CEDA Position Paper

INTEGRATING ADAPTIVE ENVIRONMENTAL MANAGEMENT INTO DREDGING PROJECTS

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Contents

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INTEGRATING ADAPTIVE ENVIRONMENTAL MANAGEMENT INTO DREDGING PROJECTS

The Central Dredging Association is committed to environmentally responsible management of dredging projects and this position paper - produced by the CEDA Environment Commission - outlines concepts of integrating Adaptive Management (AM) for the enhancement of the environment into dredging activities (inclusive of placement / disposal / reclamation).

1 Preamble

Dredging projects (including capital works as well as recurring maintenance campaigns) are often permitted with license conditions or regulations based on an assessment of the potential environmental effects. In some cases strict thresholds might be applied to assure environmental performance with levels deemed to be acceptable, based on the findings of impact assessments. In other cases less clear environmental limits are specified: sometimes due to uncertainty about effect on and responses by nature, caused by inability to fully appreciate and judge environmental conditions (sensitivity of receptors) and potential project effects (vulnerability to changes); or for other reasons such as sharing responsibilities and risks. Effects on the environment can be both negative as well as positive and monitoring of both outcomes is sometimes required, although monitoring of potential negative impacts is more common to ensure protection of the environment.

For those dredging projects where the outcome is less certain, or accompanied by a low confidence in the prediction of effects, a sequence of more intense and targeted monitoring, impact assessment and management actions might be implemented on a continuous or regular basis for the duration of (and after) the project, in order to keep project expectations and implementation requirements more manageable. This sequence of activities is jointly understood as 'Adaptive Management'(AM),

although interpretation and ways of implementation may vary considerably between projects, and even between different stakeholders on any project.

AM can be an efficient and cost-effective management process in dredging projects where the objectives are clear, yet the potential for local environmental effects are uncertain, and management actions can be implemented in a stepwise procedure to address those uncertainties as the project progresses.

AM helps to achieve desired goals by addressing uncertainty, incorporating flexibility and robustness into project design, and using new information to inform decision-making as the project develops. Goals include an efficient project design and streamlining implementation protocols to minimise wasting resources which, when holistically viewed, could be decreasing the project's overall environmental footprint.

AM in dredging projects represents a "modern" approach and has the potential to become good practice in the future. It underlines the commitment to find suitable options with strength in process optimisation from various aspects. It is not likely that AM will become good practice for all kinds of dredging projects in the future, but the advantages are seen especially for the larger scale projects and multi-year projects (including maintenance works).

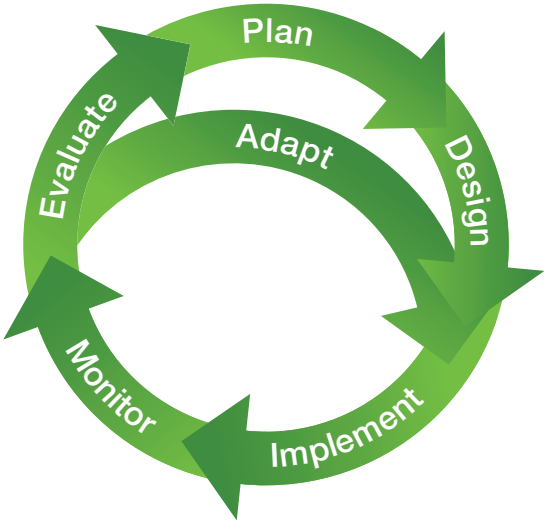
The need for integrating AM into dredging projects is already becoming recognised, but will probably increase in future, if not in response to the uncertainties resulting from climate change (CEDA, 2012), then in reaction to an ever growing awareness of the need for protection of the environment, as well as in connection to the ecosystem services approaches (CEDA, 2013).

This paper aims to provide information on the objectives of applying AM, what circumstances define opportunities for AM, which conditions need to be fulfilled by various stakeholders and how AM shall be governed during implementation of the project. Finally, lessons learned will be presented, based on case histories of successful application.

2 Adaptive Management, and what it can deliver

AM is a decision framework that facilitates flexible decision-making that can be refined in response to future uncertainties, as outcomes from current and future management actions become better understood. Adaptive management typically involves developing and implementing a management plan that defines the project goals, reviewing progress towards those goals periodically, and, in response to the outcomes of (environmental) monitoring, implementing corrective actions (and refining the plan), as needed, in future.

AM is a formal process, with specifically agreed upon steps to deal with uncertainties. AM in dredging projects prescribes a process wherein management actions can be changed in response to monitored system response, so as to maximise efficiency while maintaining or achieving a good ecological state. The basic steps of AM, included in Fischenich and Vogt (2012), are illustrated in Figure 1.



1. **Plan**: Defining the desired goals and objectives, evaluating alternative actions and selecting a preferred strategy with recognition of sources of uncertainty;
2. **Design**: Identifying or designing a flexible management action to address the challenge;
3. **Implement**: Implementing the selected action according to its design;
4. **Monitor**: Monitoring the results or outcomes of the management action;
5. **Evaluate**: Evaluating the system response in relation to specified goals and objectives; and
6. **Adapt**: Adapting (adjusting upward or downward) the action if necessary to achieve the stated goals and objectives.

Figure 1: Adaptive Management Cycle.

The monitoring - evaluation - adjustment loop is the basis of AM and can be established as a solid element of the project management.

AM offers advantages but also risks for dredging projects in that the monitoring and management required can change regularly throughout the project causing difficulties for overall project budgeting. Further, AM is not a common industry practice yet, which makes the implementation in a project difficult, as it does not come along with a "ready-to-use" solution. However, developing AM as part of project execution strategy will potentially facilitate implementation of a more optimal (less conservative) project, with inherent cost savings. Therefore, when incorporating AM into a project, early involvement and open dialogue with all stakeholders throughout all phases of the project is of utmost importance. Table 1 illustrates the pros and cons associated with AM projects; these are further elaborated later in this paper.

Table 1: Potential benefits and disadvantages of an AM approach.

Project Consideration	Potential Benefits	Potential Disadvantages
Environmental	Enables a project with uncertainties relating to the environment to go ahead with agreed monitoring and management to control actual effects. Effective method of protection for the environment, especially if tiered management approach considered. Can reduce indirect project impact by inefficient use of resources due to application of the precautionary approach.	In rare instances, Adaptive Management may be used as an "excuse" for poorly conceived design or project implementation. Uncertainties in environmental effects will need to be agreed upon with attendant management actions if monitoring indicates worse or better effects than predicted. This is a disadvantage only because it takes more time and effort to map out the effects and management actions.
Legal/Permitting	AM approach may allow projects to proceed with a licence being granted, with uncertainties about sensitive receivers to be addressed.	AM approach may conflict with prevailing laws, which are often based on the precautionary principle. Such cases need to be identified in a timely fashion with the regulating authority.
Effort and economics	AM involves a case-specific solution. Initially more effort may be required, but overall project effort shall be in line with actual environmental sensitivities, possibly resulting in lower total effort and hence cost. The continued striving for improvement will keep the attention level high, which will be advantageous for the overall result and increase knowledge in general.	Uncertainty over effort required throughout duration of project. Exact advance budgeting for total project cost will be difficult, as AM leads to case-specific changes. Allowing for provisional funds facilitating AM could be considered. Project duration might be extended, if decisions take long and/or execution has to be slowed down.
Contractual	Contract with allowances for flexibility reduces potential for conflicts.	Increased effort in contract management, i.e. who takes the project risk of increased and variable management.
Social	Stakeholder trust may be improved by transparent process, including open communication on project development.	Stakeholders may sometimes perceive AM to be used by project owners to justify unwanted (or less than optimal) project outcomes. If management reduces as a result of monitoring, there may be some reluctance to reduce the scope by certain stakeholders.

3 Implementing Adaptive Management

3.1 Management considerations

AM is more challenging than management following a fixed procedure. As for the structure of the management organisation AM basically requires:

- a temporary more intensive Monitoring, Evaluation and Adjustment (MEA) commitment;
- higher budget and resource requirements for MEA;
- a mechanism to deal with a lower or higher effort due to newly identified requirements;
- a mechanism to deal with differing total costs from the initial calculation;
- strong cross-sectoral project management skills;
- flexibility for a differing implementation timeframe.

Following the precautionary principle as frequently done within projects at present (avoiding all uncertainties), a worst-case scenario is used as basis to determine roughly the maximum project expenditure. Since AM is targeted towards a case-specific solution, it is unlikely to result in a worst-case expenditure. Depending on the environmental receptors sensitivity either worst-case scenario or a less conservative scenario might be used as starting point. Benefits potentially can be achieved on various components, e.g. finance, environment or logistics. Additionally, benefits can be achieved through alternative solutions not considered originally, but which appear to be feasible based on monitoring evaluation during the process. On the other hand, achieved results might be below initial expectations. Therefore, setting the initial criteria based on the sensitivity of the environmental receptors is crucial.

The overall goal of the project has to be defined and described by measurable Key Performance Indicators (KPI). Environmental KPIs based on the consideration of available options should be defined at the project planning stage. Furthermore, KPIs should not be restricted to the usual monitoring parameters only, but aim towards an optimal total performance, for instance, by monitoring an indicator like 'stakeholder opinion'.

AM and environmental monitoring enables adjustments to be made as the project evolves, and, therefore, builds in inherent flexibility in terms of project approach. This may result in changes of activities that can be difficult to understand, mainly by the public, and hence there is potential for criticism and questions.

Photo 1: Informing the stakeholders (Lumut project).

Bringing the public (and in general stakeholders) into the process early is a key element of AM, such that a common understanding is developed of the project uncertainties and opportunities, monitoring and possible adjustments to project operating processes. In terms of public perception, the positive aspects of AM need to be focused on and also communicated wisely in a transparent way to be able to adjust to given/arisen situations. Communication with the Regulator and prior agreement of the approach is beneficial to the success of an AM approach. The communication should start early on in the project and will need to be maintained throughout the life of the project and, in some cases, beyond. The agreement of the following aspects is important in this respect:

- specific thresholds for effect;
- tiered levels with triggers for action;
- monitoring methodology (including frequency);
- review process for adjustments;
- required response times; and
- decision-making process.

Each step identified above should be clearly set out within an Adaptive (Dredge) Management Plan document that is ideally agreed with the Regulator prior to commencement of the dredging project.

Where the interaction between project owner/developer or client, regulators, 'operators' and stakeholders is essential, also, contractors are involved as early as possible. Contractors have access to a wealth of valuable

practical experience which allows them to predict the impact of mitigation measures on the project budget and the achievable environmental result. Hence, as regards, in particular, projects with one or more substantially uncertain components (technical risk, environmental effects, etc.) a way out may be found by involving a contractor from an early stage. How this may be arranged, in a competitive setting, is illustrated in Section 3.3.

3.2 Legal aspects, e.g. permits

The legislative framework has to be considered throughout the entire project planning, design and implementation phase. All potential project approaches need to comply with current law, but do not necessarily need to be approved on their own; a combination of options can qualify for approval even if a single option would not be licensable on its own.

Due to the nature of the aquatic environment, there is likely to be many situations where there is uncertainty in the predicted outcome of a project relating to the likelihood and significance of impacts. This may influence the regulatory conditions applied to the project and lead to a precautionary approach being taken to the monitoring and management of the dredging project. Such an approach can affect the duration of a project by extending the timescale and incurring additional costs of management. With an Adaptive Management approach it is possible to ensure that management is only undertaken if needed to protect resources and that if dredging is undertaken within monitored triggers that early warnings can be applied to avoid non-compliance with regulatory conditions.

The role of the Regulator, and degree of involvement, is dependent on the specific project details and environmental conditions. Greater degrees of control are likely to be stipulated for more sensitive locations. In such situations, the Regulator may require a high degree of involvement including agreement of specific stages of monitoring or regular compliance updates.

An independent technical and environmental advisory panel can assist in decision-making by the authorities. Such a panel can agree specific stages including the setting of thresholds for determining management triggers and also for making informed decisions when monitoring results are collated. Advisory panels should have adequate powers in order not to slow down this process.

3.3 Tendering procedures

Budgeting for AM has to include a margin for budget fluctuations. Of course, the project developer wants to know how much he will have to pay at the end. However, sometimes the environmental conditions are simply too complex to make a precise estimate in advance. In particular, in this situation early contractor involvement and open dialogue throughout all phases of the project can be of utmost importance, as a tool to encourage new ideas on managing the project adaptively. That said, the project developer or owner has to follow carefully selection procedures to engage with a contractor, while the scope and conditions of the project are not yet fully set. The below steps (and Figure 2) present as guidance an example procedure (seen from the perspective of a project developer or client), based on procedures that have been successfully applied recently in the dredging industry. Note that different procedures can be adopted for project specific applications.

- Define a ‘Reference’ Project Scope, e.g. on the basis of a conceptual design, and indicate ‘grey areas’ that can be identified and elaborated during a project (contractors need to know the thoughts of the client: which areas are regarded as highly uncertain, which are considered to be essential, etc.).
- Accommodate further study and experiments in order to reduce the uncertainties mentioned above, if possible. Initially, this will be an additional cost, but in most cases only a fraction of the return obtained through this knowledge.
- On the basis of the project scope invite contractors to present their views on the project, and to highlight further uncertainties or opportunities as they see them, with a special focus on risk distribution between client and contractor. Ask for firm pricing for the fixed part of project (or a notional part of the project), with suggestions how to approach and against what effort and cost for the uncertain, flexible part. The aim is to identify potentially feasible approaches and to establish whether the submitted price levels are within an acceptable range.
- Invite all contractors to resubmit their proposals based on a Revised Project Scope, in which all feasible ideas received during the ‘first round’ are incorporated.
- To reward contractors for their early input besides price, an award mechanism to value this input should be adopted (e.g. through a pre-agreed system of bonus points or virtual tender price deductions).

Care has to be taken that, instead of rewarding, contractors are not excluded from tendering based on laws regarding foreknowledge. The client needs to establish clear criteria to evaluate these matters in order to create a transparent and auditable selection process (possibly by adhering to Best Value Procurement principles).

- The selection process may include workshops to obtain understanding and to find out more about the potential contribution of the contractor. In addition, if a joint approach is being aimed for (depending on the contract), these workshops are also tools to determine whether cooperation will be viable with the contractor.
- Contract award may take place on the basis of fixed part with fixed and variable prices, plus a valuation against KPIs, including technical and environmental performances, quality system, Health, Safety and Environment (HSE) criteria and cooperation potential.

The contract needs to allow for coping with the uncertainties and opportunities, for instance, through a lump sum price with a well-defined delay percentage related to environmental performance. If the actual performance during construction is worse or better (while still adhering to agreed work methods), a bonus-malus (pain-gain) regime may be helpful to reflect this.

Note that pain-gain sharing is purely a financial mechanism, while a bonus pool based on a KPI mechanism might be even more helpful. These key performance indicators may include next to environmental values, social, communication matters, etc. It will be clear that a sound scoring system needs to be established reflecting whether the performance is poor, normal, good or outstanding. Normal is business as usual, i.e. probably no bonus to be earned.

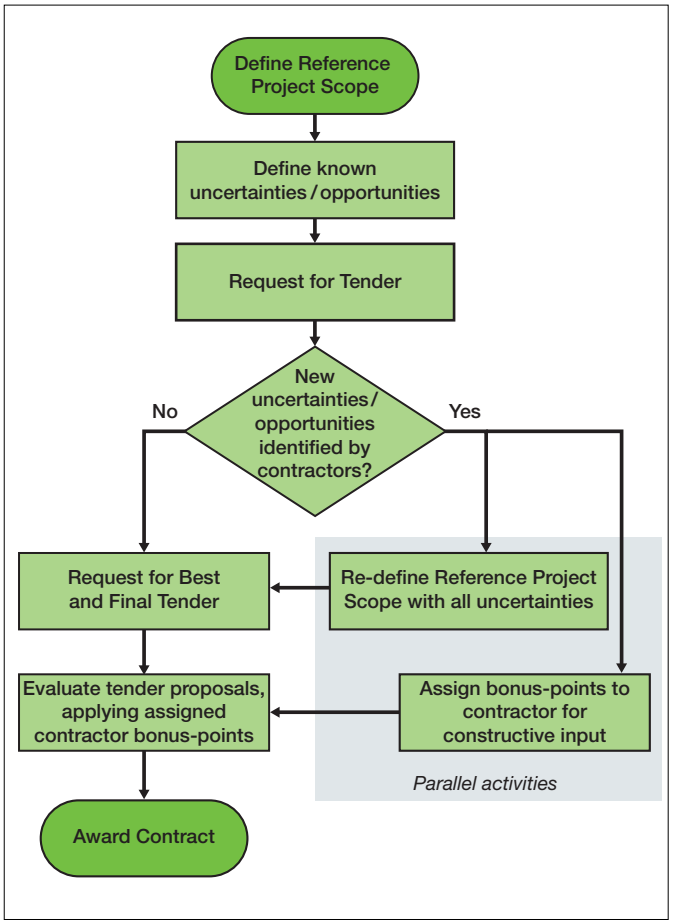


Figure 2: Example procedure for tendering an AM project from the perspective of a project developer or client.

4 Critical success factors for Adaptive Management

Clear objectives for a project's environmental requirements are essential for successful implementation of an AM approach. Ideally, tiered management triggers are set to enable early warnings to be reached such that action can be taken before an impact is likely to occur. The methods and options for monitoring and management need to be clearly defined with roles and responsibilities agreed in advance. This is usually specified in a project specific AM Plan.

4.1 The Adaptive Management Plan

Experience has found that the best way to apply AM practically is to produce a management plan which defines the types of actions, procedures and compliance measures to be implemented during the execution of the works. This is often produced as a standalone document, e.g. as an Adaptive Management Plan (AMP), Mitigation, Compensation and Monitoring Plan (MCMP), or as a section within a Dredged (Material) Management Plan (D(M)MP). Regardless of format, these documents should always be project-specific and tailored to site conditions, the environment, politics, regulations, economics and other practical considerations. The plan (and trigger levels) should be re-evaluated as and when new data are analysed throughout the life of the project to ensure the AM procedures remain appropriate. Regular discussion of the plan with the relevant authorities may also prove beneficial. If new appropriate (and approved) criteria are established, the plan can then be amended as a result of the findings of AM to improve the delivery of the project.

The AMP should include the procedure for integrating AM during the project implementation phase. Figure 3 shows a simplified approach.

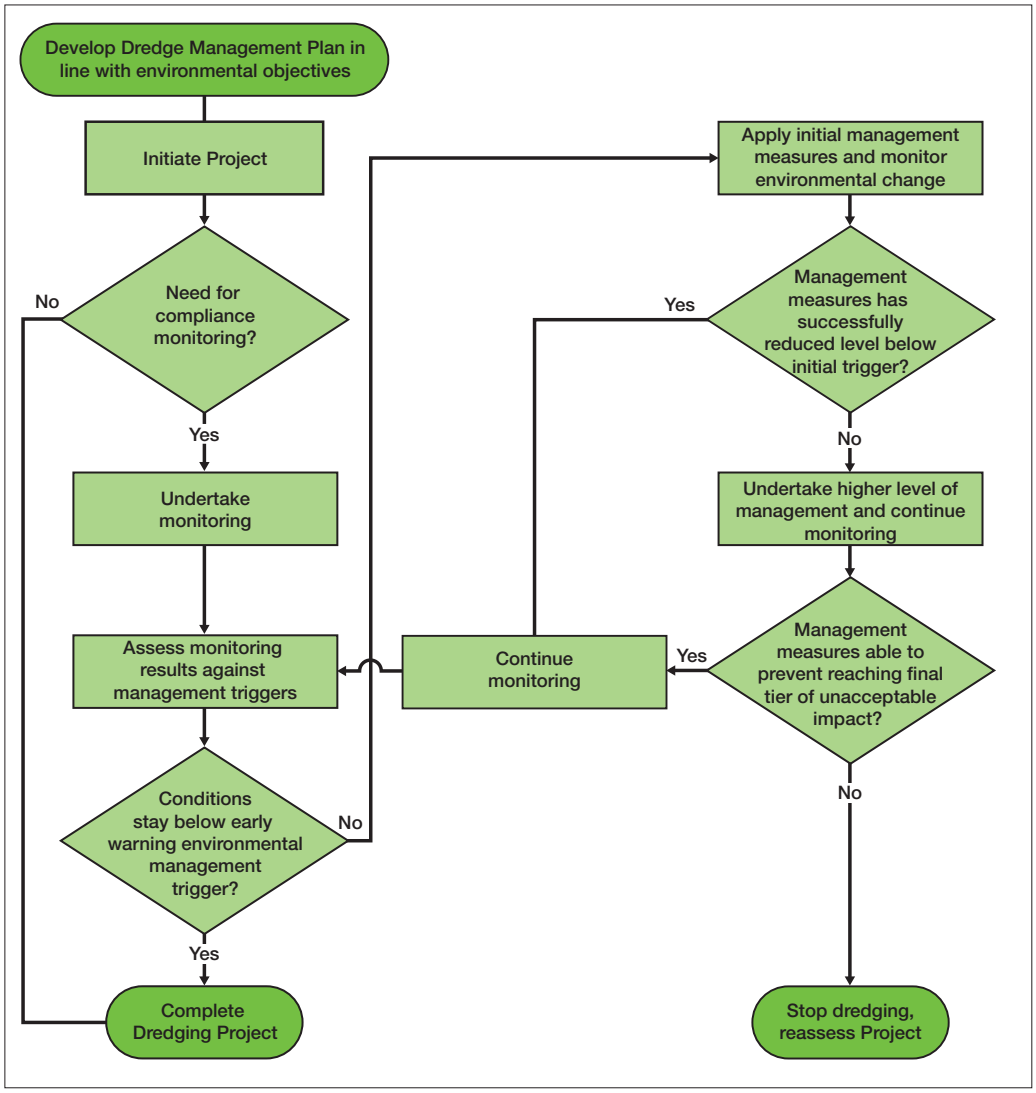


Figure 3: Simplified stepped process for integrating Adaptive Environmental Management in a dredging project.

4.2 Understanding the baseline and natural variability

Baseline information, such as that found in the Environmental Impact Assessment (EIA), is critical as it is the foundation upon which the project works are defined – via permitting and monitoring. The baseline should ideally be undertaken for a long enough period of time to ensure that any natural variability is able to be accounted for. Otherwise, changes may occur during the monitoring, which are due to long term natural trends that may affect the Adaptive Management process.

It is always recommended to collate baseline information from control (reference) sites in addition to sites that could potentially be affected by the dredging project, to compare the impacts that may occur due to natural change or change due to other projects.

4.3 Understanding sensitivity and setting management/trigger levels

By understanding critical receptor sensitivities and timings at the planning stage (e.g. migrations, breeding seasons, tolerable turbidity levels during periods of flora growth), works can be adapted from the outset to ensure the environmental objectives are met.

Modelling is typically a key method for establishing the likely zones of impact of the works on sensitive receptors. Monitoring results can be used to validate and adjust models, enabling predictions to be refined and further improving AM possibilities.

A realistic timetable for the dredging works that takes into account seasonal variations and getting the scale/scope right before the mobilisation of the monitoring spread contribute to keeping the project cost-controlled and on target. As part of the AM process, adjustments (up or down) to the monitoring may be found to be appropriate.

By identifying the ecological and economic value of sensitive receptors and the detailed nature of their thresholds for sensitivities, appropriate trigger levels and their confidence limits can be proposed. Such proposals must then be interpreted in terms of practicality with respect to the proposed works. The management approach needs to be flexible enough that it can be changed if the receptor is appearing to show an impact when it was not expected. This can work both positively and negatively; if a threshold (or trigger) level is exceeded when a reaction was expected and a reaction was not actually observed then the trigger level may be set too low and could be revised. Alternatively, if a reaction is observed before it was expected, the trigger level needs to be lowered.

> *AM can be used to monitor both physical and biological parameters. It is often better with physical parameters, as the reaction time is much quicker than with biological parameters. In the latter case, it can take a while to see any visible signs of stress, by which time it may be too late for adaptive action. Biological parameters are however important to ensure verification of the physical thresholds too.*

Defining the triggers by which the works are to be managed is clearly key. However, for AM to be truly successful, it is important that the monitoring of predicted effects on the sensitive receptors is also capable of discriminating unanticipated effects. Monitoring practices and triggers should be adapted as appropriate in response to all effects.

> *As an example of adaptive monitoring: It might be predicted that sea grass will be adversely affected by the works on a particular project. However, the monitoring could demonstrate that this is not the case, but the dugongs feeding on the seagrass are affected. Good AM would in this particular case result in the monitoring programme being adapted to monitor the effect on dugongs rather than continuing to monitor sea grass.*

The biggest issues to overcome are generally related to not understanding the sensitivities of the receptors properly and/or poor performance of monitoring.

> *It can prove to be a great challenge to set trigger levels for complex receptors like coral reefs as these stressors could be site-, depth-, species- and background-specific. For example, shallow coral reefs in murky background conditions will have different turbidity tolerances to clear water and deeper coral reef community at the same project site. This needs to be examined carefully during baseline studies as being of importance for background or reference conditions.*

4.4 Project-specific methodology for monitoring and analysis of data

In practice, the type and scale of monitoring achievable is always governed by its practicability in the field as well as the project scale (extent), duration and the resources allocated to it. This, in turn, clearly has an effect on the level of adaptation that can be applied to a project.

It is essential that the chosen monitoring practices are designed in accord with the aims and requirements of the project and AM (e.g. spatial/temporal/economic) and the environmental objectives. Questions to consider include: What area is expected to be affected by the works? Over what duration (long/short term, one-off or repeated periodically)? And what is the project budget/financial resource available to undertake monitoring and AM? It is recommended that the flexibility required of both the monitoring programme and the response to any incident(s) is defined as early as possible at the project design stage.

Photo 2: Site specific monitoring (Schelphoek project).

The methodology for monitoring should be clearly defined within the AMP to ensure that the approach is transparent and can be agreed in advance with the Regulator (as necessary). The methodology should include the objective for the monitoring work, a detailed monitoring activity design and specification for analysis, together with the reporting procedures.

It is important that causes of change due to natural events or other activities occurring at specific sites or across all sites (including reference sites) are picked up by the monitoring as these changes could affect the management approach taken. Flexibility of approach is recommended to ensure that unexpected events can be encompassed within the AM.

The monitoring and analysis methodology should be able to be easily reviewed and compared with thresholds (triggers) to enable timely decisions to be made that can then ensure AM of the dredging activity.

As an example of non adaptive (monitoring and) management: On a dredging project with strict turbidity requirements, turbidity monitoring records showed no increase by agreed short duration overflow. Consequently, the Contractor asked permission to dredge with slightly increased duration overflowing, or to reduce monitoring efforts in most remote areas where no overflow dredging was made at all. This change in work method could save both Authority and Contractor significant effort, while still safeguarding environmental control with the remaining monitoring stations. This proposed adaptation was not accepted by the Authority.

For more information on Environmental Monitoring Procedures reference is made to CEDA's information paper on this subject (CEDA, 2015).

4.5 Project-specific management responses

Management options can vary from simply investigating the reason for the exceedance of a trigger level, to moving the dredger to an alternative location or, in the extreme, to stopping the dredging activity.

It is recommended that management options are defined at a number of trigger levels to give a tiered approach. This could consist of a number of levels, whether, for example, an early warning that an intermediate effect may be about to occur and an impact could still be avoided, or that an unacceptable impact is likely to occur unless dredging activity ceases in a particular location. The number of levels within the tiered approach will depend on the objective and the options available for management.

This approach relies on the ability to determine early warning signs of stress in the environment and to react quickly when such signs are observed to enable a reduction in the level of stress. This is not always possible as some environmental receptors only react slowly to chronic levels of stress and by the time the impact has been observed it may be too late. However, for many receptors it will be possible to detect early warning signs in time to reduce the effect and, in many cases, reverse the impact.

4.6 Well-defined roles and responsibilities

It is essential that all roles and responsibilities are defined and agreed in advance in the AMP, so that actions can be smoothly processed should they be required during the project.

The project owner/developer has the overall responsibility for ensuring that environmental objectives are met. However, there are different ways of managing an AM approach depending on who takes the responsibility for the monitoring. This can be retained by the developer or contracted out to the dredging contractor with incentives also to sign up to the environmental objectives.

Fundamentally, the ability to work as a team aiming for the same objective determines the ease of implementing AM and its likely success.

> *By making dredging contractors responsible (or share responsibility) for the environmental monitoring, they are likely to be incentivised to be more proactive/compliant with environmental restrictions and have more flexibility to manage the dredging activities and to respond rapidly to the monitoring results. A quick response time from the dredging contractor may be crucial for the success of the AM approach in many projects. This often makes it easier for all stakeholders to work as a team, which is potentially less divisive.*
>
> *If the developer is responsible, it may be better with respect to public relations but harder to manage. Different departments within the developer's organisation may have conflicting priorities (financial/time constraints vs. environmental impact), which will make internal management more complicated, not least with the dredging contractor who, without environmental responsibility, may wish just to get on and dredge.*
>
> *Use of a dual monitoring approach, whereby the dredge contractor monitors the near field plume and manages their activity based on this and the project owner monitors the conditions at the receptor sites, should be considered as this enables rapid management of the dredging activity and gives ultimate control over the condition at the receptor site to the developer.*

4.7 Effective review process

The review of data obtained from monitoring can be a time-consuming activity during a period when quick decisions are necessary for management. This stage is critical for the effective working of an AM approach. There are many stages, or reasons, where time delays can occur; for example, time to retrieve and analyse data, relocating a plant, and the level of bureaucracy or pragmatism within the project management team can all reduce the effectiveness of AM (or the ability to implement it).

In terms of the review of data and the decision-making stage, when critical decisions are to be made on a project the use of an independent review panel enables greater confidence in the results for the public and the Regulators. The review panel can be made up of a series of experts with different specialisms (potentially the same people as in the advisory panel discussed in Section 3.2). The review panel would need to discuss critical results to assist with the decision-making. It is therefore important that the review panel are able to mobilise rapidly and undertake the review within what can be a very tight time schedule.

5 Case studies

Øresund – Denmark

Project Name	Øresund Fixed Link – Dredging contract (1997 - 1999)
Location	**Øresund between Denmark and Sweden**
Requirement for Adaptive Management	The dredging works for the Øresund Fixed Link tunnel trench and island construction were made in a precious environment. As environmental responses of critical receptors are too slow for management, a spill (amount of suspended sediment flowing outside the project boundaries) budget was agreed upon, with strict adherence, but allowing for flexible management.
Outline of monitoring	Continuous monitoring of spill parameters was made, to verify compliance to the spill budget. In addition, a 'feedback monitoring' was made on the sensitive receptors to verify adequacy of the set spill budget. This so-called feedback monitoring includes selected variables that over short periods of time show quantifiable changes as a result of impacts from the construction work. The use of computer models makes it possible at an early stage to assess whether a feedback action should be taken or not, given the results of monitoring and future work plans.
Mechanism for adapting dredging activity	The Contractor was responsible for adhering to the spill budget. If exceedances were imminent he managed to mitigate by either reducing the rate of operation or by moving to another area, where budget was still available. The Owner was responsible for executing the 'feedback' monitoring. If exceedances of agreed thresholds had been observed, he could have made modifications to the spill budget.
Benefits of applying Adaptive Management	AM gave the Contractor adequate freedom to schedule and execute his operations within the limits of the firm spill budget. Good control of operations would work to his own benefit, also safeguarding the environmental interests. The experience gained is that by applying this AM principle based on targeted monitoring no environmental criteria have been violated and the works have been successfully carried out within the overall time and budget plans.
Further information	Jensen, A. & Lyngby, J. E. (1999) Environmental management and monitoring at the Øresund fixed link. Terra et Aqua, [Online] 74, 10-20. Available from: https://www.iadc-dredging.com/ul/cms/terraetaqua/document/0/7/8/78/78/1/terra-et-aqua-nr74-02.pdf.

Wheatstone – Australia

Project Name	Wheatstone LNG Project (2011 - 2013)
Location	**Western Australia**
Requirement for Adaptive Management	The Chevron-operated Wheatstone LNG Project, located 12 kilometres west of Onslow in Western Australia, involved dredging of a large volume of material over two years (2011 – 2013) to provide navigable waters for LNG shipments as well as trenching for trunkline installation. Western Australia has some of the most stringent environmental requirements in terms of managing potential environmental impacts from dredging. In particular, Wheatstone Project dredging conditions of approval included defined environmental protection outcomes for corals, seagrass, macro-algae and filter feeder communities.
Outline of monitoring	A tiered 'trigger level' approach to water quality monitoring helped to create robust thresholds with the Regulatory Authority to manage any potential impacts on corals, seagrass, filter feeder and macro-algae habitats surrounding the dredging area. Trigger levels were set for turbidity above which different levels of management were necessary including: • adapt method of dredging (i.e. rate of dredging, overflow management); • adapt method of disposal (i.e. placement location, rate of discharge); • relocating dredge area within specific zones; and • cease dredging if in non-compliance. Regular monitoring of benthic communities was undertaken to ensure protection and to determine the suitability of management triggers.
Mechanism for adapting dredging activity	The dredging activity could be adapted at different stages throughout the dredging project with different levels of management applied in response to the monitoring results. Water quality was monitored at regular intervals throughout the day using satellite-telemetered water quality instruments to provide near real-time data for use in proactive management. Assessment against the trigger levels occurred on a daily basis for the duration of the dredging activity. Review of the trigger values occurred through regular monitoring of the benthic communities using remotely operated vehicles throughout the project with comparisons drawn against the baseline and reference communities to detect any changes to the status. Daily forecast modelling was used as a valuable tool to predict potential future impacts to water quality, including cumulative impacts, enabling proactive management to address issues before they occur. Hindcast modelling (using known source terms) was also a valuable tool to differentiate the relative contribution of various dredging activities when changes to water quality occurred as well as to differentiate between dredging related and natural effects.
Benefits of applying Adaptive Management	It was possible to monitor tiered levels to ensure that warnings were available in sufficient time to enable management implementation to avoid reaching the threshold of unacceptable impact that would have stopped the dredging activity.
Further information	http://www.chevronaustralia.com/our-businesses/wheatstone/environmental-approvals

Poplar Island – United States

Project Name	Poplar Island Environmental Restoration Project, Chesapeake Bay, USA (1997 – on going)
Location	**Chesapeake Bay, USA**
Requirement for Adaptive Management	Poplar Island Environmental Restoration Project (PIERP) uses clean dredged material from the Chesapeake Bay approach channels. AM at Poplar Island comprises of developing initial project goals, periodically assessing progress towards them and developing and implementing corrective actions, if need be, in the future. Since habitat restoration was the aspect of the project where AM was applied, it focused on the following sub-goals: create a diversity of habitats including small island nesting habitat, tidal marsh habitat, upland habitats, quiescent conditions for submerged aquatic vegetation recovery and minimise/offset loss of benthic habitat.
Outline of monitoring	The AM sub-goals referenced above were broken into specific Adaptive Management elements in relation to habitat feature, desired attributes (size, flora, end use fauna, etc.) and estimated timeline. Specific targets were defined for each of these attributes (e.g. >80% of species composition to be achieved); subsequently acceptable bounds were defined for each of the targets (e.g. +/- 20%). Tools such as vegetative surveys, survey of cell elevations, material quality determinations, bird, fish and invertebrate surveys, benthic tissue sampling, marsh inundation studies, circulation studies, erosion analysis along dikes and shorelines/beaches and reef monitoring were used over time at varying frequencies to assess progress towards goals.
Mechanism for adapting dredging activity	Depending on dredging cycles and material characteristics, different locations/cells along the wetland portions of the disposal facility were filled and subsequently planted. This allowed flexibility in operations, as well as response action planning in future years, should a different result from the AM plan be observed or trending.
Benefits of applying Adaptive Management	Facilitated creation of an environmentally beneficial project as part of a beneficial use maintenance dredging project.
Further information	http://www.nab.usace.army.mil/Missions/Environmental/PoplarIsland.aspx http://www.mpasafepassage.org/poplartour.html http://www.menv.com/pages/outreach/poplar.html

MPA, MES and USACE

Photo 3: Poplar Island with different habitat cells.

Lumut – Malaysia

Project Name	Dredging works at Teluk Rubiah (2012 – 2013)
Location	**Lumut, Malaysia**
Requirement for Adaptive Management	An environmental feedback monitoring and management plan was applied in Malaysia for the dredging works at the proposed iron ore terminal developed by Vale Malaysia Minerals Sdn Bhd at Teluk Rubiah, Perak. In this project the very conservative EIA suggested as one of the mitigation measures the installation of 14 km silt curtain in waters of up to 25 m depth and exposed to wave heights of 3 m during unpredictable short term storm events. Having studied the environmental sensitivities and the feasibility of placing this silt screen the Dredging Contractor proposed not to install it but to apply AM. After all, the cost of the silt screen would have been about 50% of the project sum and the mitigating success was very questionable.
Outline of monitoring	Monitoring was twofold: daily monitoring near the sensitive receptors and scheduled intensive dredge plume monitoring in line with hindcast plume modelling. The monitoring near the sensitive receptors would reveal whether water quality near the sensitive receptors remained within the required levels. Modelling validated by focussed monitoring campaigns had to confirm that turbidity levels were in line with the predicted values. Thus, Adaptive Management on the project included also that process monitoring was an adaptive operation.
Mechanism for adapting dredging activity	Continuous communication between the Client, the Contractor's operational personnel, the Monitoring Subcontractor, the Authorities and Stakeholders allowed steering the activities day-by-day in such a way that no environmental stoppages due to exceeding trigger level had to be implemented.
Benefits of applying Adaptive Management	The project was finished ahead of schedule, in a safe way, at much lower cost than calculated based on the initially specified mitigation measures and without any environmental breach. This proved that, even on very short projects, successful implementation of AM works.
Further information	Savioli, J.C., Magalhaes, M., Pedersen, C., Van Rijmenant, J., Oliver, M.A., Fen, C.J. & Rocha, C. (2013) Dredging – How can we manage it to minimise impacts. In: APAC 2013: Proceedings of the 7th International Conference on Asian and Pacific Coasts, APAC 2013, 24-26 September 2013, Bali Indonesia. Available from: http://www.dhigroup.com/upload/publications/coastsea/Savioli_2013.pdf

Schelphoek Bay – the Netherlands

Project Name	Pilot beach nourishment, Schelphoek Bay, the Netherlands (2010)
Location	**Schelphoek Bay, the Netherlands**
Requirement for Adaptive Management	A pilot project beach nourishment with the construction of cascades was executed at Schelphoek. The following requirements for AM were defined: • Short term: Project area is the most vital shellfish production area in the Netherlands famous for its production of mussels, oysters and lobsters. The feeding grounds are very sensitive to deposition of sand. • Long term: Do you replenish on a large scale with long intervals between the replenishments? It is cost-effective, but covers large areas of tidal flats with significant amounts of barren sand. Or do you supply sand in small amounts with short intervals? This is not cost effective, but would have less impact on the ecology and fisheries. What is the impact of the cascades on the recovery process of benthic habitat?
Outline of monitoring	• Short term: A monitoring programme was set up to measure turbidity during replenishment. • Long term: Multi-year monitoring programme on, amongst others, the benthic life and the status of replenished sand.
Mechanism for adapting dredging activity	• Short term: Stop the works when limits are exceeded. Then, determine the cause of exceedance. Act accordingly. • Long term: Adjust replenishment layers (thickness) to acceptable level for early recovery of the benthic habitat.
Benefits of applying Adaptive Management	• Short term: Stakeholder management in order to get support from all parties involved. Limit restrictions on work method by Contractor. • Long term: Understanding of environmental impacts and the aquatic and terrestrial effects of dredging and replenishment.
Further information	http://www.littoral2012.eu/presentations/day2/day2_s3_vandenberg.pdf

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Abbreviations

AM	Adaptive Management
AMP	Adaptive Management Plan
D(M)MP	Dredged (Material) Management Plan
EIA	Environmental Impact Assessment
HSE	Health, Safety and Environment
KPI	Key Performance Indicators
MEA	Monitoring, Evaluation and Adjustment
MCMP	Mitigation, Compensation and Monitoring Plan

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