COMPENSATORY WETLAND MITIGATION AND THE WATERSHED APPROACH

A Review of Selected Literature

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COMPENSATORY WETLAND MITIGATION AND THE WATERSHED APPROACH: A REVIEW OF SELECTED LITERATURE

BACKGROUND

This literature review seeks to provide the Mitigation Action Plan Workgroup and the participants of the 2004 National Symposium on Compensatory Mitigation and the Watershed Approach with a summary of the current scientific thinking on many of the topics that will be addressed by the Workgroup. There is a growing body of scientific literature exploring the various aspects of a watershed approach to compensatory mitigation and restoration. Although the methodologies, criteria, and tools employed vary among authors and regions, there is agreement that adopting such an approach will require a shift towards a more proactive and planning-based approach to wetlands mitigation and permitting (Montgomery et al. 1995, Gosselink et al. 1990).

While alterations to wetlands often have impacts that extend beyond the immediate boundaries of a project, §404 permitting is conducted primarily on a project-specific basis (NRC 2001, Bedford and Preston 1988). The prevailing project-by-project permitting process has compromised the effectiveness of wetland mitigation efforts (Mitsch and Wilson 1996). The mitigation practices of the last several decades have also led to dramatic changes in the types and distribution of wetlands in the landscape, as mitigation wetlands often differ from the natural wetlands they are replacing (Gwin et al. 1999).

In the 2001 report "Compensating for Wetland Losses Under the Clean Water Act," the National Research Council (NRC) called for regulatory agencies to "modify the boundaries of permit decision-making in time and space" so that "site selection for wetland conservation and mitigation" can be "conducted on a watershed scale" (NRC 2001). The NRC's recommendation was based on nearly two decades of scientific- and management-related literature and discussion regarding the landscape- or ecosystem-based approach to wetland restoration and creation.

COMPONENTS OF THE WATERSHED APPROACH

The following components of a watershed approach to compensatory mitigation, broadly defined, encompass many issues discussed throughout the scientific literature on this topic:

- *Defining critical issues and objectives*, i.e. identifying the important issues to consider and setting management and regulatory objectives.
- *Determining the appropriate scale*, i.e. defining boundaries and determining the appropriate scale for consideration of critical issues and objectives (eco-region, watershed, etc.).
- *Understanding watershed/landscape functions*, i.e. assessing the functional and structural elements of the watershed/landscape.
- *Watershed/landscape assessment*, i.e. compiling historical accounts of the region's aquatic resources, as well as the type, acreage, and condition of remaining resources.
- *Site prioritization*, i.e. assessing and evaluating restoration/creation options and priorities, based on consideration of the watershed's aquatic resource functional needs and existing ecological and management opportunities; also, determining where, when, and how much aquatic resources need to be restored.
- *Mitigation design and performance assessment*, i.e. determining how ecosystem and watershed processes should inform compensatory mitigation design once a site has been selected and monitoring restored/created sites for effects throughout the landscape.

The following sections seek to summarize the current scientific thinking in these areas.

DEFINING CRITICAL ISSUES AND OBJECTIVES

Implementing a watershed approach to wetland mitigation requires wetland practitioners to first identify and define the critical issues that are of primary importance in the area (Montgomery et al. 1995, Almendinger 1999). Furthermore, managing natural resources sustainably and in observance of environmental regulations requires the consideration of a variety of management and regulatory objectives (Lamy et al. 2002). Many approaches stress the importance of broad stakeholder participation in the identification of key issues and goals (Gosselink et al. 1990, Llewellyn et al. 1996, NRC 2001, Lamy et al. 2002, Kershner 1997). Adopting a watershed approach to compensatory mitigation for the purposes of §404 of the Clean Water Act will present unique challenges wherever it is applied. Thus, this first level of analysis is an important planning step. Defining critical issues and objectives can take place either before or after the initial landscape level assessment, which is discussed below.

DETERMINING THE APPROPRIATE SCALE

A key issue to be resolved early in the implementation of a watershed approach is the definition of boundaries and the scale of analysis to be used in assessing and addressing the critical issues (Preston and Bedford 1988, Omernik and Bailey 1997, Griffitth et al. 1999, Fennessy et al. 2004, Montgomery et al. 1995). Although there is widespread agreement that permitting agencies should "modify the boundaries of permit decision-making in time and space," there are multiple ways to define those boundaries (NRC 2001).

Many approaches use watersheds and basins as the unit of analysis, e.g., as defined by hydrologic unit codes (HUCs), since watersheds are naturally defined units that can provide context for site-specific proposals or can be aggregated to address larger regional issues and trends (Montgomery et al. 1995, Kershner 1997, Lee and Gosselink 1988). Some maintain that HUCs are often not true topographic watersheds (Omernik and Bailey 1997), and furthermore, that watersheds are not an ideal unit for the spatial organization of ecosystem management (Omernik and Bailey 1997, Griffith et al. 1999). Arguing that watershed boundaries do not necessarily correspond to other ecological characteristics, such as soils, vegetation, climate, habitat conditions, and geology, these researchers suggest using ecologically-defined regions, or ecoregions, as the basic unit of analysis (Omernik and Bailey 1997).

Other approaches claim that no single scale should be prescribed and that the scale of analysis should be adjusted to fit the wetland and watershed functions under consideration (NRC 2001). Various combinations of watersheds and ecoregions have been proposed (Griffith et al. 1999, Omernik and Bailey 1997, Gosselink et al. 1990, Bedford 1996). Many such combinations suggest using watersheds as the unit for addressing flood storage and water quality functions and using ecoregions for addressing habitat functions (Preston and Bedford 1988).

In addition to spatial boundaries, some authors suggest that the temporal bounds of permitting and mitigation decision-making should be determined by ecological conditions. One way to define temporal boundaries for monitoring mitigation projects would be to set ecologically-based performance goals rather than arbitrarily-set monitoring periods (NRC 2001). Some researchers suggest that the time scale considered for mitigation projects should be defined by the period of time required for various wetland functions to recover (Preston and Bedford 1988, Lee and Gosselink 1988).

UNDERSTANDING WATERSHED/LANDSCAPE FUNCTIONS & WATERSHED/LANDSCAPE ASSESSMENT

Implementing a watershed approach to wetland mitigation entails the collection and integration of data over wider spatial and temporal scales than does a site-specific approach. Because of the larger scales considered, these approaches often rely on landscape-level assessment methodologies that minimize the amount of site specific data required. Fennessy et al. classify assessment methodologies as "Level One," "Level Two," and "Level Three" methodologies. Level one methodologies are broad, landscape-level assessment, level two are rapid site assessment methods, and level three methodologies include biological and physio-chemical measures (Fennessy et al. 2004).

Landscape-level assessment. Montgomery et al. outline a general framework for ecosystem management through watershed analysis, which includes *Understanding watershed/landscape functions* and *Watershed/landscape assessment.* The following questions form the basis of the proposed framework (Montgomery et al. 1995):

- How does the landscape work?
- What has happened in the past?
- What are current conditions?
- What are trends in watershed condition?
- How sensitive is the ecosystem to future land management?

Montgomery et al. delineate a process for answering the above questions that will lead the practitioner to an understanding of watershed/landscape functions and will provide an assessment of the overall watershed/landscape. The process begins with a "landscape stratification," whereby an initial characterization and classification is done according to identified critical issues. Landscape stratifications involve the classification of the landscape into discrete functional units for each of the major issues to be considered. Depending on the issues of concern, stratification can be done on the basis of vegetation, habitat types, disturbance regimes, stream channel classes, hydrology, soils, and other factors. Data on current and historical conditions are then gathered to test the hypotheses represented in the initial stratification. Landscape stratifications are revised according to current and historical data, and new "landscape unit delineation maps" are created in order to "provide the spatial context for addressing management options at scales larger than the individual project" (Montgomery et al. 1995).

While Montgomery et al., and many other landscape characterization methods, examine a wide array of indicators and variables to characterize broad patterns of ecological trends and processes (Montgomery et al 1995, Kershner 1997, Lee and Gosselink 1988, Gosselink et al. 1990), Bedford's (1996) watershed approach focuses primarily on hydrologic equivalency, because without the proper hydrologic and climatic conditions, mitigation cannot be successful and self-sustaining. As the main factor in the formation and maintenance of wetlands, it is generally recognized that hydrology should be a starting point in planning mitigation (Kentula 1997).

Bedford's (1996) method generates a "landscape profile," which is a "hydrogeologic portrait of a landscape, past and present." Developing landscape profiles begins with the definition of wetland "templates," or the unique setting that leads to the formation of particular types of wetlands within the landscape. The hydrogeomorphic (HGM) classification system developed by Brinson (Brinson 1993) is one possible way of defining wetland templates (Gwin et al. 1999). The process also includes cataloging and mapping templates, analyzing which wetland templates have been lost or modified and which templates remain, and assessing wetland "demography" (Bedford and Preston 1988), which includes the number, size, shape, and distribution of different wetland types within the landscape (Bedford 1996). Profiles can be completed using National Wetland Inventory maps, USGS topographic maps, and a minimal amount of fieldwork (Gwin et al. 1999). Ultimately, the landscape profile describes current and historical conditions of a landscape, providing a rough assessment of potential sites for wetland creation and restoration (Bedford 1996).

Bartoldus (1999) reviews a variety of additional assessment methodologies for understanding the relative ecological significance of a wetland within a watershed or region. For example, the North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) uses a GIS-based landscape-scale procedure to address the functional significance of wetlands within a region (Sutter et al. 1999). The Watershed-Based Wetland Assessment Method for the New Jersey Pinelands, which also uses a GIS-based landscape-scale approach, was designed to allow a comparative assessment of regional watersheds and their associated wetlands (Zampella et al. 1994). The Synoptic Approach for Wetlands Cumulative Effects Analysis provides a framework for comparing landscape units, particularly for watershed planning or prioritization of restoration options (Abbruzzese and Leibowitz 1997).

Site-specific assessment. While level one landscape assessments are essential to a watershed approach, many proposed approaches include assessments of site-specific conditions, functions, and values (Montgomery et al. 1995, Bedford and Preston 1988). For example, Fennessy et al. (2004) focus on several level two methods for assessing the condition of individual wetland sites, all of which must be rapid and verifiable and include site visits. Indicators relate to hydrology, vegetation and other biotic community factors, and landscape setting; but they also include soils, a less commonly used indicator. The authors express a preference for assessment methods that are applicable for all wetland types and generate a single numeric score that represents the overall condition of a site. Such methods are thought to allow for more ready comparison among wetlands in a landscape or watershed context than do methods that assign a suite of scores for various functions or provide only a single qualitative score (e.g., high, medium, low) (Fennessy et al. 2004). Other methods have been designed to generate multiple scores in order to provide decision-makers with a broader understanding of existing or predicted future conditions on a per function basis. For example, the HGM Approach, the Process for Assessing Proper Functioning Condition (PFC) and the New Hampshire Method allow users to address issues and objectives by examining changes in specific functions (Brinson 1993, Prichard et al. 1993, Ammann and Stone 1991).

While watershed functions may vary widely from one region to another, some indicators are useful assessing the hydrologic, water quality, and life support functions of wetlands in many different types of landscapes. Some site-oriented methodologies assess the importance of an individual wetland to the overall hydrologic functioning of a watershed, using indicators that relate to the wetland's ability to retain water, its position in the landscape, local relief, and the permeability of its soil surfaces (Bedford and Preston 1988, Zedler 2003). Indicators used to assess the water quality functioning of a particular wetland within a watershed context include water residence time, concentration of organic matter, landscape position relative to nutrient or pollution sources, buffer zones, and surface area available for microbial growth (Bedford and Preston 1988, Zedler 2003, NRC 2001). Life support or habitat indicators often relate to the size, connectivity, and surrounding land uses of wetland sites (Zedler 2003, NRC 2001).

Some site assessment methods widen their focus beyond the ecological function and condition of wetlands, examining the societal value attributed to each function (Hruby et al. 1995, Newbold 2002). For example, Hruby et al. (1995) developed the Indicator Value Assessment method, which uses functional scores, weighted to reflect societal values, to determine the relative importance of individual wetlands within a landscape or watershed area for each chosen function. Because watershed functions and problems occur on widely variable scales, using an appropriate combination of watershed and site assessment methodologies is essential to conducting successful mitigation and monitoring using a watershed approach (Fennessy et al. 2004).

SITE PRIORITIZATION

To be useful for permitting, planning, and mitigation in a watershed context, data on physical, ecological, and biological conditions and functions must be synthesized to create a holistic view of watershed conditions. Viewed in the context of historical watershed data, trends and patterns in watershed processes and conditions can be discerned, and judgments about the relative sensitivity and mitigation potential can be made (Montgomery et al. 1995).

Site prioritization methods vary widely depending on the goals, resources, and conditions of a particular watershed or region. Because of the spatial nature of the issue, many approaches rely upon GIS to layer, compare, and synthesize diverse datasets in order to analyze watershed patterns and prioritize areas for protection, restoration, or creation (Lamy et al. 2002). For example, Palmeri and Trepel (2002) developed a GIS-based land score system to site and size wetlands for water quality improvement within a watershed context. Their tool synthesizes climatic, hydrological, geological, environmental, and socio-economic factors to recommend restoration projects (Palmeri and Trepel 2002).

Other ecologically based methods rely on the principles of island biogeography, focusing on the maximization of patch size and connectivity (Gosselink et al. 1990, Weber and Wolf 2000). The emphasis on island biogeography is particularly appropriate when biodiversity and habitat functions are among the primary objectives of an effort, as in the Maryland Green Infrastructure planning project (Weber and Wolf 2000, Zedler 2003). Gosselink et al. (1990) also used an island biogeography-based prioritization method in planning for the Tensas basin in northeast Louisiana because nearly the entire basin is composed of forested wetlands (Gosselink et al. 1990).

Harris and Olson (1997) and Russell et al. (1997) present two separate methodologies for the prioritization of riparian restoration. Both methods recognize hydrology as the main factor in the formation and maintenance of wetlands and use it as a primary planning consideration for restoration projects. Harris and Olson (1997) used a two-stage approach to classify and evaluate reaches, and then examined reaches identified for further study in order to establish restoration needs and identify sites. Russell et al. (1997) used a GIS-modeling approach that relies mainly on two data layers – an index of “wetness potential” and land use/land cover. After these two data layers were completed, an ecologically driven, rule-based system was developed and applied to prioritize areas for protection or restoration (Kentula 1997).

Like Bedford (1996), O’Neill et al. (1997) identify geomorphology and hydrology as the key considerations in siting and designing successful riparian restoration. Their method, which was applied in the Arkansas River Basin, relies upon a hierarchical approach for identifying and evaluating sites for restoration of riparian wetlands that takes into consideration regional context, ecological conditions, and land uses. The model, which uses GIS, identifies candidate sites for restoration using physical characteristics measured at a watershed scale (topography, channel properties, sediment properties, moisture, flow/discharge, and vegetative data). Using these characterizations, criteria are established to determine site *potential*. Then, the size of sites and their proximity to open water are used to establish criteria for determining site *priority* for restoration (O’Neill et al. 1997).

Many authors identify stakeholder participation as an important element both in site prioritization processes and in watershed planning in general. Including a broad range of stakeholders in watershed assessments and site prioritization processes contributes to the prioritization of problems, identification of areas for restoration activities, and coordination with other landscape efforts. Such participation facilitates the design of efforts that better suit ecological, socio-economic, and general community values (Montgomery et al. 1995, Lamy et al. 2002). Lamy et al. (2002) suggest the formation of decision-making councils made up of the stakeholders in the community and emphasizes the need for multi-objective decision-making tools to integrate scientific and technical knowledge with socio-economic considerations. These types of tools enable stakeholders to develop a holistic view of the issues and problems in a watershed and to balance various options according to environmental and social concerns (Lamy et al. 2002).

Understanding future ecosystem responses to present-day management is discussed in some site prioritization methods as a way to identify possible build-out conditions and to ensure long-term sustainability. The EPA (2000) has advocated "environmental visioning" as a tool to aid in community-based approaches. In short, an environmental vision is the description or picture of a preferred future state for a community, chosen from several potential landscape scenarios. Environmental visioning, the "process of generation and selection of alternative landscape futures," often relies on GIS technology both to develop and to support different environmental visions (EPA 2000). By allowing stakeholders to more fully comprehend the future benefits and consequences of each choice, the process aids decision-makers in moving towards common understanding, resolving conflicts, and coordinating collective action (EPA 2000). Alternative Futures Analysis is a GIS-based environmental visioning process for community-based planning for land and water resources (EPA 2002). The analysis is based on a Steinitz's (1994) framework for landscape-level environmental design. Under this framework, landscape models are based on the state and operation of the landscape, the potential alterations to the landscape and predicted results of those alterations, and an evaluation of the alternative impacts. The framework focuses specifically on understanding and accurately depicting the current conditions and processes of the landscape, evaluating the impacts and changes resulting from different alternatives, and well-informed decision-making among alternatives (Steinitz 1994).

MITIGATION DESIGN AND PERFORMANCE ASSESSMENT

While the majority of the research on the watershed approach is concerned with assessing watershed conditions and developing landscape- or watershed-level plans for aquatic resource restoration, some research has focused on how ecosystem and watershed processes can inform compensatory mitigation design once a site has been selected (Ehrenfeld and Toth 1997, Kentula et al., 1992). In order to ensure that mitigation is self-sufficient and successful in achieving ecological goals, designers must address a site's relationship with the surrounding landscape, including the interchange of energy, flora and fauna, and material (e.g., water, nutrients, sediments, pollutants) moving between a site and the surrounding ecosystems and how a site's natural and man-made boundaries effects ecological processes (Ehrenfeld and Toth 1997). Kentula et al. (1997) suggest that, in order to ensure that a site's unique ecological setting is considered, reference data used for designing and assessing mitigation projects should come from natural wetlands located in similar land use and ecosystem settings. Additionally, in order to assess mitigation design and performance within the landscape, sites must be monitored, both to assess past design decisions and to guide future decision-making (Almendinger 1999).

ADAPTIVE MANAGEMENT AND MITIGATION AS A RESEARCH OPPORTUNITY

Although the scientific literature generally indicates agreement on the need to adopt a watershed approach to compensatory wetland mitigation, data and research that could inform such an approach is not always widely available. Most areas of the country lack extensive long-term ecological data by which trends might be assessed (Gosselink et al. 1990). Methods for assessing watershed functions, determining an individual wetland's relationship to the larger watershed, and measuring cumulative watershed impacts are often imprecise (Bedford and Preston 1988). Mitigation projects offer unique opportunities to conduct ecosystem-scale research that can both improve the state of ecological knowledge generally (Ehrenfeld and Toth 1997) and inform future watershed- or landscape-based mitigation efforts (Zedler 2003, Kershner 1997, Kentula et al. 1992).

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