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Incorporating Ecosystem Service Valuation in the Assessment of Risk and Remedy Implementation

Fabio Colombo*[a], Joe Nicolette[b], Richard Wenning[c], Mark Travers[d]

[a] ENVIRON Italy Srl Managing Principal, Via Vincenzo Lancetti, 43 20158 Milano, Italy
[b] ENVIRON USA Principal, Ecosystem Service Task Force Leader, 1600 Parkwood Circle, Suite 310, Atlanta, Georgia 30339 USA
[c] ENVIRON USA Principal, Ecology &Sediment Management Global Practice Leader 6001 Shellmound Street, Suite 700, Emeryville, CA 94608 USA
[d] ENVIRON USA Managing Principal, Site Solutions Global Practice Leader 333 West Wacker Drive, Suite 2700, Chicago, IL 60606 USA
fcolombo@environcorp.com

Remedial actions are typically based upon risk assessment and derived protection goals. Protection goals may or may not be overly protective. In developing a remedial action plan, it is necessary for stakeholders and decision makers to understand the potential benefits (i.e., gains in ecosystem service value) and costs (i.e., losses in ecosystem service value) associated with the implementation of various remedial alternatives based upon prescribed protection goals. In this regard, a formal quantification of the effect that remedial actions have on ecosystem service values is rarely considered. Consequently, tangible metrics that can describe the costs or benefits associated with the selection of remedial alternatives, and subsequently overall site cleanup, are lacking. Therefore, the potential exists for a remedial action based upon a protection goal(s) to create more harm to the ecosystem than is predicted by the risk assessment that drove the remedial action in the first place or provide marginal benefit for the effort expended. This paper provides an overview of a practical approach, based upon scientific and technically credible approaches, to better understand the potential impacts and/or benefits associated with remediating to a specified protection goal. A case study is provided that demonstrates the value of these approaches in guiding remedial decisions.
The integration of ecosystem service valuation into site decision-making is evolving and is broadly incorporated into an approach often referred to as net environmental benefit analysis (NEBA). A NEBA is an approach that enables quantification of the change in natural resource service values that would be associated with the implementation of an action (e.g., remedial action) and compares those changes to cost and predicted changes in risk. In this context, the NEBA approach uses various methods to quantify the change in ecological and human use service values associated with each remedial alternative so that comparisons between alternatives can be made. The NEBA approach is unique and innovative because it considers risk, cleanup and natural resource issues concurrently. The approach provides a necessary and value-added component to risk management decision-making and the final selection of remedial alternatives.
A NEBA approach can help stakeholders make decisions regarding the level and amount of remediation that is suggested by a protection goal. The approach, when conducted appropriately, will provide a systematic, consistent, and defensible process that can significantly enhance stakeholder support for selected environmental and land use planning decisions. This process also promotes the selection of decisions that demonstrate a balanced win for the environment and the stakeholders.

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1. Introduction

A discussion of ecosystem valuation and the benefits of considering ecosystem services (Millenium Ecosystem Assessment, 2005) related to remedial decision-making are presented in this paper. We discuss the difference between "risk" and "injury", discuss a net environmental benefit analysis approach in general, and then focus on its application to remedial decision-making. A NEBA, incorporating ecosystem service valuation, is also termed a net ecosystem service analysis (NESA)(Nicolette, et al. 2011).

2. Approach and Method Considerations

2.1 Protection goals and differentiating between risk and injury

Remedial actions are typically based upon the results of risk assessments and environmental protection goals established to restore an ecosystem damaged or injured as a result of human activity. Risk assessments are necessary to define the nature and extent of the environmental threat that will be addressed by the remediation plan. Protection goals arising from risk assessments and regulatory requirements may or may not be sufficient to eliminate the threat to human health and the environment entirely. Protection goals, however, generally strive to be overly protective based on available site-specific knowledge of the chemical or physical threat, human use of the affected environment, and ecological receptors at risk.

To understand the efficacy of protection goals, it is important to recognize that "risk" to natural resources and the services provided by ecosystems to humans is very different from an "injury" to a natural resource. It is important to segregate between actual negative impacts that have been documented (i.e., quantified through measurements) through actual field studies, potential negative impacts that are known or suspected to have occurred in the past, and negative impacts that may occur in the future. For remediation work, these distinctions are important because remedial actions addressing actual impacts are generally more urgent and costly than actions intended to be preventative or precautionary.

There is a growing recognition of the significance of ecosystem services as well as the dramatic impact site remediation and myriad of other human activities can have on these essential services. Identifying services at a contaminated site prior to the remediation process is a necessary component of reducing the negative impacts that remediation may have on the ecosystem. An ecosystem services assessment conducted concurrently with risk assessment and prior to the promulgation of protection goals could provide site remediation managers with the knowledge necessary to limit negative effects from the remediation work at the site. An ecosystem services assessment could also provide information needed for setting baseline conditions for site restoration after the threat has been eliminated or mitigated. In a recent publication, the U.S. Science Advisory Board highly recommends the evaluation of ecosystem services at the earliest stages of site remediation (EPA, 2009). These concepts have also been outlined in a paper funded by the EPA (Slack 2010).

In this regard, a formal quantification of the effects that remedial actions have on ecosystem service values is rarely considered. This is primarily due to the absence of adequate tools for quantifying different types of services objectively and translating the results into a financial or other metric that can be used to compare and contrast different remedial actions. Tangible metrics that can describe the costs or benefits associated with different remedial alternatives, and subsequently overall site cleanup, are lacking. Therefore, the potential exists for remedial actions based upon risk assessment and protection goal(s) to create more harm to the ecosystem than predicted by the risk assessment (which largely drove the remedial action in the first place) or provide only marginal benefit for the cost and effort expended.

In order to be able to compare various remedial actions and their effects on the environment, one must be able to quantify how ecosystem services change with the implementation of different site remediation actions such as soil and sediment reclamation, ground water and surface water treatment, and ecological restoration. Using scientifically-based methodologies that have been tested in U.S. courts of law, methods have emerged that quantify the net change in ecological and human use service values associated with actions that are known or suspected to affect natural habitats, land, and

water resources. These methods include habitat equivalency analysis (NOAA 1995) and human use benefits transfer analysis (REMEDE 2007). With the ability to quantify ecosystem service values, site remediation managers and regulatory specialists can compare the effects of one remedial alternative decision against another, as well as demonstrate the overall ecological and human use value associated with a preferred remedial action. This comparative process is generally termed a net environmental benefit analysis – NEBA (Efroymson, et al. 2004).

2.2 What is net environmental benefit analysis (NEBA)?

Net environmental benefit analysis shares the same theoretical foundation as benefit-cost analysis. An important distinction is that within NEBA, the environmental effects of an action on ecosystem services are included within the analysis. The NEBA approach identifies and values the primary ecosystem services that an area or portfolio of holdings provides to the public. The type, quantity, and quality of environmental services provided by an area or waterway are determined, in part, by the surrounding geographic landscape (i.e., land uses). The NEBA approach encompasses the recent emphasis in the U.S. (e.g., natural resource damage assessment regulations; NOAA 1996) and European Union (e.g., various environmental liabilities directives) on the ecological sciences to quantify and evaluate ecosystem services within a landscape context.

Including NEBA in the site remediation planning process can be particularly helpful when the balance between environmental risks and the benefits from remedial actions are ambiguous or uncertain (Efroymson, et al. 2004). NEBA, which requires risk assessment information as input, can provide value at contaminated sites where:

- The contaminated site presents the opportunity to retain significant ecological value;
- The remedial action(s) are themselves believed to be environmentally damaging;
- The ecological risks from site contaminants are relatively small, uncertain, or limited to a only a portion of the ecosystem;
- The chances for remediation or restoration failure are potentially high; and/or,
- Changes to the risk-benefit-cost scenario appears to be disproportionate to costs (i.e., the costs far outweigh the likely positive outcomes from the work).

The first step involving the use of NEBA to evaluate ecosystem services is to identify what services the site provides. Currently, the best method to approach this is to identify a subset of services from a comprehensive list of ecosystem services that apply to the site. Depending on how large the site is, the identification of services that will become the focus for remediation planning may be relatively simple or more complex. It will be helpful to garner support from knowledgeable experts such as ecologists, remediation engineers, geoscientists, and others during this work to reduce uncertainty and hasten the process. Another way to approach service identification is to initially define the type of ecosystem targeted for remediation. Understanding the type of ecosystem will help narrow the applicable services that need to be considered.

The purpose of a NEBA is to help stakeholders make decisions that are defensible, systematic, consistent, and understandable to the public. Decisions that possess these attributes will achieve environmental objectives at the least cost while effectively managing actual or perceived risks to the public. The application of the NEBA approach to remediation planning, when conducted appropriately, provides a systematic, consistent, and defensible process that can significantly enhance stakeholder support for selected remedial actions at contaminated sites and environmental and land use planning decisions. This process promotes the selection of decisions that demonstrate a balanced consideration for environmental protection and the needs of different stakeholders (e.g., community, business, and regulatory groups).

2.3 Site remediation and NEBA

The second step in NEBA is a formal quantification of ecosystem service values, both ecological and direct human use values. In the context of site remediation, NEBA provides a formal quantification of the change in ecosystem service values that would be associated with the implementation of a remedial action and compares those changes to cost and predicted changes in risk. As part of developing a remediation plan, the results of NEBA help stakeholders and decision-makers to understand the potential benefits (e.g., gains in environmental quality, human risk reduction, ecological

restoration, and new or restored recreation opportunities) and the possible costs associated with different remedial alternatives and their ability to address on-going or perceived injuries to the environment.

One example of a NEBA framework for collecting and comparing different ecosystem service attributes is presented in Table 1. As such, a NEBA evaluates not only the effect of remedial actions on human and ecological risk scenarios, but also evaluates how they impact ecological and human use services. In the U.S., regulatory agencies are obligated to assess and understand the information presented in Table 1 and to consider the relationship between remedy costs and how different remedial actions might help or hinder efforts to reduce human health and ecological risk. This activity increasingly occurs in the latter stages of the feasibility study (FS) process in both state and federal site cleanup programs.

Table 1. Example of a NEBA Analysis Table.

Remedial Action	Ecological Services (dSHYs)	Human Use Value (monetary)	Human Risk Profile	Ecological Risk Profile	Cost (monetary)
Alternative 1					
Alternative 2					
Alternative 3					
Alternative 4					

In addition to understanding how potential remedial alternatives affect both ecological and human use values, a NEBA also incorporates the consideration of restoration actions that augment ecosystem service values within the remedial alternative selection process. For example, once high risk areas are addressed through remediation, marginal risk areas may have the potential to be offset using a restoration project that creates ecological and/or human use value, especially given projected fate and transport mechanisms associated with the marginal risk areas. A NEBA, incorporating quantified ecosystem service metrics, provides a scientific basis for balance between effort and benefit gained. A NEBA can help identify the “breakpoint” where remedial costs become disproportionate to benefits gained and in doing so facilitate the design of remedial alternatives that maximize value to the public. The overall package of remedial and restoration alternatives are evaluated to assess their combined impact on the total ecological and human use services provided by a site.

3. Case Study Results

3.1 Ecosystem service valuation and sediment remediation in northern Italy

At a large alpine lake located in northern Italy, NEBA was conducted to provide a formal quantification of the change in key ecosystem service values that would be associated with the implementation of different remedial actions for addressing sediment contamination in the harbor. The site was located in Pallanza Bay located along the western shore of Lago Maggiore in the northern alpine region of Italy. The objective of the work was to combine ecosystem service quantification approaches with ecological and human health risk assessment and remedy cost analysis to quantify changes in ecological and

human use services, ecological and human health risk, and cost associated with different possible sediment remediation actions.
The work was conducted in the following five steps:

- Identify plausible remedial alternatives;
- Quantify ecological service losses and gains associated with implementation of each remedial alternative;
- Quantify human use service values associated with implementation of each remedial alternative;
- Evaluate how human health and ecological risk profiles might change theoretically as a result of the implementation of each remedial alternative; and,
- Develop order-of-magnitude cost estimates for each remedial alternative.

Four remedial alternatives were considered for Pallanza Bay including: monitored natural recovery (MNR); MNR combined with riparian enhancement along the Toce River; capping, and dredging. Remediation work focused on reducing DDT levels in sediments and the associated health and environmental risks to communities surrounding the bay and lake.

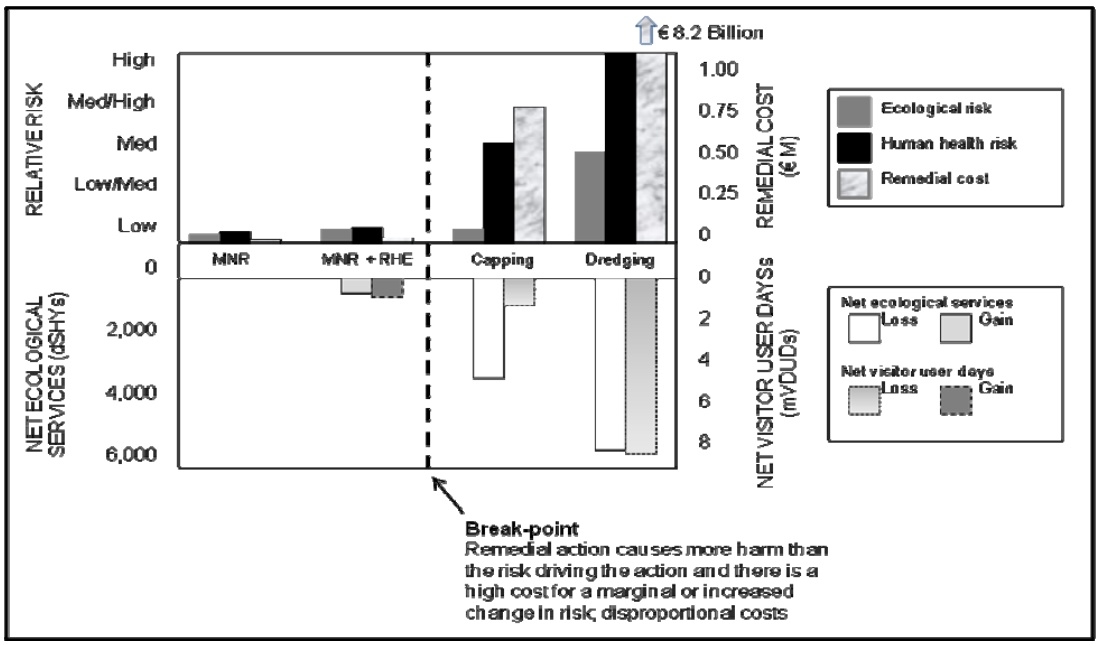

Figure 1: Preliminary comparative analysis: comparison of remedial costs, risk profiles, and impacts to ecological and human use services.

The results of the NEBA are shown in Figure 1. Using a NEBA approach to collect and evaluate human risk, ecological risk, remedy costs, and changes in ecosystem services, the results indicated that engineered remedial alternatives involving the installation of sediments caps and the dredging of sediments are not viable options for addressing conditions in Pallanza Bay (Figure 1). Sediment capping and dredging provide no meaningful reductions in ecological and human health risks, result in substantial detrimental effects on both ecological and human use service values, and are characterized by costs that are disproportionate to the slight incremental benefits derived from either type of remedy action. In fact, the implementation of engineered remedies may increase ecological and/or human health risks. The costs for capping and dredging remedy actions range from approximately € 750,000,000 to € 8,250,000,000 and are significantly higher than costs associated with either a monitored natural recovery (MNR) remedy (€ 1,500,000) or a combination of MNR and riparian enhancement along the shores of the bay (€ 20,000,000). Based on this comparison, the NEBA

indicates that there is a “breakpoint” above which remedial costs appear disproportionate to the benefits gained. This is substantiated through the quantification of ecological and human use service gains or losses associated with each remedial alternative.

4. Conclusion

A NEBA approach, incorporating ecosystem service values, can help stakeholders make decisions regarding the level and amount of remediation that is suggested by a protection goal. The approach, when conducted appropriately, will provide a systematic, consistent, and defensible process that can significantly enhance stakeholder support for selected environmental and land use planning decisions. This process also promotes the selection of decisions that demonstrate a balanced win for the environment and the stakeholders.

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