Discussion Articles

A Conceptual Framework for River-Basin-Scale Sediment Management

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DOI: http://dx.doi.org/10.1065/jss2003.08.083

Abstract

A key problem in unifying sediment assessment and management approaches is in defining the hierarchy of decisions within a management framework. A basin-scale framework should be comprised of two principal levels of decision making; the first for basin-scale evaluation (site prioritisation) and the second for site-specific assessment (risk ranking). High priority, high risk sites and sites prioritised for management for socio-economic objectives should then be evaluated for management options. Although it is site-specific risks and objectives that will be managed, solutions may involve actions in other parts of the river basin (e.g., source control). A basin-scale assessment involves the balancing of a Conceptual Basin Model (CBM, which considers the mass flows of particles and contaminants, screening level assessment of sediment quality and archived data), and basin-scale objectives (BOs) to generate a Basin Use Plan (BUP). The Basin Objectives should define the ecological, regulatory and socio-economic goals for both the river basin (and its outlet to estuaries and the sea) and specific parcels of sediment. The development of a Basin Use Plan balances the CBM and the BOs, and should then result in a site prioritisation for further management that best meets the objectives of all stakeholders. On the other hand, site-specific assessment and management is characterised by tiered assessment and the determination of site-specific risk. Management options are driven by site-specific impact on BOs, site-specific risk, technical and economic feasibility and regulations. The proposed conceptual approach to basin-scale sediment management provides a possible framework for addressing the complexities inherent in managing sediments at both a basin-wide and site-specific scale.

Keywords: Assessment; Basin Objectives (BO); Basin Use Plan (BUP); catchments; Conceptual Basin Model (CBM); holistic management; quality; quantity; river basin; SedNet; sustainability; sustainable sediment management framework; watershed

1 Background

As our understanding of sediment systems has evolved, it has become increasingly clear that effective and sustainable management strategies must focus on the entire sediment cycle, rather than on one unit of sediment at a time. The mission of SedNet (the demand-driven European Sediment Research Network) is "to be a European network for environmentally, socially and economically viable practices of sediment management at the river basin scale" (Brils 2002). One of the main aims of SedNet is to "develop a document containing recommendations in the form of guidance and key-solutions for integrated, sustainable sediment management (SSM), from local to river basin scale (SSM Guide)" (Brils 2003). SedNet is not the first organisation to develop sediment management guidance (see Apitz and Power 2002, for a review of some of these approaches), but some of the goals and drivers differ for SedNet. Firstly, as an EC-sponsored program, it must address a number of international and cross-border issues not always addressed in other approaches. Secondly, in line with the new regulatory focus of the Water Framework Directive, SedNet specifically addresses river basin-wide sediment management. Thirdly, while most guidance documents have been generated for specific aspects of sediment management (such as dredged material disposal or environmental management, Apitz and Power 2002), a basin-scale approach must integrate various sediment goals and provide a universal framework. Different nations, organisations and stakeholders have different objectives when they address sediments, and a framework must be devised that allows goals and priorities to be balanced in a transparent way. The goal of SSM demands that sediments are managed, not one parcel of sediment at a time, but with the interactions between that parcel, and all current or potential sources or sinks within a river basin, in mind (Förstner 2002).

Because sediment management has generally been fragmented, by those who manage sediments for various reasons (maintaining waterways, controlling hot spots, flood defence, controlling siltation, mining for construction material, maintaining fisheries, etc.), by relationship with sediments (researcher, sediment 'owner', 'sediment producer', and regulators), by regulatory framework, nation, or discipline (toxicologists, chemists, geologists, engineers) and by environment (freshwater, estuarine, marine, lakes, rivers), many people use the same terms for different steps in the sediment management process. For example, sediment assessment and management frameworks designed for dredged material disposal decisions are fundamentally different from those designed to determine whether contaminated sediments pose a risk *in situ*. For one thing, these frameworks are applied at very different points in a decision process. In the former, a management decision has already been made (to dredge) and the assessment focuses on the selection of an appropriate disposal site. In the latter, questions are being asked about whether risk exists, and whether there is a need to manage the sediments at all. Different methods, assays and assumptions apply, but it is often difficult to clarify these differences, since similar vocabularies are applied. In a dynamic, interacting river basin, to achieve SSM, the various practitioners of sediment management must come to the table before any sediment management decisions are made and generate Basin Management Plans that will balance the environmental, economic, social and regulatory needs throughout the basin. To achieve this, a common language and framework must be developed, such that priorities can be established, information needs can be defined and filled, and sediment can be managed in a sustainable way. The dynamic nature of river sediments and the international aspects of the problem call for a new approach to sediment management that requires that transport, quantity and quality are explicitly addressed throughout the framework. This paper lays out one such approach. While the main focus of this paper will be river sediments, it should be emphasised that the sediment cycle is a dynamic continuum from sources such as soil, through streams and rivers and ultimately to estuaries and the sea.

2 The Interdependence of Sediment Quality and Quantity

Historically, sediment management was driven by quantity issues. Sediments were dredged to maintain waterways, or removed as a resource. Partly through a lack of environmental understanding, questions about quality were not paramount. More recently, sediment quality has become the dominating factor, in response to growing environmental and human health concerns and because of restrictions on how we dispose of dredged sediments. Currently, much of the thinking on sediment management and sediment risk assessment assumes that sediment quality is *the* issue. However, even when quality is seen as the dominating concern, sediment quantity can be critical in creating risk and determining management options. It is the interdependence between the management of sediment quantity and sediment quality that has not been effectively addressed in most assessment and management frameworks.

Sediments themselves can provide a risk or benefit to the wellbeing of a system, through excess or lack or through incompatible physical characteristics. For example, sediments in rivers, estuaries, reservoirs, lakes and impoundments can reduce storage and flow capacity, increase flood risk, damage hydropower installations, degrade habitats, erode river channels downstream of sediment 'blockages', and undermine the stability of channels and infrastructure (e.g. erosion of bridge piers). Benefits include a sediment supply to the nearshore environment (with implications for longshore drift/coastal stability), the provision or sustenance of wetland and aquatic habitats, sediment extraction for use in building/road industries, and beneficial use/capping of contaminants.

By thinking about sediments holistically (i.e. at the river basin level) we may also need to consider some non-traditional 'contaminant' issues. For instance, many river banks and flood-banks are highly contaminated with historical industrial waste or even dredged material. During flood events, contaminated sediment deposited on fields may take fields out of 'agricultural use' classes. Nutrients bound to sediments may play an important role in eutrophication (e.g. Alexander et al. 2002), and pesticides and pharmaceuticals bound to sediments may prove to be a long-term chronic problem (e.g. Brown et al. 2003,Vermeire et al. 2003).

Sediments are part of a hydrodynamic continuum, and sediment sources may or may not be the same as that of any contaminant with which they are currently associated. If we first consider a simple linear continuum of sediments through a system, under the action of gravity sediments will tend to move from land to river to estuary and to the ocean. This is complicated at many points by flooding (river to land), tides (ocean to estuary/river), removal and deposition (estuary, river, ocean to land), so sediment transfers are not always unidirectional. If we take action at one point in this continuum, then we would expect the main impacts to be downstream – or down the energy gradient. However, there may also be indirect implications elsewhere in the system. We can use this simple conceptualisation to think about the risks associated with sediment in three ways:

- the impact of a removal or addition of sediment quantity on sediment quantity elsewhere (quantity-quantity, e.g., removing sediment upstream may cause erosion downstream),
- the impact of removal or addition of sediment quantity on quality elsewhere (quantity-quality, e.g., removing sediment upstream may cause erosion or exposure of contaminated sediment downstream),
- the impact of addition or remediation/removal of a quality problem on quality elsewhere (quality-quality, e.g., removing contaminated sediment upstream reduces the risk of contaminated sediment deposition downstream).

Whilst these three scenarios are not mutually exclusive, this approach may provide a vocabulary for classifying different types of risk associated with different types of sediment-contaminant related actions in a river basin as a whole. Holistic management must consider mass transfers from source to sink. Thus, a river basin-wide sediment management plan must consider materials that can plausibly become sediments in its assessment and management scheme. There is thus a need to broaden thinking on sediment management and risk assessment to a basin-wide approach that addresses both quantity and quality of sediment and the fact that the actions we take in managing sediment or sediment sources in one place may well have impacts elsewhere. The interdependence of quality and quantity issues in dynamic river basins demands a holistic approach, and precludes a decoupling of these issues.

3 Basin-scale vs Site-specific (parcel) Assessment and Management

There are a number of reasons to manage sediments holistically, at the basin scale, rather than parcel by parcel as problems arise. Firstly, it is implicit in the Water Framework Directive. Furthermore, dealing with sediments parcel by parcel is reacting to symptoms rather than looking at causes. In a dynamic system, parcel-by-parcel management can be a short-term solution. If sediments are hydrodynamically connected, it makes sense to manage them in a manner that prioritises those that pose risk downstream, and to do this

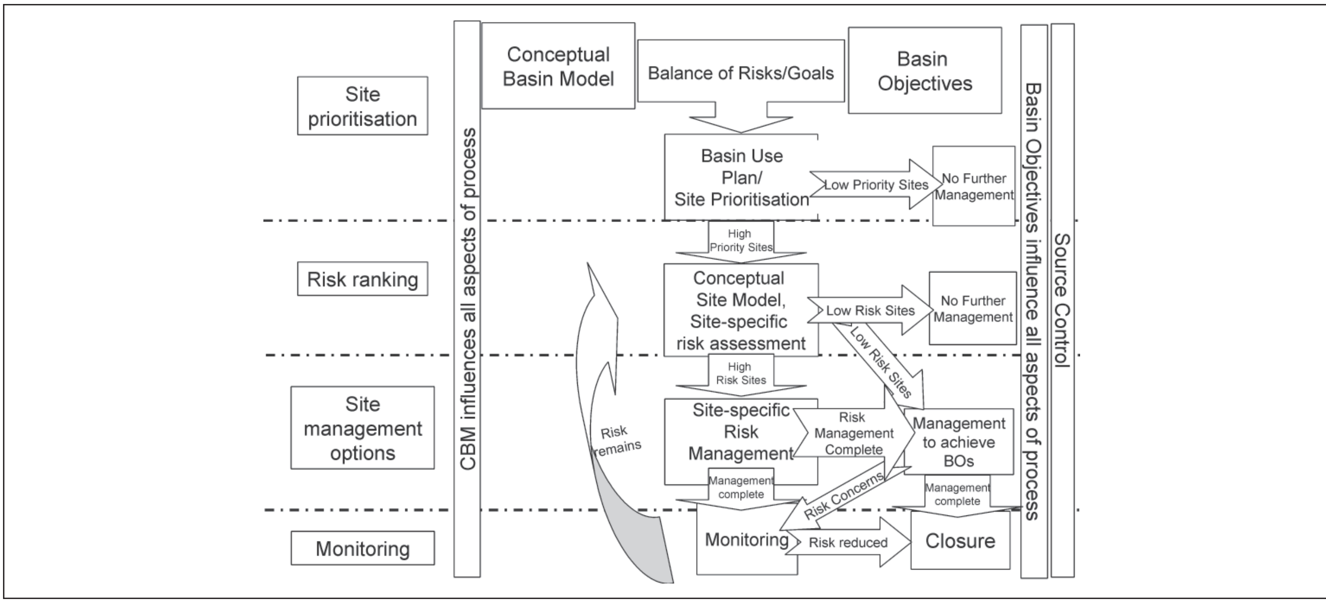

Fig. 1: Proposed conceptual approach to basin-scale sediment management

in a manner that considers the entire sediment and contaminant budget, from source to sink. Furthermore, impacts and benefits of sediment management actions for purposes other than risk reduction (e.g., waterway maintenance, wetland development, etc.), should be evaluated in concert with the remedial goals in a basin. Such an approach will provide insight into the highest impact potential changes in agricultural, industrial and development practices that may reduce sediment and contaminant inputs, as well as maximizing the potential for beneficial use, and hence reduce the cost of maintaining waterways and protecting the environment. This is a route to sustainable development. By planning management at the river basin scale, costs are saved by reducing the risk of repeated management/intervention after re-contamination, and through economy of scale for potential treatment and remedial alternatives. Money, which is presumably limited, is allocated based upon balancing basin objectives including net risk reduction, not purely by political pressure or site visibility. In this approach, we at least understand the compromises that are implicit in decisions we make about environmental management.

While SedNet advocates river basin management, assessment frameworks developed thus far only address a single parcel or unit of sediment at a time. A solution is to devise a framework that puts sediment and contaminant sources in a river basin in terms of one another, balances these issues with socio-economic goals for a basin, allows for ranking/prioritisation, and then feeds into parcel-specific risk analysis. In such an approach, sediments are evaluated at a basin scale, and then at a site-specific scale. Two potentially overlapping terms should be defined, for the purposes of this discussion:

- Site prioritisation – Evaluating parcels of sediment within a region in terms of hydrodynamics, risk, regulatory and socio-economic goals to rank and prioritise sites for management order or focus,
- Risk ranking – Evaluating individual sediment parcels to determine and rank their risk relative to benchmarks, site- or basin-specific criteria.

A key problem in unifying sediment assessment and management approaches is in defining the hierarchy of decisions within a management framework. **Fig. 1** presents a proposed decision framework for basin-scale sediment management. This framework is comprised of two principal levels of decision making. The first for basin-scale evaluation (site prioritisation) and the second for site-specific assessment (risk ranking). High priority, high risk sites and sites to be managed to achieve socio-economic objectives are then evaluated for management options. Although it is site-specific risks and goals that will be managed for, solutions may involve actions in other parts of the river basin (e.g., source control).

A basin-scale assessment involves the balancing of a Conceptual Basin Model (CBM, which considers the mass flows of particles and contaminants, screening level assessment of sediment quality and archived data, discussed in greater detail below), and Basin-scale objectives (BOs, discussed below) to generate a Basin Use Plan (BUP). The Basin Use Plan should define the goals for both the basin and specific parcels of sediment, and should result in a Site Prioritisation for further management. On the other hand, site-specific assessment and management is characterised by tiered assessment and the determination of site-specific risk. Site-specific Management Options are driven by site-specific impact on BOs, site-specific risk, technical feasibility and regulations.

4 Conceptual Basin Model (CBM)

Just as a Conceptual Site Model (CSM) allows risk assessors to consider the flow of contaminants to target organisms in support of site-specific risk assessment (e.g., ASTM 1995), an understanding of the particle and contaminant mass flows within a river basin in support of basin-wide management and prioritisation can be defined as a Conceptual Basin Model or CBM. The flow of sediments, whether clean or contaminated, can impact the relative risk, quality or potential utility of downstream sites. Furthermore, actions taken in the basin can affect sites downstream, increasing or decreasing the quality of downstream sediments, as well as altering the dynamic balance of particles. It can be argued that it is the relationship between hydrodynamically connected sediments, in terms of quality, quantity and energy, which defines their relative risk, and their priority in a risk management strategy. However, site-specific decision frameworks have not generally addressed the dynamic relationship between sediment parcels in a formal way.

We will begin with the assumption that, in a basin, one can define an energetic continuum between sediments, from source to ultimate sink, and that sediments move along this continuum. The analogy of a 'jerky conveyor belt' has been used (Naden 2003), though perhaps traffic flow models are more appropriate. For simplicity, we will assume that this flow is unidirectional (i.e., sediments move only in one direction), though it is clear that there are discontinuities and sinks (a dam will stop a sediment flow, at least over long time periods). If one divides a basin into 'parcels' of sediment of a given size, one can define the position of a parcel of sediment on an energetic continuum, and its relationship to other sediments, as either a sink or source for an adjacent parcel. Thus, sediments and source materials have an energetic and quantitative relationship with one another. We also assume that sediments can, and have been, ranked in terms of quality. The definition of quality will depend upon the benchmarks and objectives selected for a basin, as is discussed below. However, for a given measure of quality, one can characterise parcels of sediment relative to one another.

Then, one can map the sediments in a basin in terms of their energetic position (source to sink) and quality. **Fig. 2** illustrates a conceptual diagram of a projection of sediment energy (source vs sink) and quality. The x and y axes represent latitude and longitude. The z axis on the bottom graph represents the energetic state of a parcel of sediment (in many cases, this represents elevation in the basin, as particles move from the source to the oceans). In this illustration, potential sediment (e.g. soil) is included. In a dynamic system, this assessment should include not just those materials that are currently sediments, but also materials such as soils, mine tailings, etc. that can reasonably be expected to become part of the sediment cycle during the lifetime of a management approach. This example is an oversimplification in many ways, one of which is that the entire surface is included, while in a real risk map there will be many areas which do not represent sediments or plausible source materials. However, this map can be used for illustrative purposes, to be refined when case study data become available. The greyscale projection at the top of the figure is a contour plot of sediment quality (based on a hypothetical chemical or biological measure). In this figure, poorer quality is indicated by black and dark grey, better quality grades to white.

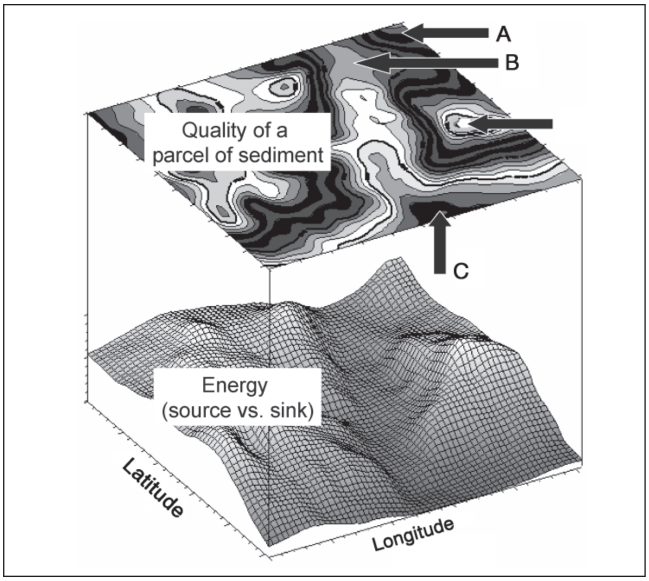

Fig. 2: *Conceptual* diagram of projection of sediment energy (source vs sink) and quality in support of the development of Conceptual Basin Models

Consider sediment parcel A. As can be seen, parcel A is black (poor quality) and has a high elevation or energy, in absolute terms, but also, more importantly, in relationship to the sediment adjacent to it, parcel B. Because A has both higher energy and poorer quality than parcel B, it can be considered high priority sediment, as it not only represents potential in-place risk, but also potential risk to adjacent sites. This can be contrasted with parcel C. This sediment is also black (poor quality) but it is at a lower energetic level than the adjacent sediment parcel D. Thus, though potential in situ risk exists, transport risk is relatively low. It should also be pointed out that since the up-stream (in energetic terms) sediment parcel D is of relatively high quality, the prioritisation of C can be considered even lower, as the clean sediment upstream, D, may attenuate the risk at C. These features can be summarised in a conceptual way as in **Table 1**. For this example, sediments can be prioritised as a function of quality, energy and potential benefit. Transport risk can be defined as the risk of contaminated sediments moving downstream to less contaminated sites. Transport benefit, on the other hand, is the possibility that clean sediments can move onto, and possibly attenuate, downstream contaminated sites. There are other potential risks and benefits of sediment movement that can be considered as well. For this scenario, one can then conclude that the relative order of management priority is: A>C>B≥D.

Table 1: Prioritizing sediments in terms of one another

Sediment unit	Quality	Energy	Transport risk	Transport benefit
A	low	high	high	low
B	high	low	low	high
C	low	low	moderate	moderate
D	high	high	low	high

In the development of a Basin Use Plan, sediments will most logically be subjected to site-specific risk assessment and management in the order of priority suggested by the above analysis. While relatively simplistic, this approach allows for sediments to be prioritised in common terms relative to one another in order to determine order of risk management, and allocation of resources. As sediment goals are refined, this model can either be simplified or adapted for greater complexity. Of course, objectives for sediment other than risk reduction must be balanced as well, as will be discussed below.

The above assumes that there is a minimum, and uniform, amount of hydrodynamic and quality information about sediments throughout the basin that allows us to make some first-order decisions about the relative priority of these parcels of sediment. Quantity and mass flow issues must be addressed in a basin-scale assessment. There are a number of hydrodynamic models available to predict mass flow of particles. GIS-supported models and databases developed in support of water quality studies [such as SWAT (Neitsch et al. 2001), GREAT-ER (Feitjel et al. 1998), TERRACE (Beaudin et al. 2002)] might provide a model or springboard for how to map particle and contaminant mass flow in river basins.

The information used to evaluate quality will depend upon the definition (and measure) of ecological quality, and the management goals for a basin. Clearly, both chemical measures and toxicity assays have strengths and weaknesses as preliminary screening tools, but it is not feasible to apply all methods to all sediments in a regional prioritisation. Indicators of quality will depend on management objectives and may include: hazard quotients, risk ranking, concentrations of specific contaminants, eco-toxicological indicators, health or bio-accumulation. Essentially, for basin-scale management, some uniform measure of sediment quality must be selected and applied throughout the area. It must be sensitive enough to detect potential risks, broad-based enough to allow for a comparison of sites with different contaminant types (unless the management goal is focused on only one or a few contaminants) and should provide a broad dynamic range – sediments with different levels of potential risk should be distinguishable from one another. Thus, output cannot be purely digital, but should indicate relative degree of potential risk. Quality indicators for such a basin-scale assessment should be sufficient to provide preliminary prioritisation of sites, but simple or cheap enough for wide, cost-effective coverage. For data-rich catchments, data mining can be used. For a basin-wide assessment, screening-level measures may be appropriate. Some countries, river basins and regions have already initiated such regional assessments (e.g., Peerboom and Hattum 2000), others have not.

5 Basin Objectives (BOs)

It is not only the components of the CBM that will drive a prioritisation of sediments. Societies have a number of socio-economic goals for sediments and river basins which include regulatory, economic, aesthetic, recreational and ecological factors. In order to sustain economies, evaluate, prioritise and improve ecological status of sediments, stakeholders must decide on objectives, and how they are to be measured and balanced. The Water Framework Directive mandates "Good ecological status of water bodies" (WFD 2000/60/EG). Those who work with sediments have no trouble understanding and communicating the link between sediments and the ecological status of water bodies, but the definition of 'good ecological status' can be debated endlessly. The Habitats Directive mandates that there is a 'Duty to demonstrate no harm' (Council Directive 92/43/EEC). Whether this 'duty' applies to future, ongoing or planned anthropogenic activities, the consequences of these, or to various environmental media, must still be clarified. Most international bodies, including SedNet, speak of the goal of 'sustainability'. SedNet defines this term as "The multipurpose management of sediment with full attention to adverse effects, so as to enhance the utility of river basins in the future" (Brils 2003).

However, EU programmes driven by economic goals such as the Common Agricultural Policy (CAP) currently subsidise practices that may conflict with environmental sustainability. For example, wheat and maize are now being grown in the UK on highly erosive and sloping soils. Such practices are causing enhanced flooding, streets and gardens filled with sediments, and severely silted watercourses. So, national, international and/or basin-wide goals must be defined. Is the goal to reduce the mass balance of contaminants in a watershed, to limit the exposure of these contaminants to the food chain, to reduce risk (to what?), to protect benthic organisms, fisheries, shipping or farmers, or to achieve the 'right' amount of sediment of the right type for ecological requirements? How can this be measured? How does this fit into a policy or framework?

The above are serious questions that must be addressed, and that will ultimately control how we prioritise sites, how we assess and manage them, as well as how extensively we include an evaluation of land-based practices in a sediment management strategy. Inevitably goals will vary from place to place and even from time to time. Not all objectives may be achieved, but the question of who decides on the necessary compromises is also an important one. It can be argued that it is useless to remediate parcels of sediment in a dynamic system until the entire sediment and contaminant cycle is addressed.

There must be a definition of objectives for the management of a given river basin (Basin Objectives). Factors to be considered include 1) meeting regulatory criteria (e.g., WFD, Habitats Directive, North Sea Treaties, National and local legislation), 2) maintaining economic viability (e.g., navigation, fisheries, flood control, recreation), and 3) protecting sensitive environments (based upon the Habitats Directive, spawning grounds, exceptional value, etc., a site may merit exceptional protection not covered by other criteria). To identify BOs, all stakeholders must come together, and define what the site-specific and regional goals for a basin are. Such stakeholders may come from many fields – regulators, dredgers, fishermen, shippers, environmentalists and the general public, among others, should have input. The CBM should be available to provide insight into how various site-specific actions might affect other sites and their potential use.

6 Basin Use Plan/Site Prioritisation

A combination of the CBM and the BOs should result in the development of a Basin Use Plan (BUP). This plan will include a prioritisation of sediment sites in terms of potential risk (using the CBM), basin objectives, and potential for beneficial use/resource sharing during management. A critical component of the BUP should be a plan for source control via appropriate prioritisation of sediment parcels and the evaluation of activities in the basin that provide continuing input of contaminants or interfere with sediment balance issues.

In order to be effective, an understanding of the sources and mechanisms of sediment and contaminant inputs is necessary. There are a number of types of sediment and contaminant sources in a dynamic system:

- Local historical – in this case, the source (of contaminant or sediment) is from nearby, has been controlled, and the major concerns are to prevent spreading and to control risk in place. These risks, in general, are controllable at the site (dependent upon site-specific conditions).
- Remote historical, point source – in this case, contamination or sediment came from upstream, but the source has been controlled. Concerns include residual diffuse input (e.g. metals in river banks and flood protection banks). One of the goals of sediment parcel prioritisation in basins is to assure that such potential risk sources are managed, if possible, before downstream parcels (barring cases in which very high site-specific risk moves a parcel up in priority, in which case the upstream input is not the primary risk driver).
- Active point sources – in general these are being controlled by legislation. However, catastrophic failures and isolated spillages may still occur.
- Quasi-diffuse sources – these, rather than being specific point sources, can be residues of controlled point sources (as above) or diffuse (but not entirely ubiquitous) sources from the basin. These can be sources of both sediment and contaminant such as pesticides, veterinary pharmaceuticals, nutrients, input from atmospheric deposition, metals/pharmaceuticals/LAS from sludge spreading to land. This is the subject of much current research, and the WFD may drive reduction of such contamination, which may also (coincidentally in some cases) reduce sediment inputs to rivers. To control such risk requires basin-wide changes in agricultural and industrial practices. Such contamination is not manageable until sources are controlled.
- Non-point sources. If contaminants in sediments result from ubiquitous background levels, either from natural or anthropogenic sources, there is little that can be done about risks as a result of such inputs, so even if present, risk is not manageable in an active way.

How potentially competing goals are balanced is not a purely technical decision, but rather requires the application of socio-economic and political decision making. Acceptance and implementation of this framework will require significant work, both technical and political. Different nations, organisations and stakeholders have different goals for sediment management. While SedNet is an open organisation, and seeks input from all European nations and from academia, business, government and NGOs, representation is not uniform. Whether a single framework can successfully provide the tools for these disparate agendas and stakeholders to be reconciled remains to be seen. However, the definition of Basin Objectives, and the subsequent development of a Basin Use Plan and Site Prioritisation is a critical part of sustainable sediment management. This paper does not address how these choices will be made, since significant work must still be done on defining river-basin-wide and/or Europe-wide methods, goals and priorities. The purpose of this paper is to suggest a framework within which to clarify the dialogue.

7 Site-specific (parcel) Assessment and Management

Site-specific risk assessment should then be carried out on high-priority sites. A framework for site-specific sediment assessment and management is being developed by SedNet, and will not be discussed here. There are also many other site-specific frameworks in the literature. For site-specific assessment to be meaningful within a basin-scale framework, CBM, BOs, and source control must be considered at each step.

Management options must be evaluated, both in terms of site-specific and basin-scale impacts. For instance, for low-risk sites that are prioritised to be managed to meet non-remedial Basin Objectives, management options must still be evaluated in terms of the CBM, overall Basin Objectives and source control issues. For contaminated sites, the most cost-effective solution for a site may be upstream source control. On the other hand, some options that solve the problem at a site may have negative impacts for other sites in the basin. These issues are particularly important in dynamic river basins. Questions that should be asked during selection of management options include:

- Is the site erosive or depositional?
- Will management options change that, and how will that impact other sites?
- Can sediments coming in be counted on to aid in risk reduction, via burial, mixing or attenuation?
- Does sediment coming in bring new contaminants?
- Do remedial options increase risks downstream?
- Is the sediment a resource needed in the basin, e.g., in order to provide habitat or prevent channel erosion?
- Are the characteristics (e.g., grain size, organic matter content) of sediment arriving at a site appropriate to the objectives for the site?

For high-risk sites, after management actions have been selected and applied, monitoring must continue until risks are deemed to have reached acceptable levels. CBMs should be either continuously updated or periodically reviewed, and re-balanced in terms of changing BOs and BUPs. Sediment management will be an iterative process, but if done properly, resources can be allocated for maximum benefit.

8 Conclusions

The proposed conceptual approach to basin-scale sediment management provides a possible framework for addressing the complexities inherent in managing sediments at both a basin-wide and site-specific scale. Acceptance and implementation of a basin-wide approach will require significant work, both technical and political. A successful development of a basin-scale decision framework should provide a basis for parties with very different goals for sediment to come together in support of sustainable sediment management. Because all stakeholders are ultimately stewards of the same ecological and economic resources, breaking down these divisions should ultimately help to balance their objectives in a sustainable way.

Acknowledgements. This paper was originally a white paper and presentation for SedNet Working Group 5, Workshop 2. The authors acknowledge discussions with members of both WG 4 and WG 5, which helped refine the paper. This paper also benefited from discussions at *Holistic Sediment Management: UK Goals, Needs and Approaches*, a workshop held on April 10, 2003 at the University of Reading. SEA acknowledges partial support from ONR-IFO and both authors from SedNet WG 5 for travel costs.

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Received: June 27th, 2003
Accepted: August 22nd, 2003
OnlineFirst: August 22nd, 2003

JSS – J Soils & Sediments 2 (2) 54 (2002)

Sediments and the European Water Framework Directive

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The very successful installation of the 'Demand-driven European Sediment Research Network (SedNet)' [1] provides a stable common platform for both researchers and practitioners in this field. Demand-driven? Surely, demand within a new market first has to be developed. Until now, very few 'problem owners' face a large majority of potential 'solvers', as has been indicated from an inquiry among SedNet participants. At first, 'harmonization' of sediment quality objectives and management performance is needed for both the European river basins and with respect to the most sensitive areas within these basins – floodplains, estuaries and coastal zones. Distinctions such as 'problem owners' and 'problem solvers' should then become obsolete.

The self-declared problem owners to date are mostly located at the mouth of the large rivers and they are in a rather uncomfortable situation as they have to pay the expenses for all former, actual and future shortcomings in the emission control within their catchment area. According to available information, there should be many more 'interim owners' of sediment problems in the upstream river basin. Many of them, however, ignore their problems or claim to follow a procedure called 'sediment relocation'; among the latter, the problems for the management by the 'end owners' can be aggravated further.

In fact, it is not really a transfer of contaminated sediment to its original site, but rather a down-locating (as re-cycling of waste materials mostly is a down-cycling), which contradicts the ecological principle of not to disperse, dilute or mix pollutants but rather treat them at the site of their highest concentrations. Although the large-scale effect of natural and technical resuspension processes is well-known – for example, typical patterns of dioxin congeners from the Bitterfeld area can be detected in the sediments of the Port of Hamburg in the Elbe River more than 300 km downstream – sediment problems in river basins are still regulated locally, sometimes by means of dubious threshold values.

Here, a clear deficiency of the European Water Framework Directive (WFD) becomes evident. The WFD aims at achieving a good ecological potential and good surface water chemical status in European river basins until the year 2015 by a combined approach using emission and pollutant standards. These consider priority pollutants from diffuse and point sources, but neglect the role of sediments as a long-term secondary source of contaminants. Such a lack of information may easily lead to unreliable risk analyses with respect to the – pretended – 'good status'.

The requirements for a river basin-wide sediment concept will be even more challenging than the actual Water Framework Directive. It will include inventories of interim depots within the catchment area (underground and surficial mining residues, river-dams, lock-reservoirs), integrated studies on hydromechanical, biological and geochemal processes, risk assessments on sedimentary biocoenoses and, last but not least, development of decision tools for sustainable technical measures on a river basin scale including sediment aspects. Many of these could be promising themes for interdisciplinary research in the European Commission's 6th Framework Program.

[1] Brils J (2002): The SedNet Mission. JSS – J Soils & Sediments 2 (1) 2–3