stated processes is ongoing communication and consultation. The risk assessment process is essential in determining issues and impact potential and indicative management and monitoring tools (Table 3).

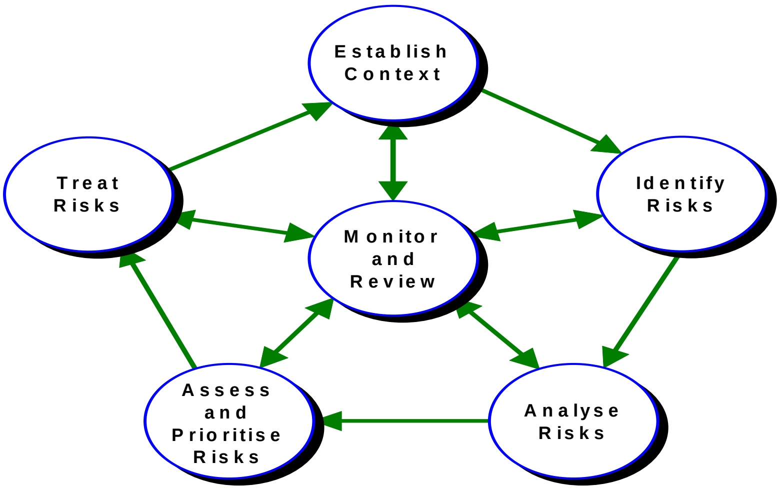

Figure 4. Model for risk assessment

One of the challenges in EIA is balancing policy and individual project management. Developers often wish to know up front how their project will be managed and what it will cost in terms of time and money. These questions are linked to risk assessment and further guidance is provided in Table 3 for four scales of minor to complex projects. Obviously, the more complex the project with more risks, the more management is required in minimising risk.

The questions in Table 4 are also useful to explain the issues and their relationship with the information that can be obtained and the costs and benefits of different tools and techniques.

Table 3. Assessment levels, impact potential and indicative monitoring and management tools (modified from GBRMPA 2004).

Level	Title	Impact Potential	Level of Environmental Impact Assessment	Indicative Management Tools
1	Minor Project	Minimal and/or transient	Routine administration	Compliance
2	Small Project	Low and or short term	Targeted baseline measurement period. Key interest group community consultation and EIA	Site inspection, Deed, > $50,000 bond
3	Medium Scale Project	Medium scale project, Public Interest, Sensitive Environment, Moderate and medium-term impact	Extended baseline measurements and wider community consultation. Detailed EIA	Site inspection + issue based monitoring, EMP, Deed, > $250,000 bond
4	Complex Project	Large scale project, Public Interest, Sensitive Environment, long-term, Irreversible and/or major impact	Extensive baseline measurement period covering all relevant parameters and seasons. Extensive community consultation process. Detailed EIA	Site inspection + issue based and adaptive or feedback monitoring, EMP, MRG, Environmental Site Supervisor, Deed, > $500,000 bond

MONITORING AND MANAGEMENT

Environmental Impact Monitoring is an important process that is required to confirm that a project is meeting the agreed level of impact and that the predictions of impacts developed in the EIA process have been accurate. Inclusion of an adaptive monitoring process allows the nature of the dredging and relocation works to be continually adjusted so that maximum productivity can be maintained whilst environmental protection criteria are still achieved.

In order to develop an effective monitoring program it is necessary to identify the values of the area that are of concern and require protection or management. Once the value to be protected is defined, by applying an understanding of the processes of the particular dredging and relocation exercise and its interaction with the physical environment of the site (eg. wind, waves and currents), it is possible to predict the impacting processes and vectors that may apply to the identified value.

Selection of an appropriate monitoring method should include consideration of key issues, what proven methods are available, risk, and whether to either directly monitor the identified environmental values (e.g coral) or to adopt an indirect monitoring process that monitors the vectors of impact or other sentinel organisms that will respond more rapidly to the impact vector than the target value (e.g water quality) (Table 4). For example, in a dredging program that is adjacent to a coral reef in a remote location with regular poor weather, it may be better value to monitor water quality changes (eg: turbidity) at the site through remote telemetry rather than directly monitor coral health when the turbidity response of the corals at that site is well understood. Importantly, a baseline survey of the principal value (in this example coral) is required to provide a measure of pre-project conditions of impact and control (see below) sites and for measurements of change as the project progresses, this will form the basis of any comparison to confirm that the project was completed without exceeding the impact criteria agreed for the coral community. Baseline data are still vital even if monitoring is to be indirect (eg turbidity) to also allow monitoring to revert to direct coral monitoring should the turbidity monitoring indicate that agreed thresholds have been exceeded and there is a risk that corals will be impacted. Upfront agreement of this style of staged monitoring where initial monitoring is indirect (eg turbidity) whilst all results are below the agreed trigger thresholds and then escalate to direct monitoring (eg coral) if the agreed trigger thresholds are exceeded is economically effective in protecting the principal value if the vector and impacting process are clearly understood.

The use of staged monitoring programs can therefore offer financial incentives to the dredgers to operate at levels that do not exceed the agreed triggers, hence, saving monitoring costs whilst the operation remains in a state of conformance with agreed triggers.

In all cases, monitoring must utilise proven methods if it is to be effective. More experimental techniques may be appropriate if they are also supported by other proven methods.

As all natural systems are in a constant state of change, it is vital to include off-site “control or reference” sites in a monitoring program to ensure that natural changes do not mask impacts and equally that natural changes are not interpreted as impacts. Selection of appropriate “control” sites is vital for the comparison to be valid, that is the "control" sites need to be outside the reach of the impacting process and the habitat and coral community must be as close as possible to that present at the impact monitoring sites, including water depth, coral cover and composition, water currents, turbidity, waves and aspect.

Two of the techniques in Table 4 are explored in more detail. The first is Environmental Management Plans (EMP), which are an essential tool to manage operations and to ensure practical steps are taken to complete the project while providing the necessary protection for the environment. The EMP should be simple, effective, designed to suit the particular operation/location and dynamic (can change with time, including through continual improvement). Generally, an EMP will comprise an introduction/description of the operation and the surrounding area and then a series of elements that deals individually with the issues specific to the operation and site. See Table 5 for more information on EMPs and how they can be applied.

The second technique is satellite imagery that is potentially useful for large projects where there is likely to be significant variability of the impacts of dredging and material relocation (see Figure 5). This technique is reasonably cost effective, visual and has been valuable for community and managers for understanding spatial spread, movement and dispersion of sediment plumes on a near-daily basis (Wang et al. 2006) but is not always reliable due to cloud cover, technology limitations such as resolution and breakdowns and poor response time due the level of coverage and satellite images illustrate the surface-visible impact and not the bottom-layer impact. However this technique is good value for ‘big picture’ causality of field-collected data.

Table 4. Management questions and monitoring techniques. Key-EMP- Environmental Management Plan, ESS- Environmental Site Supervisor, MRG- Management Response Group.

Question	Technique	Description	Advantages/ Disadvantages	Data collected
Is coral likely to be impacted by dredging or material relocation?	Scoping Risk Modelling Baseline	Search of existing information Meetings	Scoping and risk assessment meetings focus all stakeholders on key issues and mitigation Modelling provides visual options but requires good information, and if environment is variable, it may be inaccurate (up to 300 %, Morris, 2004)	Presence/absence of coral Scale and risks of works on coral Wind, wave, currents, turbidity Options
What is the area or species impacted?	Quantitative surveys, maps at impact and controls Risk assessment Satellite photos	Field surveys to investigate impact and possible control sites	Surveys useful for small areas (10's to 100's metres) Satellite photos useful for large area (km's)	Percentage cover and diversity of coral at several locations
What are the communities views?	Consultation	Brochure, letter, meetings, media	Have all key stakeholders been consulted? Have they been involved in decisions?	Perceptions, values, community activities, existing use
How can impacts be minimised?	EMP Modelling Management Reference Group Rehabilitation Risk assessment	Regulatory tools such as permit Adaptive tools such as MRG Project refinement / redesign	Changes and unpredicted impacts will occur Need decision-makers to work in partnership with developer Managers input into acceptable levels	Options for works impacts on environmental, economic and other values
Are the predicted impacts in the EIA accurate?	Modelling verification Monitoring	Computer printouts, reports Field data on realised response	Monitoring may be costly (often 0.5-10% of construction costs) Provides feedback for continual improvement Essential for managers and community	Comparison of EIA hypothesis with what happened
Has the dredging complied with all legislation, permits?	ESS Auditing Partnership	In-house or independent review or audit	Transparent and adaptable process	What has happened?

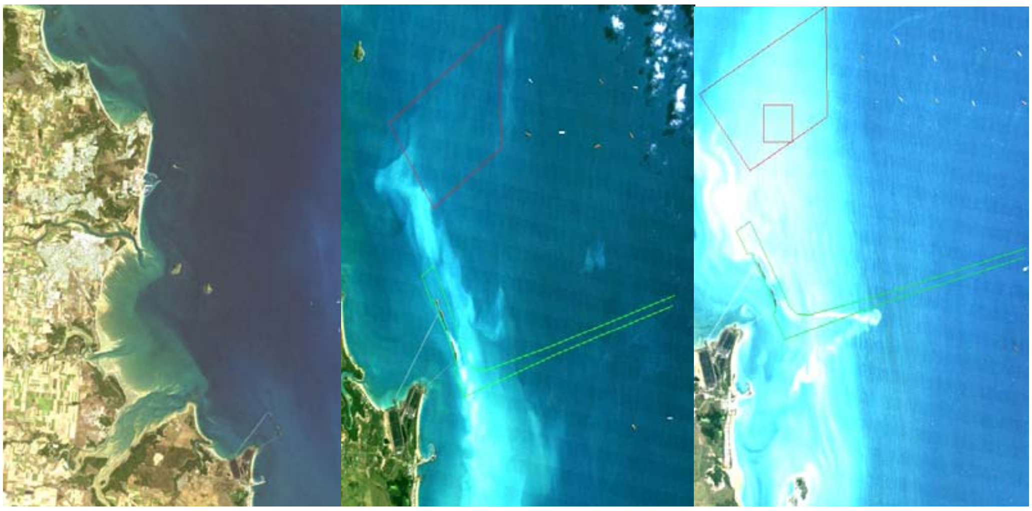

Figure 5. Baseline satellite photograph compared to two plumes during dredging at Hay Point, Australia.

Table 5. Structure of activity or issue based EMP elements.

EMP Element Component	Activity based EMP eg. "Dredging"	Issue based EMP eg "Coral Health"
Activity or Issue	The activity of the operation/construction being managed or considered.	The environmental matter being managed or considered.
Potential Impact/s	Description of the potential effects of the activity on all environmental issues	Description of the potential impacts of all activities on the environmental issue
Aim	What the EMP element hopes to achieve for that activity	What the EMP Element hopes to achieve for that environmental issue
Management Strategies	How the activity will be managed to achieve the aim	Same as activity
Performance Indicators	What will be measured to show that the aim is being met.	Same as activity
Responsibility	Who will be the person nominated to manage this element	Same as activity
Monitoring and Reporting	How, and when will the performance indicators be measured to test whether the aim has been achieved.	Same as activity
Corrective Action	Improve. The action to be taken and by whom, if a performance requirement is not met.	Same as activity

BEST PRACTICE EXAMPLE - ADAPTIVE MONITORING AND MANAGEMENT PROCEDURES

Adaptive Monitoring and Management Procedures – sometimes termed Feedback EMMPs (Environmental Monitoring and Management Plans) are presently regarded as international best practice for managing and avoiding dredging impacts in proximity to sensitive environmental receptors such as corals (Doorn-Groen and Foster, 2007). The Feedback EMMP is based on environmental quality objectives (EQOs, which are quantifiable compliance targets covering multiple temporal and spatial scales) and effective and rapid response mechanisms, to allow feedback of monitoring results into compliance targets and work methods. The EQOs are set by the regulator, based on the results of the pre-project EIA, and are usually developed in consultation with relevant stakeholders.

Modelling of sediment spill and sedimentation is used to determine the maximum daily production rate and daily sediment spill that could be allowed while still meeting the EQOs. This is referred to as the spill budget, and is used to control the dredging activity on a day-to-day basis. Data on the level of sediment spill are then collected from every dredging run by sampling the spill at source (for example, in the dredger overflow). These data are used to model the sediment plume from each dredging run. The model results are then used to assess the impact of the realised dredging activities at multiple locations, and even from multiple projects, so that cumulative effects are taken into account.

Tolerance limits for sensitive receptors (e.g. coral reefs) are established based on literature and site specific experimental data, and agreed by the regulator and relevant stakeholders. These are used to determine whether or not the level of suspended sediments or sedimentation at a given environmental receptor, based on the modelling, meets the EQOs or not on a daily basis. The feedback process is then undertaken, so that if the EQOs are not being met, the spill budget is adjusted accordingly (for example vial re-timing of activities to benefit from tidal windows) or other mitigation measures (e.g. silt screens) are used, to bring the dredging into compliance with the EQOs. This feedback and adjustment of dredging rates occurs on a daily basis, well before any impacts could actually occur (or be detected) in the field. Habitat monitoring is used to update tolerance limits if required and provide documentary evidence that EQOs are being met.

CONCLUSIONS

Over the past few decades, environmental issues have dominated the agenda of many governments, national and international organisations. As the overall global environmental quality has declined and human pressures on resources have increased, there is a need for government, industry and the community to adopt best practise. The cumulative environmental impacts of thousands of capital and maintenance projects are of global concern (Wilkinson, 1998; 2004; UNEP, 2006). However, some countries have shown leadership and planned and minimised their impacts on environmental values such as coral reefs while maintaining essential port and shipping activities. We should be adopting these best practise examples for future capital and maintenance projects.

When properly applied, scoping and long-term planning involves options, risks and decisions, and then followed by comprehensive project-based EIA processes with adaptive monitoring programs and management are effective at protecting the environmental values of a site. Staged monitoring programs may also provide economic incentives to dredgers to operate in a state of conformance with agreed environmental performance criteria.

A major challenge is to have a common approach to the terminology, methodology and management of dredging and material relocation. The terminology for impact assessment varied between projects in Table 2 with impacts measured by percentage, area and distance. Similarly the terminology for monitoring and management in Table 2 varied between projects and included BACI (Before After Control Impact), EIA, EMP, Feedback EMP, Environmental Site Supervisor, Management Response Group, reactive monitoring and spill budgets.

This paper introduces some ideas that will be further developed in PIANC Working Group 15 guidelines for “Dredging and Port Construction around Coral Reefs”. It is the aim of an Environmental Committee and PIANC Working Group 15 to produce state-of–the-practice guidelines on appropriate EIA, management and mitigation measures of dredging and port construction around coral reefs. The generic guidelines on dredging and material relocation around coral reefs will also account for local unique conditions using examples from case studies. Moreover, the guidelines will highlight the important issues in the planning of such work and how they might be addressed. If you would like to comment on the draft guidelines please refer to PIANC (2007). These guidelines are due to be completed in early 2008.

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ACKNOWLEDGEMENTS

We would like to acknowledge the initiative by PIANC to form a working group to develop guidelines on Dredging and Ports in Coral Environments. We would also like to acknowledge the contribution of the members of PIANC WG 15: Constantijn Dolmans (Secretary General- International Assoc. Dredging Companies, Netherlands), Paul Erftemeijer (Delft Hydraulic, Netherlands), Kobbe Peirs (Jan De Nul, Belgium), Caroline Fletcher (HR Wallingford) and Hidekazu Yamamoto (ECOH Corp, Japan). We would also like to thank numerous other PIANC members, governments, ports, consultants, scientists and managers who have contributed to useful discussions.

We thank Dr Tony Ayling for the use of photos in Figure 2 and Geosciences Australia for the satellite photos in Figure 5.

We thank John Dobson (Eastern Dredging Association), Dr Eric Wolanski (Australian Institute of Marine Science), Dr Rick Morton (Port of Brisbane Corporation) and Peter McGinnity (Great Barrier Reef Marine Park Authority) for providing comments on the draft manuscript.