ELSEVIER

SUSTAINABLE MANAGEMENT OF SEDIMENT RESOURCES
VOLUME 4

SUSTAINABLE MANAGEMENT OF SEDIMENT RESOURCES

Sediment Management at the River Basin Scale

SedNet

P.N. OWENS
EDITOR

Elsevier
Radarweg 29, PO Box 211, 1000 AE Amsterdam, The Netherlands
Linacre House, Jordan Hill, Oxford OX2 8DP, UK

First edition 2008

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-444-51961-0
ISBN-set: 0-444-51959-9
ISSN: 1872-1990

Printed and bound in Hungary

08 09 10 11 12 10 9 8 7 6 5 4 3 2 1

Contents

Costs and Benefits of Sediment Management

A.F.L. Slob[a], J. Eenhoorn[b], G.J. Ellen[a], C.M. Gómez[c], J. Kind[d] and J. van der Vlies[a]

[a]*TNO Environment and Geosciences, Postbus 49, 2600 AA Delft, The Netherlands*
[b]*Rijkswaterstaat Bouwdienst, Postbus 20000, 3502 LA Utrecht, The Netherlands*
[c]*Universidad de Alcalá de Henares, Facultad de Ciencias Económicas, Plaza de la Victoria s/n, 288802 Alcalá de Henares, Spain*
[d]*Rijkswaterstaat RIZA, Postbus 17, 8200 AA Lelystad, The Netherlands*

1. Introduction

Different 'options' for sediment management will usually be available for a given situation. In economics, several instruments and tools have been developed to recognize and evaluate these options in a rational way. This chapter is about economical and financial tools to support the decision-making process, which forms part of a much broader sediment management framework (see Chapter 2, this book); other tools, such as monitoring, modelling and tracing techniques, are described in Chapter 5 (this book). A modern instrument is Societal Cost-Benefit Analysis (SCBA). In the literature 'Societal Cost-Benefit Analysis' and 'Social Cost-Benefit Analysis' are used indifferently. We will use here the term 'societal', because this reflects the purpose of SCBA: underpinning decisions that are beneficial to society. Decision-makers can be supported in a well-balanced way by evaluating the different options with the help of a SCBA. In this chapter we will describe the development of SCBA (Section 2) and the way it can be applied to sediment management (Section 3). Then we will present two examples of application of economic analyses for sediment and water management. The first example describes a SCBA that was applied to the dredging of sediments in the Netherlands (Section 4). Another example is an economic analysis with respect to river basin management (Section 5). This example is included here because the EU Water Framework Directive is an important driver for this type of analysis and it is a good illustration of the direction that the application of economic instruments for sediments may take. The subject of liability around sediment issues is touched upon in Section 6. The liability issue may become a major lever to raise awareness about, amongst other things, sediment issues, which can provoke an accelerated attention for policy measures with respect to (contaminated) sediment issues. The last section gives a summary of the chapter.

2. Societal Cost-Benefit Analysis

Everyone is used to the rationality of making decisions on the basis of a balance of gains and losses, or advantages and disadvantages. The idea behind such a balancing approach is that we only do things that yield us net gains and, when we can choose between alternatives, we choose the one that offers us the greatest net gain. This is the simple foundation of cost-benefit analysis. However, cost-benefit analysis (CBA) defines costs and benefits in a particular way, and it stretches the idea of an individual's balancing of costs and benefits to society's balancing of costs and benefits [1]. Behind CBA lies the paradigm of strict rationality: every actor is acting in such a way that net gains are generated. This approach can be elegant, but also has problems. The question is whether all actors act in a strictly rational way. Furthermore, CBA must often deal with effects that affect well-being (e.g. a decreased feeling of safety or loss of nature) that cannot be expressed in a straightforward way in terms of money, as is the case with the so-called welfare effects, e.g. a rise in income. These so called 'imponderables' and 'intangibles' have to be valued and balanced against the other effects, which may cause debates because the appreciation of these effects may vary widely between actors and situations.

Costs and benefits are defined according to the satisfaction of needs or preferences. Formally, everything is a benefit that increases human/societal well-being, and everything is a cost that reduces human/societal well-being. For the economist, whether or not well-being may be affected is to be discovered by looking at people's preferences. If an individual states a preference for situation A, then the benefits of moving to A must be positive for that individual. Why A is preferred is not the immediate concern, although no one would argue that the individual should not be allowed to get to situation A if it involves some immoral or illegal act. This is subject to the wider considerations about the 'morality' of allowing people 'to get whatever they want'. CBA functions on the basis that a 'better' allocation of resources should meet people's preferences [1].

The example above concerns the individual, but what is required when more people are affected by a certain decision? The instrument of Societal CBA is developed for this type of question. The word 'Societal' is used in the literature to refer to three different aspects of a CBA. First, it denotes the idea that in the evaluation the effect of the project on *all* individuals in society is included, not only on the parties directly involved (consumers and producers of the project). Second, it recognizes that distributional effects are being included. Without the distributional effects one is making an economical rather than a societal evaluation. Third, SCBA is used in situations where markets are imperfect and market prices are not always reflecting the individual's willingness to pay. A societal price would therefore mean that the market price should include effects that the market does not record, or records imperfectly. The word 'societal' is used to stress that one is attempting to give full expression to the preferences of all individuals, whether they are rich or poor, or directly or indirectly affected by the project [2].

The broad purpose of SCBA is to support decision-making that is beneficial to society. More specifically, the objective is to facilitate the more efficient allocation of society's resources. There are two major types of SCBA and two subtypes of SCBA. First of all is *ex-ante* SCBA, and this type assists with the decision about whether scarce societal resources should be allocated by government to a specific policy – whether a programme, project or piece of regulation. Thus its contribution to public policy decision-making is direct, immediate and specific. The second type is *ex post* analysis and is conducted at the end of a project. At the end, all of the costs are 'sunk' in the sense that they measure what choices have been made for the project. There is also less uncertainty about what the actual benefits and costs are. The value of such analyses is broader and less immediate as they provide information not only about the particular intervention but also about the 'class' of such interventions. In other words, such analyses contribute to 'learning' by government managers, politicians and academics about whether particular classes or types of projects are worthwhile. Eventually the weight of evidence may lead to a policy change. The first sub-type is a SCBA that is performed during the course of the life of a project and is called *in medias res*. Some elements of such studies are similar to an *ex ante* analysis, while others are similar to an *ex post* analysis. The final type of SCBA compares *ex ante* predictions with *ex post* measurements or, more likely, with *in medias res* estimates for the same project. This *comparative* type of SCBA is most useful to policy-makers to learn about the effectiveness of SCBA as a decision-making and evaluative tool [3]. Table 1 summarizes the ways in which the various types of SCBA serve different purposes. There are different approaches to performing a SCBA [2–4]. In Table 2 we present the nine basic steps of SCBA as described by Boardman *et al*. [3].

As with many methodologies and theories, CBA has been widely discussed among scientists. According to Self [5] and Lohmann [6], an important 'defect' in the CBA theory is that cost-benefit analysts claim that it is an objective technique or yardstick for recommending a policy decision. 'They are claiming in the first place that it is possible to quantify in monetary terms all sorts of

Table 1. Different types of Societal Cost-Benefit Analysis (source: modified from [3])

Value	*Ex ante*	*In medias res*	*Ex post*	*Comparative*
Resource allocation decision for this project	Yes – helps to select the best project or make 'go' vs 'no-go' decisions, if accurate	If low 'sunk' costs, can still shift resources. If high sunk costs, usually recommends continuation	Too late – the project is over	Same as *in medias res* or *ex post* analysis
Learning about actual value of specific project	Poor estimate – high uncertainty about future benefits and costs	Better – reduced uncertainty	Excellent – although some errors may remain. May have to wait a long time for this information	Same as *in medias res* or *ex post* analysis
Contributing to learning about actual value of similar projects	Unlikely to add much	Good – although contribution increases as SCBA is performed later. Need to adjust for uniqueness	Very useful – although some errors remain. Need to adjust for uniqueness. May have to wait a long time for this information	Same as *in medias res* or *ex post* analysis
Learning about omission forecasting, measurement and evaluation errors in SCBA	No	No	No	Yes – provides information about these errors and about the accuracy of SCBA for similar projects

factors that normally are not so expressed, secondly that the money terms used in the analysis really do possess the common property which they appear to have, and thirdly that these figures represent measurements of some concept of community welfare which can or should stand, if not as a unique criterion for decision-makers, then at least as one important criterion of the best policy' [5].

Table 2. The realities of doing a Societal Cost-Benefit Analysis (source: modified from [3])

The theoretical steps of a SCBA	The reality of doing a SCBA
Decide whose benefits and costs count	Contentious whether global, national, regional or local perspective is appropriate
Select the portfolio of alternative projects	Potentially infinite, the analyst should select an appropriate subset
Make an inventory of potential (physical) impacts and select measurement indicators	Difficult to identify specific impacts where unresearched scientific or biological processes are involved. True impacts may be unobservable
Predict quantitative impacts over the life of the project	Prediction is difficult, especially over long periods for complex systems
Monetize (attach Dollar or Euro values to) all impacts	Sometimes appropriate market values don't exist. Often the most important benefits are the most difficult to measure
Discount for time to find present values for costs or benefits arising over extended periods (years)	Different theories suggest different societal discount rates
Sum: add all benefits and costs (separately)	Some argument about the appropriate decision criterion
Perform a sensitivity analysis	Potentially infinite, the analyst must select an appropriate subset
Recommend the alternative with the largest net societal benefits	This is usually easy. It normally does not present any practical analytical difficulties, just political ones. The one exception is where sensitivity analysis shows that net present value estimates are very uncertain

The main point of criticism is that it is a tool based on an 'excess of rationality' and tries to rationalize what cannot be rationalized. Decisions that may have effects like the destruction of nature, damage to health (both animals and human beings) or even loss of life, for example, are especially difficult to rationalize because these effects are difficult to value.

But the tool of CBA is nevertheless used. This is often because of a practical vision of CBA as clearly described by Kelman: 'Nonetheless, we do not dispute that cost-benefit analysis is highly imperfect. We would welcome a better guide to public policy, a guide that would be efficient, morally attractive, and certain to ensure that governments follow the dictates of the governed. However, the decisions that must be made by contemporary decision makers do involve painful choices. They affect both the absolute quantity and the distribution of not only goods and benefits but also of physical and mental suffering. It is easy to understand why people would want to avoid making such choices and would rather act in ignorance than with knowledge and responsibility for the consequences of their choices. While this may be understandable, I do not regard it as an acceptable moral position. To govern is to choose, and decision makers – whether elected or appointed – betray their obligations to the welfare of the people who hired them if they adopt a policy of happy ignorance and non responsibility for consequences' [7].

3. Sediment management and Societal Cost-Benefit Analysis

Societal Cost-Benefit Analysis has been often applied to water management issues [8, 9], whereas its application to sediment issues is not very widespread. As was explained earlier, it is a tool with a long history that, at least potentially, contributes to a better, transparent decision-making processes. However, this implies a good understanding of the relevant system, the definition of the problems and the specification of the alternative solutions to these problems. In modern SCBA applications, this also implies the involvement of stakeholders (see [9] and Chapter 7, this book), not only to get insight into the system but also to specify the alternative actions that should be evaluated in the SCBA. A method that can help to streamline this process is Joint Fact-Finding (JFF). JFF can help the parties involved to resolve factual disagreements in ways that are acceptable to all parties. In JFF, stakeholders with differing viewpoints and interests work together to develop data and information, analyse facts and forecasts, develop common assumptions and informed opinions and, finally, use the information they have developed to reach decisions together [10].

A very crucial condition in the application of SCBA for sediment management is, therefore, to define the policy problem and the alternative actions to solve this problem. This may sound trivial, but is not as easy as may seem at first glance. One must bear in mind that economists or experts in the field of sediments are not automatically capable of articulating societal or policy problems. For example: What would happen if no sediment management actions were taken in a specific river? What kind of problems would then occur? Not only in terms of the more technical problems, such as the accumulation of sediment, but also with respect to the functions that might be affected, such as recreation, safety, transportation by ship, etc.

The following, hypothetical, example was discussed in a SedNet workshop on Societal Cost-Benefit Analysis that was held in Warsaw, Poland on 18 and 19

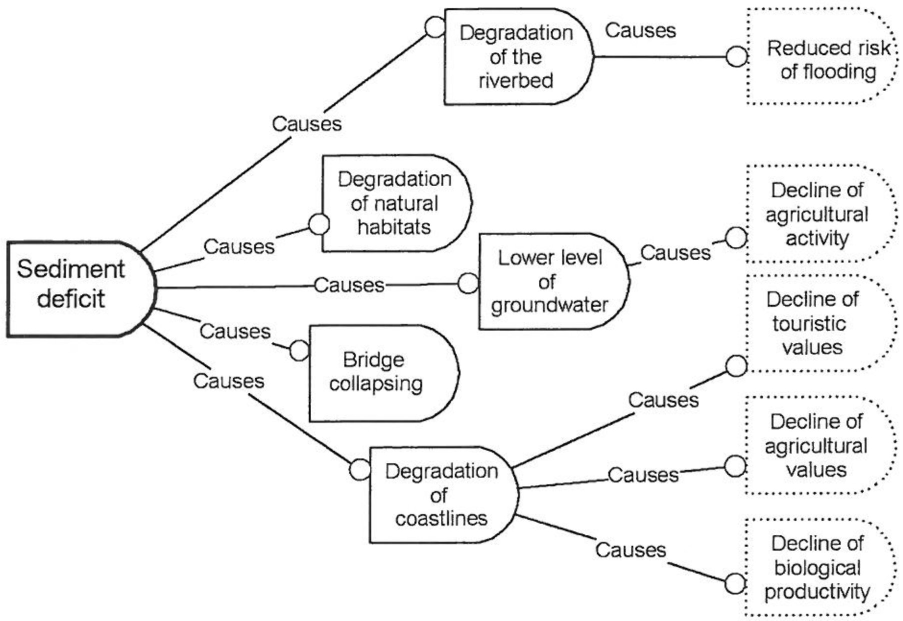

Figure 1. Sediment deficit and its adverse effects

March 2004. It illustrates the difficulties in posing the right questions. The hypothetical problem is a collapsing bridge caused by the erosion of sediment. The sediment management plan should undergo a SCBA and is aimed at minimizing the risk of the bridge collapsing. The description of the problem is the first important step in a SCBA and, therefore, a causal scheme was composed of the possible negative effects of sediment deficit in rivers (see Figure 1).

It is shown that the collapsing bridge is not the only problem related to sediment deficit, but that sediment deficit is related to a whole array of different problems, like decline of biological productivity, decline of agricultural values, etc. So the problem does not become any easier to handle. From the question 'What kinds of impacts does a sediment deficit actually have?', we arrive at the question 'How do we know that there is a sediment deficit?' To answer this question, we should compare the current situation with the 'natural' situation, but this raises the problem of establishing what the 'natural' situation is. It becomes clear that the problem has a temporal scale that has to be taken into account. This raises even more questions, such as 'Is it because of a dam that we have a sediment deficit and shouldn't we therefore evaluate the dam?' This shows that a clear problem description might take quite some time. Knowing the affected values and articulating the policy problems from a broad societal perspective is an essential part of 'understanding the system'. To get this broad societal perspective, stakeholders from different backgrounds and with different interests should be involved (see Chapter 7, this book).

In order to conduct a SCBA it is imperative to have or obtain a very good understanding of the system and its problems. This means that, first, an analysis and an inventory should be made of the problems in the present, and possibly future, situation (see also Chapters 4 and 5, this book).

Second, an analysis should be carried out of the relevant exogenous developments to gain insight into the 'system': the definition of the problem and the evolution of this problem in the course of time if no actions are to be taken.

Third, SCBA is not a content-free, economist tool. Economists often do not have the knowledge that is needed to give content to the method. Therefore, it is necessary to involve all technical expertise, knowledge about eco-systems, and other knowledge from stakeholders. The involvement of stakeholders will not only lead to better knowledge, but is also needed to gain support for the actions that will result out of the SCBA. In other words, a multi-disciplinary approach in an interactive setting with the stakeholders is needed to obtain a clear insight into the existing problems and to conduct a transparent decision-making process.

Fourth, although SCBA includes the application of valuation methods, e.g. to value effects of certain functions like recreation or nature, the tool as such is *not* a valuation method, but an *e*valuation method, weighing alternative actions against each other. This is possibly one of the biggest misconceptions about SCBA. The method needs different actions to tackle a problem. This implies that alternative actions should be generated and the resulting changes should be measured against the so-called 'zero-alternative': 'doing nothing' in an autonomously developing situation. These measurements demand the insights of experts and stakeholders about the system that is influenced.

Fifth, often when the effects of the actions (the changes in well-being and/or welfare) are valued, economists and/or policy-makers are accused of manipulation. It is, therefore, always necessary to specify the effects in their own entities first, before applying any monetary values. The assumptions and methods that are applied to value the actions should be open for discussion. A whole range of methods and guidelines have been developed for this purpose and can be applied in the course of time. When uncertainty is high it may be necessary to apply different methods next to each other and to carry out a sensitivity analysis.

To summarize, the following steps should be taken in a SCBA:

- Analyse the system and define the problem.
- Make an analysis of the evolution of the problem if no actions are taken (the so-called zero-alternative).

- Specify the alternative actions that may be taken to solve the problem (one may use selection criteria such as: the alternatives should not be in conflict with (inter)national laws, should be formulated together with stakeholders, and should be realized within five years, etc.).
- Analyse and specify the possible effects of these actions in terms of changes (compared to the zero-alternative). The effects include possible substitution effects (e.g. the problem at hand may be relocated and can occur elsewhere).
- Indicate the level of uncertainty when predicting these effects (needed for sensitivity analysis).
- Quantify the effects of the actions and value them (not weighing).
- Welfare valuation should be made of all effects irrespective of their nature and irrespective of the place where they occur: always of physical entities (less sediments, more water for irrigation, more nature, etc.) and wherever possible (also) in monetary values. A whole range of different methods exist (Hedonic pricing, shadow prices, travel costs methods, contingent valuation).
- Some effects may occur during a period of time. Discounting rules should be applied to calculate the net present value. (It may be useful to use more than one discounting rate.)
- Compile a SCBA balance sheet with costs on one side and benefits on the other.
- Select and decide (with the relevant stakeholders) what the most appropriate actions are to be taken.
- Decide on extra research questions that have to be answered, develop a monitoring system and conduct any reevaluation.
- In all steps: involve stakeholders (see Chapter 7, this book).

Until now the discussion on SCBA has been mainly theoretical. The following two sections will describe examples of the application of economic instruments in practice. The next section will present a SCBA analysis with respect to sediments in the Netherlands.

4. Example 1: CBA of dredging in the Netherlands

Napoleon Bonaparte called the Netherlands 'Sludge from the Rhine'. Although intended as an insult, this is an apt description of the Dutch landscape, given the enormous deposits of sediment in the 'settling basin' that the Netherlands happens to be. The Dutch waterways support several principal functions, such as recreation, shipping and ecology. To maintain these important functions, dredging is necessary. Although the quality of the sediment is now better, in the 1960s through to the 1980s the sediment was contaminated. This introduced a new problem: increasing costs of dredging and a shortage of disposal facilities for contaminated dredged material. Due to the lack of sufficient disposal capacity (partly as a result of NIMBY: Not In My Back Yard) and increased costs, together with lagging funding, a large backlog was created. These sediments originate both from remedial (environmental) as well as maintenance projects. This backlog was quantified in 2001 and led to the question of whether the benefits of increased dredging, necessary to diminish the backlog, counterbalanced the costs. In Tables 3 and 4 an overview is presented of the major water functions and the dredging volumes.

As shown in Table 3, deferred maintenance of sediment increases by 3.5×10^6 m^3 each year. This will lead to a doubling of the total backlog in about 20 years. The two major functions threatened by deferred maintenance are shipping and agriculture. Contrary to maintenance, the 50×10^6 m^3 for remediation (Table 4) diminishes every year at a rate of 1.3×10^6 m^3. Remediation is closely related to the ecological function of the Dutch waterways, but also relates in part to dredging activities in urban areas (e.g. dredging of canals).

Table 3. Actual vs required maintenance of sediment dredging activities (values $\times10^6$ m^3 $year^{-1}$)

	Required annual dredging	Actual annual dredging	Yearly built up deferred maintenance
Shipping	3.0	1.6	1.4
Ecology	0.1	0.1	0.01
Urban	1.3	0.6	0.7
Agriculture	4.9	3.6	1.4
Recreation	0.03	–	0.03
Total	*9.3*	*5.8*	*3.5*

Table 4. Total deferred maintenance and remediation of sediment (values $\times10^6$ m^3 $year^{-1}$)

	Total deferred maintenance	Remediation	*Total*
Shipping	21	–	*21*
Ecology	6	44	*50*
Urban	6	5	*11*
Agriculture	14	–	*14*
Recreation	39	0.5	*40*
Total	*86*	*50*	*136*

In 2003 the Dutch Ministry of Transport, Public Works and Water Works launched a study of the costs and benefits of increased dredging. The goal of this study is to answer the following two questions:

1. What are the economic costs and benefits of increased maintenance, if annual sedimentation equals annual dredging (reaching equilibrium)?
2. What are economic costs and benefits of eliminating the deferred maintenance and of removing the contaminated sediment in 10, 25 or 40 years (getting rid of the deficit)?

These two questions are graphically represented in Figure 2.

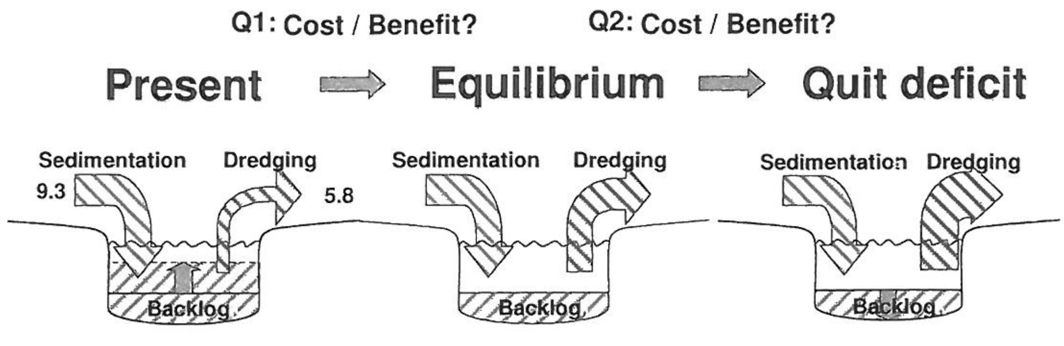

Figure 2. Representation of the two questions in the Societal Cost-Benefit Analysis of the sediment balance of the Dutch waterways

The CBA was carried out following a participatory approach, in which all relevant stakeholders were actively involved, and focused in particular on the following sectors and aspects:

- Shipping: insufficient dredging of waterways results in reduced draught for vessels, implying a reduced load per ship and hence increased transportation costs. This makes shipping relatively less attractive compared to transportation over land, leading to a reduced demand for shipping (modal shift).
- Agriculture: insufficient dredging of regional waters increases the probability of flooding agricultural lands, causing an increase in loss of crop production and eventually terminating the use of land for agricultural purposes.
- Flood hazards: insufficient dredging of rivers increases the probability of flooding the lower elevation polders, unless other measures, such as increasing the height of dykes, are taken.
- Ecology: ecological benefits accrue due to the remediation of contaminated dredging material.

Table 5 shows the costs and benefits of reaching equilibrium and of removing backlogs and remediation in 25 years. In both cases, the net present value is positive. Interestingly, the principal beneficiaries of reaching equilibrium are shipping companies and farmers, while removing backlogs and remediation mainly results in shipping benefits and ecological benefits. This can be explained with the values from Tables 3 and 4, which show that major deficiencies in annual maintenance are in waters with a shipping function or drainage from agricultural areas, whereas the majority of contaminated sediment is found in water with a nature function.

Table 5. Results of the Societal Cost-Benefit Analysis of dredging in the Netherlands (present value in euros×10^9)

Aspect	Reaching equilibrium	Removing backlogs and remediation in 25 years
Costs	1.1	0.4
Monetary benefits		
Shipping	0.9	0.8
Agriculture	0.5	0.1
Reduced flood hazards	0.1	0.0
Total	1.5	0.9
Net present value	0.4	0.5
Other benefits		
Ecological benefits*	5%	20%
Recreational benefits	Positive, but not quantified	Positive, but not quantified
Urban benefits	Positive, but not quantified	Positive, but not quantified

* Compared to present situation.

This study has produced some powerful insights that can enable high and low level decision-making about increasing Dutch dredging activities. It has shown that increasing dredging efforts to reach equilibrium (annual sedimentation equals annual dredging) is beneficial for the Netherlands. The same applies to the economic costs and benefits of eliminating the deferred maintenance and of removing the contaminated sediment in 10, 25 or 40 years.

4.1. Public perception and valuation of biodiversity

In Section 3 we mentioned that a whole range of methods are available for valuation of actions to express the actions in terms of money. One of these methods is the 'willingness to pay' method. This method has been applied in the context of the SCBA presented above. A large scale survey has been carried out in order to assess public perception and valuation of contaminated sediment clean-up and the corresponding positive effects on biodiversity in and around aquatic ecosystems (rivers and lakes) in the Netherlands. The positive effects on biodiversity of this clean-up were assessed by expert judgement. Based on this expert judgement, two possible scenarios of environmental change and the corresponding effects on biodiversity have been developed: a baseline scenario without any additional clean-up efforts; and a policy scenario with additional clean-up efforts.

These scenarios were included in a survey sent to a cross-section of 5,500 Dutch households. The households were asked a range of questions regarding their knowledge and perception of water quality problems in general and contaminated sediments in water systems more specifically. Their attitudes and preferences towards the presented scenarios were also requested. About 1,000 households responded to the survey, providing a rich blend of views and opinions, thereby adding an important public dimension to the overall impact assessment.

Besides providing important indicators about public perception of water quality problems and the need to do something about them, the survey also aimed to estimate public willingness to pay for an increase in biodiversity as a result of increased contaminated sediment clean-up efforts. In this assessment, willingness to pay was used as an indicator of the public non-market benefits of increased clean-up efforts compared to the baseline scenario. In the willingness to pay approach, a monetary value is included for the non-market benefits related to biodiversity preservation and enhancement. This can then be used to see to what extent the necessary investment costs to clean-up the stock of contaminated sediments in the Dutch water system can be justified.

Almost 95% of the Dutch population who responded to the survey indicated that they believe it is important to increase clean-up efforts for contaminated sediments in aquatic ecosystems, and 75% of respondents are willing to pay extra for this as well. Average willingness to pay ranges between 10 and 50 euros per household per year. Relating this amount to their actual annual water bill, this corresponds to a maximum increase of 10% over the next 10 years. Using a conservative aggregation and estimation procedure, and expressed in terms of present value for the cost-benefit evaluation, the total economic value equals 523 million euros.

5. Example 2: Economic analysis and river basin management in relation to the EU Water Framework Directive

In this section an example is given of the application of economic instruments to water management, for which the Water Framework Directive (WFD) is an important driver. It provides a good example of what could be applied to sediment management. The WFD [11] 'aims to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and ground waters'. Its specific purposes are defined in Article 1, as:

1. to prevent deterioration of, and where necessary enhance, the status of aquatic and related ecosystems;
2. to promote sustainable water use;
3. to aim to progressively reduce, and for priority substances eliminate, pollution from hazardous substances;
4. to ensure reduction/prevention of groundwater pollution; and
5. to contribute to the mitigation of floods and droughts (see also Chapter 3, this book).

Although ecological quality is the main criteria to judge the quality of water ecosystems, the main purpose of the WFD is to contribute to the 'provision of a sufficient supply of good quality and quantity of water services as needed for sustainable, balanced and equitable water uses' [11]. The WFD recognizes that water uses by the economic system determine the ecological quality of water ecosystems and, therefore, that influencing water uses is a key to sustainability. Decisions on water management must take into account benefits and costs to society. In this way, water ecosystems are viewed as part of society's natural capital that must be managed in a sustainable way: preserving the integrity of the water environment and its associated ecological functions is the only way to guarantee the services provided by them for the economic system. Water ecosystems provide scarce water services to many conflicting societal and economic targets, and the Directive promotes and sets a common framework for economic principles to guide decisions in four main respects:

1. the valuation of water services and its alternative uses (Article 5);
2. the identification of costs of the provision of water services having regard of the polluter pays principle and the efficient use of them (Article 9);
3. the use of economic instruments to achieve the desired objectives, including pricing and market mechanisms (Article 11); and finally
4. the use of economic appraisal methods to guide the water resource management decision-making process.

In this section we mainly address the last of the aspects mentioned above and more specifically the role of CBA in general, and cost effectiveness analysis in particular, as decision support tools in the implementation process of the WFD. Although the use of economic principles for water management has been encouraged for a long time, and its importance has been enhanced with the appearance of water demand instruments, the WFD approach is highly innovative in many respects. The economic analysis of the WFD implies an important challenge because of the lack of proper information systems and databases and also due to the lack of tested methods for empirical applications. River basins are complex ecological systems with many interactions that need to be taken into account (see Chapter 1, this book). Sediment balances depend on the river hydromorphology (see also Chapter 4, this book). Water quality and quantity are closely linked to each other. The connections between runoff and underground water are not well known. There are many competing water uses for any water body, and present decisions on water abstraction have uncertain effects on future welfare. Additionally, although important progress on valuation methods of water services has been attained in previous decades, results are not completely robust and there is still some important discussion on the proper way to integrate the value of the many water services implied in a common integrated framework. Two points must be made to understand how the WFD copes with these problems in a practical way.

First of all, (socio-)economic analysis and SCBA must not be interpreted as a decision-taking framework but as useful tools in the decision-making process. For that reason the economic analysis needs to be integrated with other expertise and analyses in supporting the development of river basin management plans. Efforts into more detailed economic analysis should be proportionate and concentrate only on significant water management issues, areas of conflicts between uses and where the integration between environment, economic and societal issues is problematic; in other words, where economic analysis can help in making better decisions.

Second, economic analysis should serve to improve the quality of the societal decision-making process, informing about possible policy choices or helping to justify these choices and conveying information to the public/stakeholders. Involvement of stakeholders into the economic analysis is a way to bring expertise and information, provide opportunities to discuss and validate key assumptions, and to increase societal involvement and the acceptance of the results of the economic analysis (see Chapter 7, this book). According to the WFD, economic analysis should report on information, assumptions and approaches used for obtaining results in a transparent way as a prerequisite to enhance information and participation of the stakeholders.

To understand the function of CBA in the water management decision process, it is important to compare the abstract theory of SCBA with the way this theory is transformed into practical recommendations to implement the WFD. Ideally, SCBA is a method to solve different policy problems in a common framework. A necessary condition for applying SCBA is to solve two basic informational problems. The first one refers to the benefits associated with an improvement in the ecological quality of a water body, and the second one refers to the question of the opportunity costs to obtain such an improvement.

The benefits are represented as the welfare gains that result from both the increased capacity of the water ecosystem to provide services to the economic system (for instance, improved recreational services, reduced flood risk or a higher guarantee of water supply in dry periods), and the preservation of existence and option values (associated with a higher biodiversity, increased options for future generations, etc.). Figure 3 illustrates the marginal benefits of improving water quality as a decreasing curve, showing that the quality is improved at a decreasing rate. To capture these benefits, society must 'invest in' or pay the opportunity cost of improving the ecological quality. These costs come from the investment and operation expenses of the measures needed to improve water quality and also from the negative effects of reducing the economic pressures on the water ecosystem (or by reducing water abstraction, pollution, economic uses of head waters, etc.). The hypothetical marginal cost of ecological quality is represented in Figure 3 by the increasing curve.

If we were able to gather all the information about costs and benefits associated with an improvement in the ecological quality, the application of CBA would become a relatively easy task. In that case, society must simply try to improve the water quality up to the point where the cost of improving quality in the margin is not higher than the benefits society can obtain from this change. Ideally, CBA would allow us to solve many economic questions at the same time. First, as we have seen, the method provides a way to define the optimal ecological quality. Second, it is also a way to measure the environmental gap that needs to be closed to reach that optimal target. This gap is simply the difference between the current and the optimal ecological status. Third, it provides a method to measure the welfare gains that may be obtained when the optimal status is reached (represented by the triangle WG in Figure 3). And finally, it is a way to identify the actions that should be taken to obtain the optimal status at the least cost to society (all the policy measures having a marginal cost lower than the marginal benefit of the ecological improvement measured at the optimal ecological quality) and to design the optimal river basin management plan.

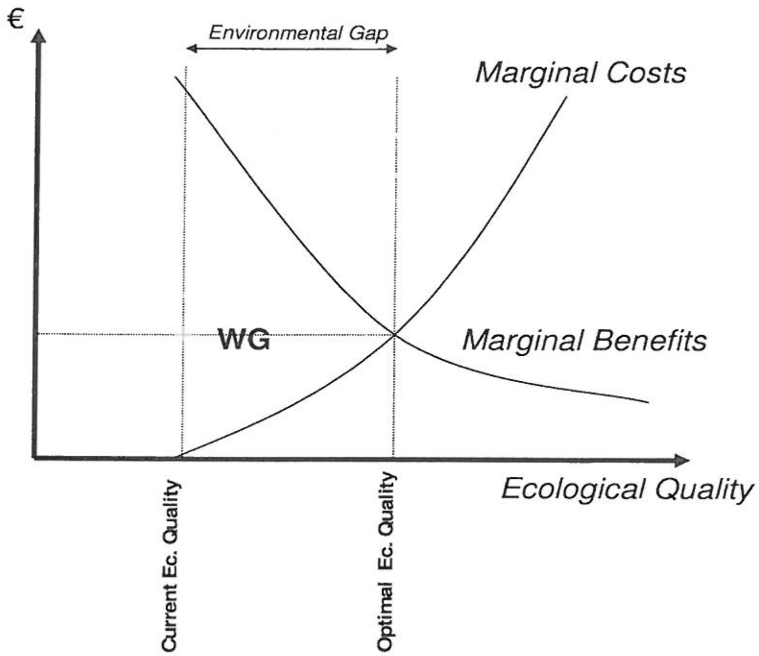

Figure 3. The theory of Cost-Benefit Analysis applied to the EU Water Framework Directive (see text for explanation)

Nevertheless, recommendations from abstract theory are rarely easy to put into practice. Experience in water management has led to the conclusion that the costs of the actions needed to improve ecological quality are easy to value in a simple and precise way. Contrary to costs, the benefits of ecological improvements are diverse, including the welfare gains to landscape, recreation, safety, biodiversity and so forth. Most of the benefits are local and their values can not be easily transferred from one ecosystem to the other. Many of them are qualitative and difficult to value in welfare terms, different cost valuation methods lead to different values and the values obtained are always uncertain.

To cope with these informational restrictions, and to make economic analysis feasible in the practical arena, the WFD assumes that societal decisions on water management must be taken in an iterative institutional process, where the starting point must be the setting of a desired ecological status on the basis of technical knowledge and stakeholder involvement. These preliminary objectives may be refined in a more advanced phase of the WFD implementation when SCBA will play a key role.

The decisions sequence may be represented by a process including the following main phases. First, a preliminary target of a good ecological status of the different water bodies or a water basin is defined. Second, the combination of policy measures to obtain the desired target with the least cost to society is determined. Third, the benefits associated with the ecological improvement are identified and described, but not valued. Fourth, the measure of costs and the benefits are presented to stakeholders in order to determine whether benefits are perceived as high enough to justify the effort needed to obtain the good ecological status. If the answer to the previous question is affirmative, the analysis proceeds by defining the institutional constraints, the distributive effects of the river basin measure package, the financial constraints and the many other aspects that need to be dealt with to implement the river basin plan. If costs are perceived as disproportionate, in the WFD jargon, the desired ecological status is modified by setting a less stringent ecological status (a target derogation), or by allowing more time to reach the good ecological quality (a time derogation).

One specific tool to analyse a way of reaching the predetermined 'good ecological status' is Cost Effectiveness Analysis (CEA). In the WFD the identification of the welfare gains of improving the ecological quality of a river basin is not used to set the water management policy objectives, but to assess whether the benefits are higher than the costs associated with the best alternatives to obtain the predetermined good ecological status.

Once the WFD is fully implemented, CEA will play an important role in the definition of an adequate combination of policy options that may be chosen to achieve a desired ecological status in any European river basin. Nevertheless, CEA is just an intermediate stage in the design of a river basin management plan, and should not substitute the decision-making process itself. It takes information produced by previous economic analysis, based upon calculation and estimation of costs and physical effectiveness of identified measures to meet a given standard as, for example, the Good Ecological Quality (GEQ) or the Moderate Ecological Quality (MEQ) of the river basin. The output(s) of CEA are especially relevant since an ultimate CBA (as well as the consultation process) that would lead to final decisions about objectives, timing and required measures, will need to be developed on that basis. The CEAs prepare the ground for the SCBA with a wider scope.

The rationale of the CEA is shown in Figure 4. This figure shows the marginal cost (MgC) of achieving a given level of a parameter of environmental quality (Q). We can think of Q as measuring a given attribute, such as the concentration of a specific pollutant, water temperature, the rate of flow, etc. The marginal cost curve reflects the supply side of providing a better environmental quality and can be derived through ranking all the alternative policy options according to the marginal cost of providing an increase in parameter Q. This type of analysis can also be applied to sediment management, whereas sediment balance is only one parameter for ecological quality. Figure 5 illustrates a hypothetical example where the environmental quality is a measure of the distance of a sediment balance with respect to a natural regime.

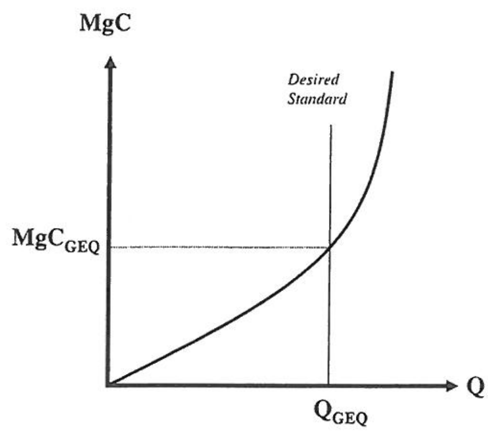

Figure 4. Cost effectiveness analysis (see text for explanation)

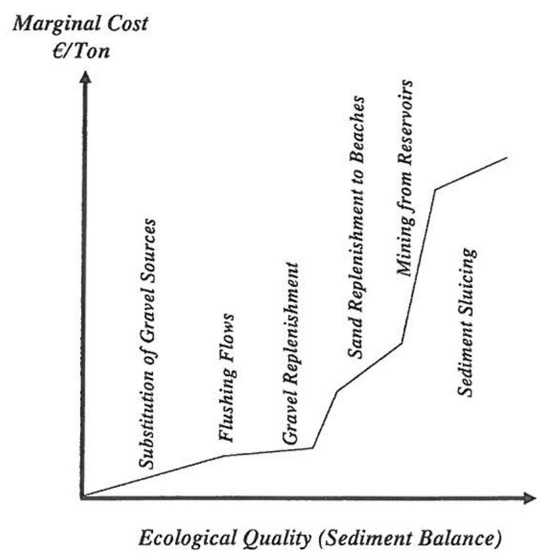

Figure 5. Example of marginal costs of restoring sediment balances

There are several options to improve the sediment balance. As an illustration, the following list contains the most representative examples of restoration and remedial measures to improve sediment balances, based on the literature:

1. Substitution of gravel mining sources. Designed to reduce or eliminate instream gravel mining by defining a minimum elevation of the thalweg or by allowing extraction of only a fraction of the natural annual bedload

sediment supply. This will increase the cost of sediment as an input for construction and other economic activities.

2. Flushing flows. A measure designed to partially remove fine sediments accumulated on the bed and to scour the bed frequently enough to prevent encroachment of riparian vegetation and narrowing of the active channel [12].
3. Gravel replenishment below dams. Artificially added gravels to enhance available spawning gravel supply can provide short-term habitats. Experience shows that imported gravels are highly mobile and thus measures need to be taken on a regular basis, depending on the magnitude of the runoff [13].
4. Sand replenishment to beaches from headwaters, river transport and offshore sources. Designed to compensate sand supply reductions to beaches due to a reduction in sediment delivery from streams and to avoid increased risk of shrinking and cliff erosion.
5. Mining aggregate and industrial clays from reservoirs. Although financially expensive, this measure may be economically viable when the benefits of increasing reservoir capacity and the environmental benefits of reduced instream and floodplain mining are taken into account.
6. Sediment sluicing and pass-through from reservoirs. A measure designed to partially restore continuity of sediment transport. Special care must be taken to control the possible negative effects of an abrupt increase in sediment load on water quality and aquatic habitat conditions downstream.

The application of CEA to this set of measures may lead to a marginal cost curve of improving sediment balances, as is represented in Figure 5.

The main challenge for the implementation process of the economic analysis aspects of the WFD is to integrate the many different alternative measures that may be taken in any water body to improve any single quality parameter. The goal is to obtain the least-cost combination of policy measures that guarantee the overall good ecological quality of the entire river basin. In this integration process special care must be given to the following aspects. First, there is the integration of different measures taken at different water bodies to improve a given ecological quality parameter. With respect to sediment management, for example, the river basin can be divided in three zones: the erosion zone (typically the headwaters), the transport zone and the deposition zone (for details see Chapter 4, this book). By planning at the basin level, the cost of, for example, improving continuity between the erosion and the transport zone will reduce the need to reduce sediment extraction in the deposition zone. In other words, part of the marginal restoration cost of restoring continuity is compensated for by the avoided compliance costs downstream.

Second, there is the integration of different measures performed to improve different quality parameters. In this case, improving sediment balances, for example, will have an internal effect in the river basin, by enhancing available spawning areas, thus reducing the cost of reaching the good ecological status. In another example, flushing flows may prevent the encroachment of riparian vegetation avoiding other restoration measures. Measures intended to restore sediment balances may substantially improve water quality. In sum, the integrated cost effectiveness analysis proposed by the WFD provides the tools needed to appreciate the benefits of any single measure in terms of the avoidance of the societal cost of guaranteeing the desired ecological status of the river basin.

6. Environmental liability and sediments

Next to the WFD, described in the previous section, another directive from the EU that could have a great impact on sediment management is the Environmental Liability Directive (ELD) (also see Chapter 3, this book). The ELD was approved by the Council and the European Parliament on 30 and 31 March 2004, respectively. The Directive will enter into force on the day of its publication in the Official Journal. The ELD aims 'to establish a common framework for the prevention and remedying of environmental damage at a reasonable cost to society' [14]. The Directive not only covers damage to persons or goods and contamination of sites, but also damage to nature, especially to those natural resources that are important for the conservation of the biological diversity in the Community. The ELD wants to reach its goal by implementing the 'polluter pays principle', which ensures that whoever causes environmental damage pays to remedy the damage. To ensure an effective implementation of this Directive, persons or non-governmental organizations adversely affected or likely to be adversely affected by environmental damage should be entitled to ask the competent authority to take action. The EU deems that because environmental protection is a diffuse interest, non-governmental organizations promoting environmental protection should be given the opportunity to properly contribute to the effective implementation of this Directive (Directive 2004/35/CE, note 25).

This Directive will have a great impact on sediment management, and the costs and benefits that have to be taken into account, because organizations in addition to those concerned with environmental protection will have a strong instrument to emphasize the importance of sediments in the ecosystem. Government organizations and companies have to be very careful in influencing the quality and quantity of sediments, as they will be accountable for their actions. This means that, in the end, they will have to pay the bill to restore the quality of the ecosystem. For example, when a government organization decides to build a hydroelectric dam, which would have a great impact on sediment balances, the government organization is obliged to make amends to restore this. Another aspect of the ELD, which is of great importance especially to sediments, is the polluter pays principle. Thus far it was sometimes difficult, if not impossible, to track the sources of certain sediment contaminants, especially in rivers that ran across national borders. This meant that the government organizations that had to deal with the contamination also had to pay for the remediation. However, with the implementation of the ELD, the development of techniques that can be used to track the source of the pollution (see Chapters 4 and 5, this book) deserves more attention, as these techniques would enable government organizations to actually claim the costs.

The ELD, therefore, provides a strong basis to raise the awareness of organizations of the consequences of their actions. Environmental liability with respect to damage to nature is a prerequisite to making economic groups feel responsible for the possible negative effects of their operations on the environment.

7. Conclusions

This chapter has given a short introduction into the methodology of SCBA in relation to sediment management. SCBA is an elegant tool to evaluate different policy options based on a rational approach. One has to bear in mind, however, that human decisions are not very rational, and that rationalities between different groups will differ. To obtain meaning from a SCBA to these different rationalities, it is necessary to involve stakeholders in the steps of the SCBA. The first step in a SCBA is to do a system analysis and to define the problem. As we have shown in this chapter, this is not as easy as it may seem. First, different groups will have different views on the problem, but most of all, problems in a natural system will have relations to each other, so solutions will have relations to different problems (in different ways). An assessment of the problem(s) and solutions will help to gain a better insight into these relations. The various steps in a SCBA are presented in Section 3 and the example of sediment dredging in the Netherlands showed these steps. For the valuation of the different actions that can be undertaken, different methods are available. In the Dutch example, the application of the 'willingness to pay method' was shown. Overall, the Dutch SCBA is a nice example of the application of SCBA to sediment management and produced some powerful insights that helped decision-making about Dutch dredging activities. The example of application of economic analysis instruments to water management options shows the influence of the EU WFD on the application of economic instruments and illustrates how cost effective analysis can support decision-making.

Whether we use a SCBA or other economic analysis instruments for decision support, we should be aware of the limitations of these methodologies. Nevertheless, SCBA can be a very useful and powerful tool to help societal decision-making and to facilitate the more efficient allocation of society's natural resources, of which sediment represents one type. The following chapter (Chapter 7, this book) considers in more detail the specific role of stakeholders in the decision-making process for sediment management.

References

1. Turner RK, Pearce D, Bateman I (1994). Environmental Economics: An Elementary Introduction. Harvester Wheatsheaf, New York.
2. Brent RJ (1996). Applied Cost-Benefit Analysis. Edward Elgar, Cheltenham.
3. Boardman AE, Greenberg DH, Vining AR, Weimer DL (1996). Cost Benefit Analysis: Concepts and Practice. Prentice-Hall, London.
4. Bouma JJ, Saeijs HLF (2000). Eco-centric cost-benefit analysis for hydraulic engineering in river basins. In: Smits AJM, Nienhuis PH, Leuve RSEW (Eds), New Approaches to River Management. Backhuys, Leiden, pp. 167–178.
5. Self P (1975). Econocrats and the Policy Process: The Politics and Philosophy of Cost-Benefit Analysis. Macmillan, London.
6. Lohmann L (1998). How Opinion Polling and Cost-Benefit Analysis Synthesize New 'Publics' (source: http://www.thecornerhouse.org.uk/briefing/07cba.html).
7. Kelman S (1981). Cost-benefit analysis: an ethical critique. AEI Journal on Government and Society Regulation, January/February: 33–40.
8. Bouma JJ and Schuijt K (2001). Ecosystem valuation and cost-benefit analysis as tools in integrated water management. In: Midttømme GH, Honningsvåg B, Repp K, Vaskinn K, Westeren T (Eds), Dams in a European Context. Swets & Zeitlinger, Lisse, pp. 154–163.
9. Stuip MAM, Baker CJ, Oosterberg W (2002). The Socio-Economics of Wetlands. Wetlands International and RIZA, The Netherlands (source: http://socioeconomic.unep.net/reports/SocioEconomics_of_Wetlands.pdf).
10. Susskind L, McKearnan S, Thomas-Larmer J (1999). The Consensus Building Handbook: A Comprehensive Guide to Reaching Agreement. Sage, Thousand Oaks, CA.
11. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy.
12. Reiser DW, Ramey MP, Wesche TA (1989). Flushing flows. In: Gore JA, Petts GE (Eds), Alternatives in Regulated River Management. CRC Press, Boca Raton, FL, pp. 91–135.
13. Kondolf GM, Kattelmann R, Embury M, Erman DC (1996). Status of riparian habitat. In: Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and Scientific Basis for Management Options. Wildland Resources Center Report no. 37. University of California, Centers for Water and Wildland Resources Davis, CA, pp. 1009–1030.
14. Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage.