Central Dredging Association

Ecosystem Services and Dredging and Marine Construction

The Central Dredging Association (CEDA) is committed to the environmentally responsible management of dredging activities and hydraulic works and in this paper – produced by the CEDA Environment Commission – seeks to raise awareness and understanding of the Ecosystem Services concept and to contribute to the wider discussion on its application within the dredging community

For the future development of dredging activities and the environment in general, the concept of *Ecosystem Services (ES)* is of increasing importance as a tool for achieving sustainable development. The concept of ES links human well-being to the environment.

The ES concept received considerable impetus with the publication of the Millennium Ecosystem Assessment[1] (MA) in 2005 [1]. International policymakers such as the World Bank, UNESCO and the EU embraced the concept to integrate the economic value of ecosystem services for inclusion in policy decisions.

The general concept of Ecosystem Services

As emphasized in the Brundtlandt report [2] humankind's economy, health and survival depend entirely, though often indirectly, upon natural resources. Together with population growth, growing consumption rates and the intensification of land use and transportation, the demand for natural resources has increased. The impacts of these consumption patterns have become abundantly clear: Natural resources, which were supposed to be infinitely and freely available, are becoming scarce or degraded. To ensure sustainable development finding a balance between the environmental, social and economic aspects of projects is imperative. The objective of ES is to classify, describe and assess a value to natural resources and ecosystem services in order to make it possible to link the environment to human well-being.

In the MA ecosystem services have been categorised into 4 groups: provisioning services (food, water,..), regulating services (flood control, air purification,..), supporting services (navigation, …..) and cultural services (recreation, aesthetic experiences,..).

The service itself originates from an *ecosystem function*. An ecosystem function is the s*et of structures and processes* which eventually deliver the service, for example, the navigability of channels and harbours. A *benefit* to human well-being generated by an *ecosystem service*[2] often requires a technological investment. As such ships are needed for making use of the service of navigation. Dredging or marine construction works can be an investment to improve the service of navigation. Such an investment will change the system delivering the service and therefore will raise a pressure.

The ES concept is a tool that can help to find a sustainable balance between pressures and services in ecosystems. In this way, the approach of a project can be pro-active/opportunity-driven (win-win situation) instead of defensive (minimisation of pressures). The ES concept therefore offers a new way of thinking as a tool for decision-making about sustainable development.

ES relevant to dredging and marine construction projects

Ecosystems that are impacted by dredging or marine construction works are coastal systems, estuaries and river systems (e.g, deep and shallow seas, beaches, mud flats, sand banks and wetlands). When making an overview of the most important ecosystem

[1] The **Millennium Ecosystem Assessment,** released in 2005, is an international synthesis by over 1000 of the world's leading biological scientists that analyzes the state of the Earth's ecosystems and provides summaries and guidelines for decision-makers. It concludes that human activity is having a significant and escalating impact on the biodiversity of world ecosystems, reducing both their resilience and biocapacity. The report refers to natural systems as humanity's "life-support system", providing essential "ecosystem services". The assessment measures 24 ecosystem services concluding that only four have shown improvement over the last 50 years, fifteen are in serious decline, and five are in a stable state overall, but under threat in some parts of the world.

[2] As such, every single service is connected to an intertwined web of structures and processes, finally supported/insured by the support or resilience of the entire ecosystem. Essential functions in the ecosystem, such as natural population dynamics and nutrient cycling, are therefore called 'supporting services', covering all of the biodiversity within the ecosystem.

services of coastal ecosystems and river ecosystems (Table 1), without including detailed differences between ecosystems (e.g. ecotopes and or functions and processes), the ES of shipping/ navigation, flood protection and construction materials clearly emerge as the most relevant to dredging and marine construction. This is not surprising since dredging and marine construction are primarily undertaken to increase the delivery of these services. These services, viewed in the conjunction of the expected consequences of climate change [3], are of increasing importance for society.

As to all other ecosystems services of aquatic ecosystems: Dredging may enhance or degrade them. That depends on the situation and the project design.

Table 1. Ecosystems services of coastal and river ecosystems and how they are influenced by dredging activities and marine construction works

Ecosystem service (or good)	How is the service or good influenced by dredging?
1. Flood protection	Dredging enhances this service when sediments are supplemented for flood/coastal protection or when sediments are removed to make more room for water discharge in rivers. Marine works provide engineered structures to protect land against flooding.
2. Navigation/Shipping	Dredging enhances the service since it deepens waterways.
3. Construction materials (sand and gravel)	Construction materials can be delivered by Dredging. Mining of construction materials offshore (dredging) will change the hydromorphology and. decreases the amount of construction materials present in the system.
4. Seafood	Dredging may temporarily reduce fish harvests as a result of an increase in the turbidity of the water or disturbance of the sea floor. Dredging may permanently enhance fish harvests when it restores fish nurseries or creates hard substrate of shell fish.
5. Recreational possibilities	Whether dredging increases or decreases this service depends on the design of land reclamation or river bank deepening. Restored floodplains can be used for recreation.
6. Water quality and/or purification (nutrients, oxygen level, contaminants)	Dredging alters the morphology of the system. This can lead to a loss of habitat and species important for water quality. As a short-term effect dredging can decrease the local water quality. Sediments are a sink for contaminants. Dredging of contaminated sediments decreases the contaminant load. Dredging may enhance this service significantly when wetlands with reed vegetations are created and when proper hydrological conditions are created (increase of $O2$ levels).
7. Non use possibilities (legacy, bequest)	Dredging may decrease local biodiversity (especially at the sea floor) and thereby reduce the bequest value. Dredging may increase local biodiversity when a new ecosystem, nurseries or migration routes are created. In marine construction specific materials (e.g. eco-concrete) can be used to increase local biodiversity.

Application of ES in dredging and marine construction projects

The challenge for the sector is to make use of the ES concept and show that dredging and marine construction projects can reconcile both societal (economic) and environmental requirements. Mitigation of negative environmental impacts (short-term effects) during the realisation phase of dredging and marine construction is already common practice [4, 5, 6]. But when applying the ES concept, it is very important that the various (relevant) fields of expertise will be involved at an early stage in decision-making about the project. This will ensure that different aspects will be integrated in the project design and the decision-making process. Design and procurement practices should facilitate this.

In general the application of the ES concept requires that a multi-disciplinary project team takes 3 important steps:

1. Assessment of the relevant ES
2. Valuation of services and pressures
3. Design of the project

1. Assessment of the relevant ES

For assessment and valuation of ES in general, but also on a project scale, a typology is needed in which the relevant direct and indirect pressures and impacts are identified. It is of crucial importance that a detailed analysis is made of the functioning of the ecosystem in order to understand how the different ES are delivered. An analysis of Drivers, Pressures, State, Impacts and Response (DPSIR) is recommended as a starting point for such an assessment to develop further (tailor-made) details of the categories in Table 1. The use of dredged material (DM) can be beneficial [5] and therefore should always be within the scope of an assessment.

Although in the field of ES the scientific debate about definitions, classification and typology of ES is still on-going, this does not need to hamper the application of the concept in practice. In project-specific situations existing classification systems, such as the MA or others [1, 7, 8, 14], can be used as a kind of checklist. To prevent double counts services and functions should be distinctly defined in order to ensure that overlap is avoided. A proper (relevant) scale (spatial and temporal) should be used for identifying the impacts relevant for an assessment.

For whole oceans, the impact of a dredging project is not significant, but at the scale of a regional system or a habitat it may be relevant. Furthermore, it should be kept in mind that impacts/pressures are often local or limited in time and that benefits or services will manifest themselves during a longer period. These two factors (short term vs long term) should be balanced in an assessment.

2. Valuation of ES services and pressures

To make it possible to incorporate the outcome of the assessment into decision-making, the services and pressures of a project for society must be quantified. This process of valuation can start when the relevant services and pressures of the project are identified, assessed and quantified. Methods such as Cost Benefits Analysis[3], Life Cycle Analysis and/or Life Cycle Costs, which are already frequently used in projects, can be used for the valuation.

There are several difficulties in the valuation of ES:

- One difficulty in valuation is that many of the ES are non-marketed. The question is how to give a monetary (market) value to the huge variety of such services and how to incorporate that value into a world (green) economy. This question is also part of an on-going scientific debate, but again this should not be a constraint for the application of the ES concept in dredging and marine construction projects.

- It is increasingly recognised that the valuation of ecosystem services is highly context specific, and has to be guided by the perspectives and requirements of the beneficiaries. Valuation issues cannot be resolved in an unbiased way by economists alone. Therefore a reasonable approach would be to value services and pressures together with stakeholders.

- The existing regulatory framework has to be incorporated in the valuation process. Existing regulations may already have valued certain environmental aspects implicitly. For example, embedded in the European policy of Natura 2000 is the idea that natural areas are valuable and therefore need protection. However, existing regulations often focus on pressures only, whilst the concept of ES can be used for balancing pressures and services. The existing regulations therefore will not automatically facilitate the concept of ES. They can even be a constraint. In the interim report on *The Economics of Ecosystems and Biodiversity* (TEEB) it is noted that we may have to rethink the way market systems operate and try to ensure that the contribution nature makes to human well-being is fully recognised. New types of regulatory or legal measures are also likely to be needed in the future, to secure the public benefits which arise from land and its associated biodiversity resources [10].

3. Design of the project

The aim of ES should be to integrate the outcome of the assessment and valuation into the project design. When the ecosystem functioning is analysed the design process can start. This is an iterative process to explore options to integrate the proposed project goals with other services or functions and to explore whether natural processes can be used to achieve the integrated project goals. Again stakeholder involvement is important.

[3] In the Netherlands a book ("Kentallenboek") with economic indicators for the value of Nature, Water, Soils and Landscape is used as a specific tool for Cost Benefit Analysis. The idea is to update this book regularly on the basis of the experiences with the use of it.

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For project design processes with stakeholder involvement, different tools are available. For example, the Building with Nature programme[4] developed guidelines and tools for eco-dynamic development and design (EDD) in order to integrate economic development, nature values and quality of life.

Value Engineering[5] (VE) is another project management technique that seeks the best functional balance between cost, reliability and performance of a product, project, process or service. VE is a function oriented, systematic team approach and study to provide value. Often, this improvement is focused on cost reduction. However other important areas such as customer-perceived quality and performance (impacts and services) are also of paramount importance in the value equation. A tailor made combination of available methods is probably quite possible.

Case studies of ES in dredging and marine construction projects

In a growing number of dredging and marine construction projects elements of ES have been addressed. Often such examples originate from well-known international programmes as Building with Nature, Working with Nature, Building for Nature, Green Climate Adaptation Measures and Eco-Engineering. Such programmes promote and facilitate the use of an integrated pro-active approach which helps countries, consortia and local firms to innovate and upgrade their environmental practices.

In general inspiring examples can be found in projects where a need for enhancing services such as flood protection, navigation and sand and gravel mining is ascertained and project owners try to combine these needs with the enhancement of other services such as recreation, biodiversity and water-quality/purification.

The case of the Sigma Plan to regulate urban flood control

The Flemish government is faced with the problem of protection the population against floods in the Sea Scheldt, the Flemish part of the Scheldt estuary. The existing flood protection plan for the Scheldt, which is called Sigma Plan[6], stems from 1977 and needed to be updated because high water levels are increasing due to morphological changes in the estuary and because of the possible effects of climate change. Several alternatives have been developed to update the protection plan. They consist of various combinations of higher dikes, a storm flood barrier, controlled inundation areas with or without a reduced tide and managed realignment.

A flood control area consists of a low lying polder surrounded by a dike, but the height of the dike near the estuary is lower so the dike can be overtopped during storm floods. As the water is entering the polder, the water levels upstream are reduced significantly. At low tide the water flows from the polder to the estuary through outlet sluices.

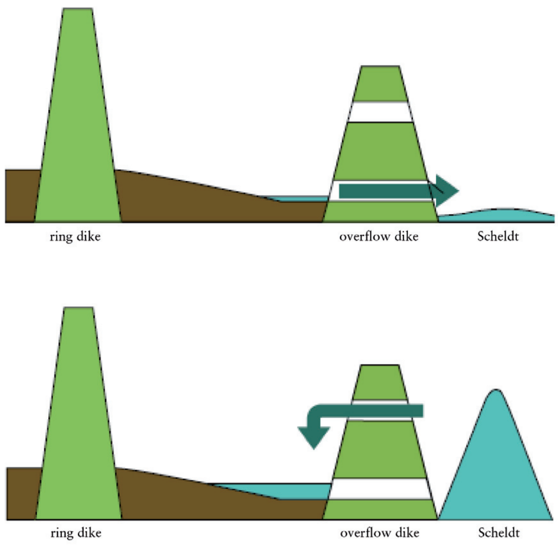

Figure 1: Cross section of a controlled reduced tidal area [16].

The polder itself can be used either for agriculture or as tidal marsh with a controlled reduced tide entering the polder through inlet sluices (figures 1 and 2). Managed realignment consists of removing the existing dike and replacing it by a new dike more inland, creating new tidal areas in the previous land. All the studied alternatives generate similar flood protection benefits. To determine the ecosystems benefits an inventory was made of their ecosystem services. A value was calculated for the services of fish harvest, wood harvest, shipping possibilities in relation to erosion and sedimentation, water quality, carbon storage, recreational and non-use opportunities. The calculations showed that the delivery of extra ecosystem services by a nature oriented management results in much larger benefits [11].

[4] http://www.ecoshape.nl/ecoshape-english/home

[5] **Value engineering** (VE) is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.

[6] http://www.sigmaplan.be/nl

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Figure 2: Sluices in the project area Kruibeke-Bazel-Rupelmonde

However the calculated benefits have to be offset against the costs and this was done also in a societal cost benefit analysis. This analysis showed that an intelligent combination of dikes and floodplains can offer higher benefits at lower costs compared to more drastic measures such as a storm surge barrier near Antwerp [16]. Based on these results, the Flemish government approved the integrated management plan consisting of the restoration of approximately 2500 ha of intertidal and 3000 ha of non-tidal areas, the reinforcements of dikes and the creation of flood control areas.

The case 'Working with Nature' for estuarine flood defence

The Working with Nature philosophy as set out in the 2011 PIANC Position Paper [13] provides a practical approach to including consideration of ecosystem goods and services in the project development, appraisal and decision-making process. Therefore it is compatible with the concept of ES. The case study, which is a composite example based on the experiences of working in estuaries in the east of England, illustrates how adopting the Working with Nature philosophy can also deliver improvements in ecosystem services.

The toe of an estuarine flood defence (an earth embankment) is being exposed and eroded, leading to concerns that the structure may eventually fail completely – with an associated risk of tidal flooding. Adopting the approach advocated by Working with Nature (i.e., understanding the environment before thinking about the solution) enables the project proponent to understand that:

- historically a wide area of mudflat and salt marsh fronted the seawall
- the structure is now exposed to increased wave action because of coastal squeeze (i.e., the intertidal area is narrowing as a result of relative sea level rise)
- this situation may be exacerbated by navigation dredging as the sediment removed from the port approach channel is currently disposed of outside the estuarine system
- the number of over-wintering birds using the foreshore has declined significantly as the foreshore has narrowed
- local fish catches were reduced significantly when the salt marsh eroded and
- the land behind the seawall is no longer suitable for arable use owing to saline intrusion.

As the intertidal area eroded, the following ecosystem services declined or were lost:

- Wave attenuation/flood risk control: regulatory service
- Food resources for wading birds: supporting or carrier service
- Fish nursery dependent on salt marsh: provisioning service
- Revenue from visiting recreational fishing: cultural or indirect service

Discussions with key stakeholders (nature conservationists, fishermen, land owners and the harbour authority) highlighted that, rather than a conventional engineering approach of constructing a concrete revetment or installing steel sheet piling, a possible win-win option would be a managed realignment of part of the flood defence supported by the retention of dredged sediment within the estuarine system. Options investigated to facilitate the retention of dredged material in the system included:

- 'rainbowing' material onto the foreshore,
- water column recharge, or
- creating a feeder berm in the shallow sub tidal area.

Whilst the preferred solution is site specific and cannot be generalised, the outcome here is a more sustainable approach to flood defence of the surrounding area, which also helps to restore or enhance the ecosystem services mentioned above.

Cases in which ecosystem structures and processes are used to create benefits

Ecosystem structures and fluxes can be used to enhance ecosystem services. For instance structures of, specific construction materials like eco concrete will support small organisms (figure 3).

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Figure 3: Eco-concrete

An example of making use of natural sediment transportation (flux) is the so-called 'sand engine' at the Dutch North Sea Coast (figure 4).

Figure 4: Sand Engine

In this project the beach was locally nourished with a surplus of sand in order to further strengthen the adjacent coastline by natural sediment transport. This has enhanced both the protective and recreational values of the area.

The experimental case of the ecological mining pit shows that sand and gravel mining can enhance the ES of seafood and biodiversity (figure 5). The goal of this project is to enhance (re)colonisation and increase biodiversity after cessation of the dredging activities by combining ecology (nature) and economy (mining) and thereby creating mutual benefit. The project explores the best ways to design and create landscapes such that, after extraction, maximum biodiversity can be reached as a result of the created underwater landscape. Preliminary monitoring results already indicated that pioneer species (benthos, fish) settle very quickly in the landscaped area [15].

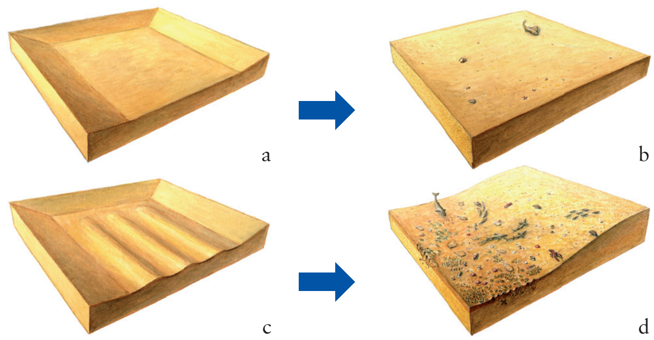

Figure 5: Concept of seabed landscaping in sand extraction areas. In analogy to seabeds with natural bed forms, landscaped mining areas (c) are hypothesized to encourage recolonisation and promote higher biodiversity and productivity (d) after completion of the dredging operations; in contrast to extraction areas with a flat bed (a), which yield an ecologically poor habitat (b) after dredging. Source: Aarninkhof et al. [15].

Resume and key messages

The concept of ecosystem services (ES) is a general tool for linking environment to human well–being. The concept or tool is of increasing importance, fits well with dredging and marine construction projects and is compatible with the 'building and working with nature' philosophies.

It offers the opportunity to consider the services and pressures of a project in a balanced and integrated way. This makes it possible to use a pro-active, opportunity-driven approach in project engineering. To utilise this opportunity the expertise of the sector, but also of other stakeholders, must get involved at an early stage of decision-making about projects. Hence an open and early dialogue between the developer, stakeholders and the regulator is a key factor for the successful application of the concept of ES.

Integration of environmental issues and especially the valuation should be done project-specifically with the involvement of stakeholders. An analysis of drivers, pressures, state, impact and response relations (DPSIR) can be used as the starting point for assessment. Properly used the concept of ES is not only beneficial to the environment, but can also be a stimulus to develop new approaches to projects under consideration. Both design and procurement practices as well as the regulatory framework should facilitate this way of working.

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The number of dredging and marine construction projects in which elements of the ES approach can be recognised is growing steadily. The most important services that can be enhanced are navigation, flood protection and construction materials. Pressures of the project's execution phase can be controlled and ample opportunities present themselves to integrate the enhancement of other services such as recreation, water quality and biodiversity into dredging and marine construction projects. For this purpose the inclusion of dredged material management in the scope of the project can be of great importance.

Application of the ES concept to the dredging and marine construction sector will demonstrate the positive influence that the sector can have for river and coastal environments as well as for society at large.

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