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Optimizing Conservation and Improving Mitigation Cost/Benefit:

Task 3: Comparison of the Ecological and Economic Outcomes of Traditional vs. Programmatic, Multi-Resource Based Approach

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1. Introduction

The objective of this report is to identify and compare the ecological and economic outcomes of a traditional project-by-project approach versus a programmatic, multi-resource based approach to the selection of compensatory mitigation sites under the Clean Water Act § 404, and Endangered Species Act §7 and §10 programs. The more progressive, programmatic approaches we examined typically selected compensatory mitigation sites using an analytic analysis of watershed or ecological needs.

Mitigation can be an important method of maintaining healthy, economically valuable ecosystems. For the purposes of this report, mitigation is defined, except where otherwise noted, as the third step of the three-step mitigation sequence: Compensatory mitigation, or offsetting for lost habitat area or functions as required by a federal or state regulatory program. The first two steps of mitigation—avoidance and minimization of adverse habitat/aquatic resource impacts—may be evaluated and used in some progressive mitigation programs as a method of maintaining ecologically and/or economically valuable ecosystems. Progressive mitigation programs that use a holistic, multi-resource evaluation of the ecological functions and the economic benefits provided by ecosystems present a way to maximize investments in ecological restoration, creation, enhancement, or preservation. Transportation agencies are in a unique position to implement progressive mitigation programs, as infrastructure development plans are generally known in advance of impacts, as opposed to urban growth models which are much less certain.

The research team, drawing on the findings of Tasks 1 and 2 (NCHRP 2010a; NCHRP 2010b), defined the range of approaches that can be applied to the process of selecting and designing compensatory mitigation sites with a focus on the costs, benefits and tradeoffs of these different approaches. In addition, this report closely examines the five approaches taken in the five states we selected in Task 2 to further illustrate the differences in costs, benefits and tradeoffs of various approaches. As discussed in Section 6 below, in the traditional category, we examine Florida and Ohio, in the midway category we examined Minnesota, and in the progressive category, we examine Maryland and Oregon's Willamette Basin.

This report includes a discussion of the relative costs of different types of compensatory mitigation methods, and the associated ecosystem services provided by each method. . The research team evaluates two core hypotheses.

> **Core Research Hypotheses: Innovative approaches to compensatory mitigation 1) will provide higher ecological, social, and economic benefits, and 2) do not cost more to implement than traditional approaches especially in those states, planning areas, or regions where conservation priority areas or regional ecological frameworks already have been developed.**

In order to test these working hypotheses of the research team it was important to know how to accurately assess the actual costs of implementing a compensatory mitigation project using the various methods, including any additional work necessary to implement the different methods

The report also includes a discussion of the variation in ecological goods and services considered in the different progressive multi-resource mitigation methods, along with a brief discussion of their potential economic value. Most of the concern in the scientific and regulatory community about current implementation of compensatory mitigation is a result of limited experimentation with - and success in documenting - the broader ecological coeffects of mitigation choices. We discuss the economic benefits of already established compensatory mitigation programs for endangered species and wetlands. The goal of the analysis is not to comprehensively identify all compensatory mitigation coeffects and their economic value. Rather, the goal is to provide examples of the data, analyses, and technical expertise needed to do such evaluations and discuss their implications for program implementation and success.

There is also a discussion of key similarities and differences between the traditional and progressive approaches to site selection in terms of data requirements, scope of evaluations, and qualitative strengths. Currently, the lack of standard methodologies for progressive site selection approaches, or even the specific objectives of the different approaches, has led to difficulties in obtaining approvals for their use in setting mitigation priorities, and in a wider adoption of more standardized progressive approaches to mitigation site selection. The research here evaluates approaches adopted by regulatory agencies, along with a variety of other approaches that were evaluated in states or regions in different parts of the United States. The goal here is to identify approaches that may significantly improve ecological and economic outcomes, that could be adopted more broadly across the country.

Lastly, this report examines the nonregulated ecological attributes or benefits identified as being conserved, enhanced, or restored by the use of multi-resource approaches. To address the scope and effect on these resources, the research team describes the available nonmonetary crediting schemes for ecosystem services or ecological benefits currently lacking markets. For types such as carbon or water storage, where markets and monetary values can be developed based on work occurring in other parts of the world, the best published or the most widely accepted valuation protocols were used to value the attributes. For other ecological values – such as biodiversity – where no markets or valuation protocols have been developed, we describe available nonmonetary approaches to evaluate the social effects of location-specific mitigation projects.

2. How Mitigation Can Support the Delivery of Ecosystem Goods and Services

Under “traditional” mitigation programs, a site’s eligibility for mitigation may be based on an evaluation of *on-site processes and features* in order to ‘replace’ the impacted processes and features. Examples of the on-site processes and features that may be considered include soil types, vegetation types, water chemistry, “natural” hydrologic conditions, maintenance of biotic integrity measures, etc. Mitigation locations that meet these criteria associated with on-site processes and features and thereby ‘replace’ the impacted areas may be considered eligible as compensation sites.

Progressive approaches to mitigation evaluate mitigation site eligibility (or priority for eligibility) use different criteria. First, progressive mitigation criteria emphasize the attainment of *ecological goals* and do not limit restoration to the site of the impact unless these on-site areas are likely to be the most successful in meeting priority ecological goals. Although these goals are the ecologically desirable outcomes of traditional on-site criteria, in progressive mitigation approaches the goals are assessed in a broader geographic context in order to ensure mitigation success in the region rather than at the site. We will refer to traditional evaluation criteria as on-site *input measures*. These input measures are only rough proxies for the ecological goals of progressive mitigation. Consider one example: a traditional mitigation would evaluate a mitigation site's potential to support a particular type of vegetation that has been directly impacted; in this case that that vegetation type becomes an input measure when evaluating habitat suitability. In contrast, the progressive ecological goal related to vegetation would support the broader goal of protecting and restoring all habitat types that may support high priority species across the watershed or ecoregion. In other words, in the progressive approach the specific vegetation type that was impacted would not be the only vegetation type that would be considered in selecting a compensatory mitigation site since this vegetation type may be a low priority in terms of supporting identified ecological goals in a watershed or ecoregion.

The prime motivation for progressive mitigation planning is that the replacement of on-site inputs is a necessary but not sufficient condition for the achievement of broader ecological goals. Also, the off-site spatial configuration of resource features and processes strongly affects the production of ecological outcomes at the compensation site. It is therefore important to distinguish between – and relate – on-site evaluation criteria and the context of the broader ecological goals they support.

> **Summary: On-site processes and features associated with traditional mitigation scoring do not by themselves support the assessment of regional ecological goals or the delivery of ecosystem goods and services.**

> **Summary: Progressive mitigation seeks not just the replacement of lost on-site processes and features, but the achievement of broader ecological goals and the replacement and delivery of ecosystem goods and services.**

A motivation for progressive mitigation planning is that it addresses the role of wetlands, habitats, or other land uses in geographically broader *systems of ecological production priorities*. When these broader systems of production are appreciated and taken into account mitigation will deliver more and better ecological outcomes (NRC, 2001). Moreover, because many ecological outcomes are socially valuable, progressive planning will yield compensation projects with greater social and economic value than those where ecosystem service production is not taken into account (Boyd and Wainger, 2003).

We believe that the benefits of progressive planning based on knowledge of systems of ecological production in a geographically broader context is important for two distinct reasons.

> **Key Assumption: The location of compensatory mitigation (its placement within larger ecological production) is critical for: 1) the ecological success of the mitigation, and 2) the mitigation project's ability to deliver priority off-site ecosystem services and valuable social outcomes.**

3. Mitigation's Role in Ecological Production

Nature can be thought of as a complex system, where physical and biotic conditions are mediated and transformed by biological, physical, chemical, hydrological, and atmospheric processes. It is useful to employ three basic terms to describe an *ecological system*: biophysical inputs, outputs, and production functions.

Any natural process, by definition, transforms a set of inputs into a different set of outputs, much like an industrial process transforms inputs like labor and capital into outputs like cars and loaves of bread. Hydrological processes transform rainfall into ground and surface water. Biological and chemical processes transform water of one quality into water of a different quality. Reproductive, forage, and migratory processes relate biotic and physical conditions to the abundance of species. Food chains convert one form of biomass into another. Wetland processes transform the scale, location, and speed of flood pulses. Sequestration processes affect the release and in some cases transformation of chemical inputs to water or the atmosphere. Even a process as simple as "shading" relates tree canopies to the regulation of water temperature. When ecologists or other natural scientists speak of ecological processes or functions they are referring to the transformation of one set of biophysical conditions into another. Ecologists and economists refer to these processes as biophysical production functions (U.S. EPA 2009; Daily and Matson 2008; Boyd and Krupnick, 2009).

Biophysical inputs are environmental features or conditions that are converted via natural processes into different environmental features or conditions. These different environmental features or conditions are the *outputs* of the biophysical process in question. We refer to biophysical processes that transform inputs into outputs as *biophysical production functions*. Production functions are the causal link between one set of features or qualities and other features or qualities.

Summary: In order to evaluate ecological outcomes – including mitigation's effect on the production of ecosystem goods and services – it is necessary to evaluate ways in which site-specific gains/losses interact with broader systems of biophysical production.

Summary: Progressive planning's most distinctive feature is an appreciation of a given site's relationship to off-site biophysical processes, functions, and outcomes.

Progressive mitigation planning seeks to evaluate mitigation sites based on their relationship to these biophysical production functions. Two mitigation sites that are equivalent, in terms of their on-site processes and features will in general play very different roles in producing ecological outcomes and ecosystem goods and services – because of the way they interact with broader spatial patterns of biophysical production.

3.1 Ecological Production, Ecosystem Services and Spatial Planning

Evaluation of ecosystem services involves two broad missions. The first is a biophysical one associated with ecology, hydrology, and the other natural sciences. How can we protect—or, ideally, enhance— the biophysical outcomes necessary to our wellbeing? The second is an economic mission to measure and communicate the value of those goods and services. Spatial analysis is fundamental to ecosystem service assessment because both the production of biophysical functions and the social determinants of service benefits depend upon the landscape context in which those functions and services arise (Bockstael 1996).

From an ecological perspective, geographic context matters for several broad reasons. First, ecological production can exhibit non-linearities in scale and configuration – for example, where a whole produces much more than the sum of unconnected parts. Second, natural systems are often characterized by movement: air circulates, water runs downhill, species migrate, seeds and pollen disperse. Moreover, the movement of one biophysical feature—say water—tends to trigger the movement of other things— like birds and fish. In fact, the consumption of ecosystem services typically occurs off-site. Water purification, flood damage reduction, pollination, pest control, and aesthetic enjoyment are all services typically enjoyed in a larger area surrounding the site in question. To ignore, or minimize, the importance of off-site factors misses much that is central to a complete evaluation of ecological and economic outcomes. In order to maximize ecological production, we must manage with an understanding of these spatial phenomena and interdependencies.

3.2 The Connection between Mitigation and Ecosystem Services

Mitigation can be described as an intervention or action that, by altering the site's features and functions, triggers a range of subsequent ecological changes. Also, the biophysical production functions that relate interventions to changes in ecological outcomes are not limited to the neighborhood of the site itself.

As will be described in greater detail later, the measurement of biophysical production functions and prediction of subsequent outcomes is the most important aspect of a progressive approach to mitigation planning. Moreover, economic analysis of ecosystem services produced and delivered cannot proceed without it. The economic analysis of ecosystems depends entirely on our ability to measure these biophysical production functions in a spatial context.

The analytical underpinning of progressive planning is a conceptual model of ecological and physical production. Starting with a mitigation action – type and location – the production system describes the consequences of the action for subsequent biophysical changes. These production systems typically begin as theoretical hypotheses that are then validated or refuted by empirical observation and experimentation.

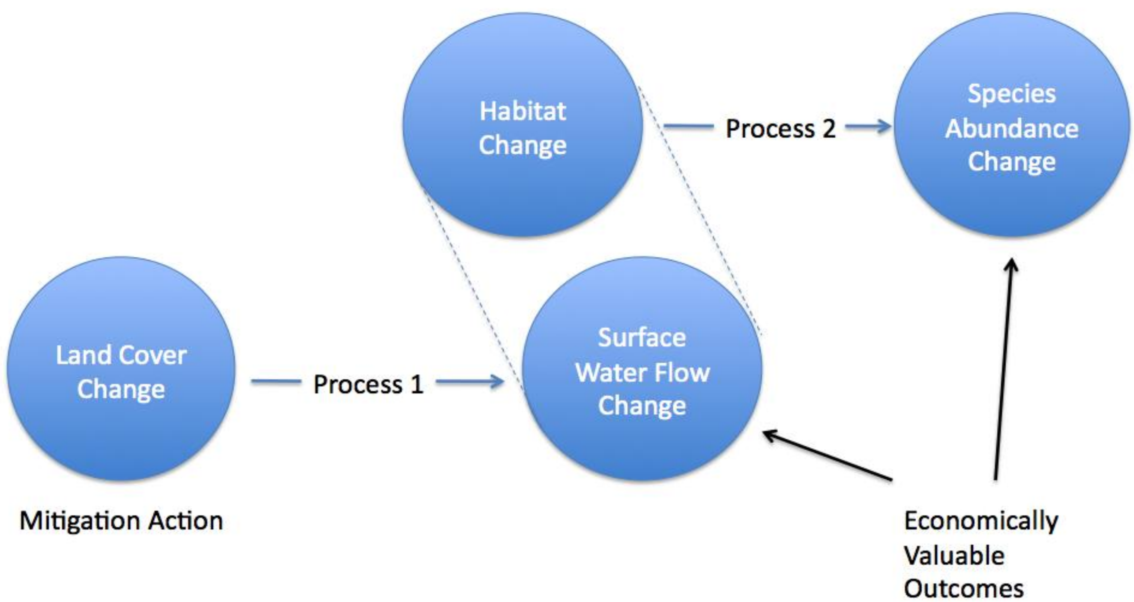

Figure 1: A simplified biophysical production system.

Figure 1 depicts a highly simplified version of such a production system. A mitigation project that changes land cover (or hydrology) triggers subsequent changes in surface water flows (timing, speed, volume) via hydrologic processes. Changes in the hydrograph will occur both near the mitigation site itself, but also across a potentially much larger area. In other words, these hydrological changes (one of the services produced) are “delivered” off-site. Not only that, these “off-site” effects will often trigger additional, subsequent ecological effects, also off-site. For example, changes in the hydrograph will affect habitat conditions for aquatic, avian, and other species via a range of chemical and biological processes. The resulting changes in species abundance yield yet another service that is delivered off-site.

3.3 The Role of Progressive Mitigation Planning and Spatial Analyses

Appreciation of, and planning around, these off-site and systems driven services is what makes progressive mitigation planning so potentially valuable. Progressive mitigation planning relates biophysical cause and effect when the cause-and-effect relationship is spatial. We call these relationships spatial production functions, because they tell us about how changes in conditions in one location (good or bad) affect the delivery of ecosystem goods and services in another. Examples of these spatial production relationships describe the dependence of:

- Species on the configuration of lands needed for their reproduction, forage, and migration;
- Surface and aquifer water volumes and quality on land cover configurations and land uses;
- Flood and fire protection services on land cover configurations;
- Soil quality on climate variables and land uses; and
- Air quality on pollutant emissions, atmospheric processes, and natural sequestration.

> **Summary: Progressive planning uses information about biophysical systems to evaluate the mitigation actions most likely to yield ecologically and economically valuable outputs throughout the system.**

In particular, the pattern of conservation lands on the landscape can significantly impact both the value of the ecological and economic attributes. In the Willamette Basin study in Oregon, the pattern of development and conservation in the ground dramatically altered the economic and ecological outputs provided by alternate landscapes (Polasky et al. 2008). Progressive mitigation assessments build into their evaluation criteria and scoring these kinds of spatial relationships and their implications for the location of the most productive mitigation projects.

> **Summary: Spatial analysis and targeting is a defining characteristic of progressive mitigation planning. Mitigation’s spatial context strongly affects its contributions to biophysical production and ecological outcomes.**

> **Summary: Planning geared toward the delivery of ecosystem goods and services is also inherently spatial. The biophysical and social landscape context within which ecosystem goods and services are delivered has a great effect on the economic and social value of those goods and services.**

Spatial context matters for another reason as well, this one related to the economic value of a given ecosystem service. As economic commodities, ecosystem goods and services resemble real estate, rather than cars or bottles of dish soap. The value of real estate is highly dependent on its location – the features of the surrounding neighborhood. This is because a given house or building cannot be easily transported to another neighborhood. In contrast, cars or soap can be easily moved around (shipped from one location to another), so their value tends to be independent of their geographic location.

From an economic perspective we can make several broad statements about the value of ecosystem goods and services; all of these relate to spatial context:

- The scarcer an ecological feature, the greater its value.
- The scarcer are substitutes for an ecological feature, the greater its value.
- The more abundant are complements to an ecological feature, the greater its value.
- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic value protected or enhanced by the feature, the greater its value.

As a concrete example, consider New York's Central Park. It is one of the most valuable sources of ecosystem services in the world, not because it is particularly desirable ecologically, but because so many people live near it and have so few alternatives within walking distance. Spatial analysis is necessary to depict and evaluate all of the factors noted above. Spatial planning allows us to map population densities, measure distance to similar parks, and easily detect the presence of other types of recreational open space and forms of access like roads.

The general proposition holds for most kinds of ecosystem services. The value of irrigation and drinking water quality depends on how many people depend on the water—which is a function of where they are in relation to the water. Flood damage avoidance services are more valuable the larger the value of lives, homes, and businesses protected from flooding. Species important to recreation (for anglers, hunters, birders) are more valuable when more people can enjoy them.

Placing a value on ecosystem goods and services also requires us to analyze the presence of substitutes for the good. The value of any good or service is higher the scarcer it is. How do you measure the scarcity of an ecosystem good? If recreation is the source of benefits, substitutes depend on travel times. What are walkable substitutes? Drivable substitutes? The value of irrigation water depends on the availability (and hence location) of alternative water sources. If wetlands are plentiful in an area, then a given wetland may be less valuable as a source of flood pulse attenuation than it might be in a region in which it is the only such resource. In all of these cases, geography is necessary to evaluate the presence of scarcity and substitutes.

Finally, many ecosystem goods and services are valuable only if they are bundled with certain manmade assets. These assets are called "complements" because they complement the value of the ecosystem service. Recreational fishing and kayaking require docks or other forms of access. For example, a beautiful vista yields social value when people have access to it. Access may require infrastructure—roads, trails, parks, housing, all of which are spatially configured.

4. Wetlands' Role in the Production of Ecosystem Services

A motivation for progressive mitigation planning is that it can produce greater economic benefits by stimulating greater production of ecosystem goods and services. How do wetlands contribute to that production?

Ecosystem goods and services are economically and socially valuable ecological outcomes. Wetlands are an important component of the biophysical "factories" that produce many of these services. In most cases, a wetland's location in the landscape affects its productivity as a generator of these services. For example:

4.1 Wetlands Act as Buffers against Storm Surge and Flood Pulses

Wetlands retain standing water and reduce the velocity of surface water flows more effectively than other land types (Mitsch and Gosselink, 2007). Wetlands can reduce the depth, speed, and duration of flood events in a watershed or coastal system. Demissie and Kahn (1993) found volume of water conveyed downstream during peakflow and floodflow decreased 3.7% and 1.4% respectively for each 1% increase in wetland area. The lack of wetlands has been implicated in the flooding of the Upper Mississippi and Missouri River Basins (Parrett et al. 1993).

The ecosystem service associated with this biophysical function is a reduction in economic and social damages associated with flood events. The avoided costs of soil erosion, infrastructure damage, private property damages, and reductions in business and other activity depend on damaged property are the "service" provided. Wetlands can also reduce the need for grey infrastructure designed to prevent flooding. The avoided cost of grey infrastructure is another measure of wetlands' value.

Several spatial factors affect the delivery of the service. The way in which a specific wetland reduces flood risks is principally a function of its location relative to sources of receiving water and coastal surges. It is also a function of the configuration of other wetlands and land cover types in the area. A wetland needn't be in a floodplain for it to provide flood reduction services. Wetlands distant from a watershed outflow point and not in the floodplain can nevertheless be valuable because they absorb or slow waters eventually destined for the floodplain.

Social factors that affect the value of the service are also spatial in nature. For example, the presence and value of property or economic activity protected by a wetland system will strongly influence the costs avoided. Progressive spatial planning is thus necessary both to evaluate a given wetland's contributions to flood pulse reductions (as part of the larger hydrological system) and to evaluate the economic benefits of flood reduction arising from avoided flood damages.

It is important to note that the flood reduction services provided by a given wetland do not necessarily occur on or near the wetland itself. Rather, the service is delivered to a larger hydrological region.

4.2 Wetlands Increase Ground Water Volumes

Wetlands, by trapping water that would otherwise be lost to drainage or evaporation, are an important source of freshwater to underground aquifers.

Improvements in subsurface water supplies are a socially valuable ecosystem service whenever subsurface water is scarce or costly to acquire. Farms and industry employ water as a key input to their production. Aquifer recharge is valuable since it reduces the costs of extracting water (lower aquifer levels generally mean that more energy is required to pump water to the surface). Water availability also directly improves the yield and quality of agricultural crops. Aquifer recharge also benefits households that rely on well water or that experience constrained municipal supplies in drought conditions.

Spatial factors that affect the delivery of this service include the hydrological connections between a given wetland and the aquifer to which it is hydrologically connected. The location of increased groundwater availability is determined by the geographic extent of the aquifer being fed and rates at which groundwater moves through the aquifer. An aquifer's spatial context can be particularly important in coastal systems where saltwater intrusion can significantly degrade the quantity of freshwater present in subsurface aquifers.

The economic value of increased groundwater volumes is also dependent on geography: in particular the location of groundwater users. The more users who rely on groundwater drawn from an aquifer recharged from a given wetland, the greater that wetland's value, all else being equal.

Again, the economic value of the wetland is not necessarily delivered on or near the wetland itself. The location of delivery is a function of subsurface hydrology and can affect a relatively large region.

4.3 Wetlands Improve Surface and Ground Water Quality

Wetlands' distinctive biochemical properties are particularly effective at trapping, filtering, and converting water pollutants. These biochemical functions can directly improve both surface and ground water quality. Also, wetlands influence surface water quality by routing runoff water to aquifers which filter and later discharge to surface waters. Increased aquifer recharge can increase stream base flow levels and result in more dilution of stream contaminants between storm events. A lower proportion of water reaching streams directly through surface runoff (versus infiltration) frequently results in less pollution reaching surface water and estuaries (Dunne and Leopold 1978).

There are several ecosystem services associated with this wetland function. Improved water quality has economic value, due to health and aesthetic improvements, whenever quality is impaired. The quality of surface and ground water used for irrigation also affects the costs and productivity of agricultural operations. Wetlands can also reduce the need to invest in grey water treatment infrastructure. Also, enhanced water quality will tend to increase the value of recreation by improving the aesthetics of activities involving water-contact or those dependent on species dependent on water quality. In estuarine areas, the influence on surface water salinity can change the abundance and nature of recreational fishing species. In turn, tax revenues, employment, and commercial activity are at some level sensitive to the quality of recreation provided by local waters.

A wetland's productivity as a source of water quality improvement is determined in part by the presence of pollutants to be reduced. For wetlands to generate water quality benefits, there must be a water quality problem in need of improvement. Developed land uses, which are associated with a high proportion of impervious surfaces and agriculture, are more likely to generate water quality problems. Proximity to land uses (agriculture, impervious surface) that discharge pollutants to surface waters is thus an important spatial issue since wetlands in proximity to sources of water quality impairment will tend to yield the greatest water quality improvement benefits.

Potential sources of water contamination are a necessary, but not sufficient condition for there to be drinking water quality benefits. The water must also be used for drinking, or at least commercial or agricultural use. Aggregate demand for drinking water improvements is a function of the number households, farms, firms, and communities drawing water from aquifers fed by surface waters improved by a wetland site. Clearly, social demand for water quality – and the economic benefits of the function – vary across the landscape. In areas where groundwater is in high demand for household drinking supplies or irrigation, improvements in water quality will yield greater overall social benefits. Note again that the geographic extent of a given wetland's delivery of the service is related to the geographic extent of the aquifer it feeds.

4.4 Wetlands Support Biodiversity

Wetlands provide important and often unique forage, migration, and reproductive resources for numerous species. Wetland specific vegetation types and organic matter inputs to food webs yield particularly rich habitats for threatened, endangered, and aesthetically desirable animal species.

Wetland functions that support species existence and abundance yield a range of socially valuable services. Species are often valued "for their own sake" particularly when threatened with extinction (so-called "existence value"). In some cases species are commercially valuable when caught or harvested. In other cases, recreational benefits (from hunting and angling, birding, hiking) are dependent on the existence and abundance of particular species.

The spatial configuration of wetlands and other natural land cover usually determines the effectiveness of habitat provision. For example, ecological science emphasizes the importance of habitat connectivity and contiguity to the productivity and quality of that habitat, measured through species diversity, richness or other measures (Noss 1990; Gardner et al. 1993; Gustafson 1998; Richards et al. 1996). Terms like connectivity and contiguity are inherently spatial and refer to the overall pattern of land uses, surface waters, and topographic characteristics in a given region. Often, a minimum size and connections or pathways to other resources are needed to support migration, reproduction, and forage (Roberts et al. 2001; Green et al. 2007). Species interdependence and the need for migratory pathways are additional sources of spatial phenomena in ecology (Flather and Sauer 1996). As direct habitat support, wetlands that are in riparian or coastal zones are likely to be particularly beneficial. Wetlands filtering nutrients in riparian zones have been shown to have a greater ability to prevent nutrient deposition than wetlands further inland (Lowrence et al. 1997; Correll et al. 1992). Wetlands upstream from sensitive aquatic habitats are also particularly desirable. Moreover, threats to biodiversity tend to be a function of the spatial configuration of non-natural land uses. For example, the proportion of a watershed covered by impervious surfaces is a known risk factor for aquatic habitats, as impervious surfaces create greater runoff volumes and shorter runoff times, leading to more polluter and warmer surface water deposition (SCS 1975).

Because the ecological production function depends on the characteristics of the overall landscape, an area's spatial characteristics must be assessed in order to assess species-related ecological goals. Note that spatial assessment and planning are central to the designation of critical habitat under the Endangered Species Act and essential fish habitat under the Magnuson-Stevens Act. In the case of essential fish habitat analysis, for example, the challenge involves assessment of terrestrial, freshwater, estuarine, and marine "landscapes."

Biodiversity-related ecological production functions are spatial in nature. A given wetland's contribution to biodiversity is a function of these broader spatial relationships. It also deserves emphasis that wetland habitat may yield biodiversity improvements, not only on-site, but off-site as well.

As in the earlier example, the economic value of biodiversity that is delivered in particular places depends on the social geography of biodiversity beneficiaries. The number of beneficiaries and their access to biodiversity are key determinants of biodiversity value. The larger the number of recreators enjoying a particular species population, the greater is the economic benefit of that population. What determines the number of anglers, hunters, birders, hikers who benefit from the population? In part this is a function of populations within distances that make recreation practical. It is also a function of forms of access – roads, trails, navigable water – that allow access to these populations. Again, geographic context matters to the creation of ecosystem service benefits. The relationship of a wetland to a larger pattern of natural land uses will in large part determine its habitat-related benefits.

Wetlands may provide amenities such as open space and opportunities to view wildlife. Open space can generate benefits by providing opportunities for recreation, and by providing privacy and scenic beauty. Wetlands are also open spaces that provide habitat for a wide variety of species that can themselves have recreational value (e.g., rare birds and plant communities). The value of these services is enhanced if the wetland exists where open space and scenic vistas are scarce, and where the wetland attracts wildlife that adds to visual amenities and recreational benefits. Access is an important determinant of these benefits. All else equal, beautiful wetlands in remote, inaccessible areas are less valuable than beautiful wetlands where they can be seen and otherwise enjoyed. There are obvious tradeoffs between this wetland service and others, such as endangered species protection, where less accessibility may be preferred.

The preceding discussion of wetland-related ecosystem services underscores the progressive mitigation evaluation and planning approaches. In all of the above cases, a given wetland's contribution to social benefits is a function of biophysical and social conditions beyond the specific wetland in question. Progressive planning takes these geographic conditions, and the configuration of land uses and human needs, into account in order to identify the highest value mitigation opportunities. Failure to plan in this way will likely lead to less biophysical production or lower ecological quality, and correspondingly lower economic benefits from mitigation.

4.5 Other Wetland-Related Ecosystem Services

Two other wetland-related ecosystems are worth mentioning. First, wetlands are open space that may be valuable, not for any particularly ecological reasons, but simply because they are visually appealing. Economic valuation studies have found that wetlands can generate aesthetic benefits (Mahan et al. 2000). While wetlands can generate dis-amenities, such as odors and insects, most economic studies find that land values increase with proximity to wetlands. Doss and Taff (1996) found that decreasing a property's distance to a wetland by one block increases property value by between $960 and $2900. The value depends, among other things, on the type of wetland. Aesthetic benefits do not involve spatial biophysical production processes and are delivered on or near a particular wetland site.

Another wetland service with similar properties is carbon sequestration. Carbon sequestration is primarily a function of vegetation on-site and is less dependent on broader spatial phenomena. Also, the economic benefits of carbon sequestration are not dependent on the location of a particular wetland. A pound of carbon sequestered has the same effect on climate regulation, irrespective of where the sequestration occurs. In other words, these two ecosystem services do not create a particular need for progressive, spatial assessment and planning.

5. Other Forms of Mitigation and the Production of Ecosystem Services

Wetlands provide a particularly wide range of ecosystem services given their role in hydrological and habitat systems. But other forms of mitigation will also have similar systems-driven ecological co-effects. Changes in land cover associated with habitat creation, enhancement, and protection, for example, will yield ecosystem service benefits beyond those related to habitat per se. Habitat restoration may in many cases yield water quality improvements, for example.

Because a given mitigation action does not occur in isolation from the larger biophysical systems within which they are embedded, one goal of progressive mitigation planning is to trace the co-effects (off-site services delivered) associated with the mitigation and incorporate those outcomes into planning.

6. Evaluations of the Five Selected States

A major part of Task 2 was the identification of five states or programs within states to be selected for further evaluation and analysis (NCHRP 2010b). The states or programs were selected from the list of documented approaches to compensatory mitigation site selection under §7 of the Endangered Species Act (ESA) and §404 of the Clean Water Act (CWA), or analogous regulatory efforts at the federal or state level, being carried out nationwide. Over 150 programs were compiled and evaluated in Task 2.

In the Task 1 report, the research team identified and defined three distinct categories of compensatory mitigation approaches: traditional, "midway," and progressive (NCHRP 2010a). In Task 2, after identifying applicable ESA and CWA approaches, we categorized each of the documented case studies into one of these three categories. Our criteria for assigning approaches/case studies to each category were based on the methodology utilized in compensation site selection. The mechanism a program uses for compensatory mitigation, such as permittee-responsible mitigation (PRM), mitigation banks, conservation banks, and in-lieu fee programs (ILFs), was not a criterion for categorizing case studies, except when the mechanism dictated a program's site selection methodology.

The final step of the Task 2 report was the selection of five programs for further evaluation, two of which had been categorized as traditional, one as midway, and two as progressive. The states of Ohio and Florida were selected as traditional programs for evaluation, Minnesota was selected as midway, and projects in Maryland and Oregon were selected as progressive. In this report, each of these states is discussed in the light of the above discussion on the ecological and economic costs and benefits of compensatory mitigation programs. Relevant sections of the Task 2 report are included here for context and clarity.

It is important to stress that the purpose of reviewing different programs and projects was not to rate the overall effectiveness of a state or a program's compensatory mitigation efforts. Rather, the intent was to identify specific methods and rate their relative success in improving the ecological, social and/or economic outputs of compensatory mitigation. Finding 'evidence' of success, in this case, supports our efforts to further explore similar methods in other parts of the country and help improve the compensatory mitigation outcomes nationally. Therefore, just because we evaluated a progressive compensatory mitigation site selection method in Oregon, does not mean that Oregon's efforts throughout the state are progressive. Similarly, in Ohio, although the statewide site selection method was categorized as 'traditional' this does not mean that there are not progressive efforts around mitigation overall in Ohio.

The following sections describe the five selected programs evaluated by this study.

6.1. Ohio: Traditional Compensatory Mitigation Approach

Ohio has recently worked to develop a programmatic approach for the Indiana Bat, looking at a statewide analysis. The Ohio DOT's programmatic biological opinion (BO) notes that they will map projected impacts to Indiana bat habitat throughout the five-year life of the BO. This programmatic BO establishes that when transportation projects cause unavoidable impacts to Indiana bat habitat, "[t]he goal of the habitat protection and enhancement will be to enhance Indiana bat habitat in the long term by providing forested habitat, improving connectivity among blocks of existing habitat, and creating larger blocks of forested bat habitat." The BO states that compensatory mitigation should also occur within the same bat Management Unit, and when impacts cross a Management Unit or are near the boundaries of a Management Unit, permittees should undertake the compensation in an adjacent area. Although the mitigation approach is comprehensive and attempts to address the entire species' range, since the transportation project-induced impacts to Indiana bat habitat are all addressed on a project-by-project basis and do not involve landscape-scale planning under the programmatic BO, this program still constitutes a traditional compensation method.

Ohio was also one of the earliest states to adopt rapid assessment protocols for evaluating wetlands with ecosystem services in mind, and has implemented a Floristic Quality Index (FQI) for plants, also as a way of evaluating wetland quality (Mack 2001, Andreas et al 2004). The state has an innovative Department of Transportation in addressing mitigation. However, unlike some of the other states evaluated, the state of Ohio does not have an agreed upon or even widely accepted regional ecosystem framework (REF) outlining conservation priorities (see Achterman et al. in press for a description). The Ohio Division of Wildlife has identified focus areas in their wildlife action plan (Kalwinski and Millsap, undated), although in general these areas had a focus on game, wildlife and invertebrate species of greatest conservation concern, and lacked a focus on areas of ecological or botanical significance. The only other statewide identified conservation priorities are the conservation portfolio identified by The Nature Conservancy in their ecoregional assessments, which are already somewhat out of date, and which lacked the watershed analysis needed to identify wetland or Clean Water Act services. As a result, implementation of a progressive approach in Ohio would require investments of time for planning, data collection, and analysis. These could be done in conjunction with ongoing planning efforts, such as the update to the Ohio Wildlife Action Plan to reduce the costs, although in Ohio this would require interagency planning. In developing an REF, Ohio could then build on the work documented above on metrics and measuring the costs and benefits, thus implementing an ecoregional approach to mitigation where the costs and benefits could be demonstrated.

Researchers have completed a number of studies that use various ecological success metrics for mitigation wetlands in Ohio. These Ohio-specific research projects are a foundation on which to build more progressive planning in the state. We emphasize that these studies are not indicative of planning practices, rather of tools and data that could be applied to progressive mitigation planning in Ohio.

These wetland compensation projects were undertaken using both traditional permittee-Responsible mitigation (PRM) and traditionally sited mitigation banks. Two of the 12 Ohio studies identified in our literature review appear to be partially, but not completely, useful for integrating biophysical outcomes into the context of the human environment for analysis of ecosystem services. First, Fennessy's 1997 comparison of 14 mitigation and 7 natural sites to reference wetlands in Ohio includes an evaluation of the functional capacity of wetland sites utilizing a draft version of the Buffalo District Wetland Evaluation Methodology (BWEM). The BWEM returns ratings for a wetland's water retention ability, water quality improvement function, and habitat value. Fennessy (1997) also evaluated ecological effectiveness of mitigation sites via plant community composition, Floristic Quality Assessment Index (FQAI), soil characteristics, wildlife observations, wetland size and basin morphology, and buffer area characteristics, invoking consideration of landscape influences on wetland function. Second, Wilson and Mitsch's 1996 in-depth evaluation of five Ohio wetland mitigation projects provides a detailed assessment of hydrology, soils, vegetation, wildlife, and water quality metrics. Some of the outcome measures correspond to what we call ecological endpoints: biophysical outcomes that facilitate social and economic evaluation (see Section 8.1). Examples include plant community composition, wildlife observations, water quality, and soil quality.

Porej et al. (2003) investigated 76 wetland mitigation projects, which included 117 separate wetlands, for vegetative composition, presence of a shallow littoral zone, presence of predatory fish, surrounding land use classes (NLCD), and regulatory compliance. While these characteristics are not ecological endpoints, they do help characterize some ecological outputs along with the mitigation effectiveness. Fennessy et al. (2004) provides an in-depth study of the biophysical outcomes of ten mitigation wetlands as compared to nine reference wetlands, charting groundwater levels, vegetation, standing biomass, vegetation-based indicators, macroinvertebrate and amphibian sampling and indicators, and detailed metrics of the biogeochemical characteristics of soils and surface water. Porej (2004) sampled 41 wetland replacement sites in the Eastern Corn Belt Plains ecoregion of central OH for the presence of amphibians, birds, and landscape composition; this study additionally analyzed the presence of predatory fish and a shallow littoral zone at 117 wetland mitigation sites. Gamble and Mitsch (2007) provide a detailed comparison of the hydroperiods at ten created and six naturally-created vernal pool wetlands in central Ohio. Kettlewell et al. (2008) evaluated the "permit compliance, wetland structure, and landscape context" of state wetland permits in Ohio's Cuyahoga River Watershed. Furthermore, Gutrich et al. (2009) studied eight freshwater depressional emergent mitigation marshes in Ohio 5-19 years after their initial restoration efforts, assessing ecological effectiveness based on floristic equivalency and soil chemistry data.

Some of the studies of the biophysical performance of mitigation sites in Ohio include study tracts within mitigation banks. Mack and Micacchion (2006) evaluated nearly 400 ha of wetlands at 12 Ohio wetland mitigation banks, assessing achievement of performance standards, Vegetation Index of Biological Integrity (VIBI), wetland vs. non-wetland area at banks, percent cover by invasive species, and soil and water chemistry data. Spieles et al. (2006) evaluated two 10-year old wetland mitigation bank sites in Ohio by comparing vegetative and macroinvertebrate communities at banks with those in reference wetlands. Knapp (2006) sampled and calculated Wetland Invertebrate Community Index (WICI) values for wetland mitigation bank sites in Ohio's Huron/Erie Lake Plain ecoregion; invertebrate communities were sampled at 20 sites within 7 mitigation banks in 2004 and at 6 sites within 3 mitigation banks in 2001. Ten of the sites studied in Porej (2004) were parts of 5 private mitigation banks. Kettlewell et al.'s 2008 study includes permits that were replaced through both traditional PRM and mitigation bank credits. Again, some of these studies illustrate the potential for outcome analyses that would facilitate ecosystem services evaluation. In other cases, however, additional modeling and assessment is necessary to connect biophysical analysis to economic analysis. Example include VIBI, WICI, which are potentially useful ecological indicators but do not facilitate economic or social interpretation of economic benefits.

The Environmental Law Institute's 2007 study, Mitigation of Impacts to Fish and Wildlife Habitat: Estimating Costs and Identifying Opportunities, includes cost estimates for compensation credits in two of the three Corps districts found in Ohio. The Buffalo and Huntington Corps districts estimate mitigation bank and in-lieu fee (ILF) credit prices for wetland mitigation, and provide general estimates for the cost of stream compensatory mitigation. This study directly illustrates the costs of stream mitigation, without addressing any ecological services or other benefits that may be provided by mitigation.

6.2. Florida: Traditional Compensatory Mitigation Approach

Traditional wetland compensatory mitigation in Florida was conducted through on-site, permittee-responsible mitigation, mitigation banks, and public offsite mitigation areas, which operated similarly to traditional in-lieu fee mitigation programs. The documentation we reviewed provides no explanation of site selection methodologies for traditional mitigation projects in Florida.

A number of Florida studies identified the use of biophysical outcome measures. The most comprehensive study is Reiss et al.'s 2007 assessment of the ecological and regulatory success of 58 wetland assessment areas within 29 mitigation banks across the state. The analysis of ecological success included use of a number of on-site and off-site measures, including the Uniform Mitigation Assessment Method (UMAM), Wetland Rapid Assessment Protocol (WRAP), two Hydrogeomorphic Wetland Assessment (HGM) guidebooks, Florida Wetland Condition Index (FWCI), and Landscape Development Intensity (LDI) Index. UNAM generates functional scores for location and landscape support, water environment, and community structure, which potentially could be used to evaluate a site's ecosystem goods and services. WRAP seems particularly conducive to analysis of the social benefits resulting from a mitigation site, including scoring categories for wildlife utilization, overstory/shrub canopy, vegetative ground cover, adjacent upland support/buffer, field indicators of wetland hydrology, and water quality input/treatment.

In Florida, the LDI Index was developed to assess the viability of potential or existing mitigation banks, with the assumption that hydrologic function and overall ecological significance was likely to be greater in undeveloped areas than in developed areas. While perfectly logical in theory, in practice this has the tendency of moving mitigation from the more urban areas impacted by development and experiencing the wetland losses, to the more rural and less threatened areas. In addition, while the methodology is likely to increase hydrological function, it is not likely to be able to identify areas with other significant regulated resources, primarily water quality limited areas or threatened or endangered species. A more useful assessment for demonstrating social benefits are calculated values for the LDI based on a 100-meter radius surrounding each wetland assessment site and each entire mitigation bank. The LDI is "an index of human activity based on a development intensity measure derived from nonrenewable energy use (e.g., fertilizer, fuel, electricity) in the surrounding landscape."

The HGM guidebook for depressional wetlands in central Florida evaluates sites for surface water storage, subsurface water storage, nutrient cycling, characteristic plant communities, and wildlife habitat and could be useful for evaluating the social benefits of mitigation. The Everglades flats wetlands HGM guidebook uses the same criteria, but combines surface and subsurface water storage scores into one category. FWCI is probably less useful for social benefits analysis, as it uses detailed scorings of diatom, macrophyte, or macroinvertebrate community composition at a wetland site.

Researchers have conducted a number of other local and regional studies recording qualitative or quantitative biophysical outcomes of traditional wetland compensatory mitigation projects in Florida. Lowe et al. (1989) evaluated the success of 29 wetland creation sites in the St. Johns River Water Management District (WMD) based on their success in meeting regulatory conditions of permits/consent orders and creating viable wetland habitat, as judged through qualitative assessments of a site's wetland species coverage, hydrology, and ability to support appropriate macroinvertebrate and fish populations.

Erwin (1991) examined 196 wetland impact permits in the South Florida WMD and evaluated the regulatory compliance and ecological effectiveness (surface hydrology, vegetation) of the 40 permits that required mitigation. A 1991 study by the Florida Department of Environmental Regulation (FDER) reviewed 119 wetland creation sites required by 63 Florida Environmental Resource Permits (ERPs) for adherence to permitted design and the ecological success of the site, as judged by whether a site is, or appears on a trajectory to become a functional wetland of the intended type. Streever et al. (1996) compared 10 created and 10 natural wetlands in central Florida in 1993 to assess differences in dipterans in freshwater herbaceous wetlands. Shafer and Roberts (2008) returned to 18 tidal mitigation sites in central/southern Florida in 2005 that were originally evaluated in 1988. Their research reassessed mangrove community composition and stand structure in 10 of these wetland mitigation sites to chart long-term trends in the development of vegetation at the site. Finally, in 2000 the Florida Legislature's Office of Program Policy Analysis and Government Accountability (OPPAGA) released a report that provided an overall status of wetland mitigation in the state including data on permit compliance, but the ecological performance measures used to measure compliance were not necessarily consistent across different wetland compensation projects (FL OPPAGA 2000). All of these studies confirm the widespread understanding that in spite of mitigation requirements, laws, and the state's best efforts, a long-term erosion of wetland functions continues to occur.

To identify measures which characterize wetland mitigation costs, the OPPAGA's 2000 report provides the range of costs for acres or credits of wetland compensation derived from different types of compensatory mitigation (creation, restoration, enhancement, and preservation) and the three different mitigation mechanisms. ELI's 2007 study, Mitigation of Impacts to Fish and Wildlife Habitat: Estimating Costs and Identifying Opportunities, also includes cost estimates for wetland compensation credits from mitigation banks and ILFs in the Jacksonville Corps district. While credit costs are useful, particularly because they reflect what permittees need to pay for credits, including the actual costs of restoration would also be useful in reflecting actual costs in relation to services provided.

Florida has had many studies relating the biophysical outcomes of wetland mitigation to their value as ecosystem services. Ruhl and Salzman (2006) examined the socioeconomic effects of wetland mitigation banking throughout the state. The authors collected permitting information for all active and sold-out wetland mitigation banks in FL, and for the 24 banks with adequate information, analyzed demographic trends in population density, median income, and minority population induced by banking. Boyd and Wainger (2003) performed a more detailed case study of the effects of a single mitigation bank, the Little Pine Wetland Mitigation Bank, on the value of wetland ecosystem services, as assessed through landscape indicators indicative of ecosystem service values. The authors used landscape indicators to assess services for improved drinking water quality/abundance, reduced flood damage, improved aquatic recreation, and open-space recreation, aesthetic, or species existence benefits. Initial landscape indicators were utilized to evaluate locational advantage, service scarcity, complementary inputs, risks and changed future conditions, and income and equity at impact and bank sites. As discussed below, Florida has moved on to create a few set of exceptional and detailed landscape indicators.

Florida developed one of the earliest spatial statewide conservation strategies developed by the Florida Department of Fisheries and Wildlife (Cox et al. 1994) which identified a set of conservation priorities identifying lands needed to conserve Florida's wildlife. The map, shown below from the report, is the first of a large set of statewide analysis developed across the United State to assist in focusing conservation in the areas most important to ecological resources, in this case wildlife. Many states have used this effort as a model, and created statewide or regional conservation strategies modeled after it (Defenders of Wildlife 1998; Noss et al. 2002).

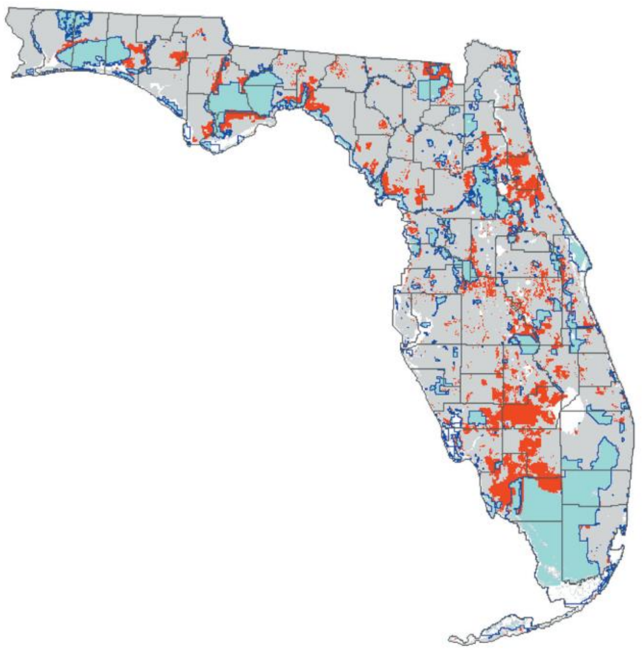

Figure 2: Florida's "Closing the Gap's Conservation Blueprint" (1994).

The Florida State University's Natural Area Inventory (FNAI), has updated statewide conservation priorities for all species and habitats as part of the Florida Forever project. The project created data and online tools to be used for prioritization of acquisition and protection of conservation areas. Relevant to identification of mitigation priorities would be the15 maps identifying strategic conservation areas, rare species, under-represented ecosystems, large landscapes, natural floodplain function, functional wetland and other priorities. Since data on conservation priorities in the state have already been developed by credible sources, the use of an REF to guide mitigation efforts in Florida would require extremely limited costs related to data development or analysis, most costs being limited to the process of deciding on the most effective or important resources to evaluate (FNAI 2010).

An analysis comparing the established mitigation banks in Florida with the set of priority maps created by FNAI is shown in Table 1, below.

Table 1: Measures showing existing mitigation banks overlaps with conservation priorities. Data courtesy of Gary Knight, Director, Florida Natural Areas Inventory, Florida State University.

DEP Mitigation Banks: Florida Forever Measures Evaluation — TOTAL ACRES = 135,186

MEASURES	Acres[a]	%[a]
B1: Strategic Habitat Conservation Areas		
Priority 1	4,253	3%
Priority 2	78,103	58%
Priority 3	10,295	8%
Total Acres	92,650	69%
B2: FNAI Habitat Conservation Priorities		
Priority 1	376	<1%
Priority 2	3,409	3%
Priority 3	15,523	11%
Total Acres	19,308	14%
B3: Ecological Greenways		
Priority 1- Critical Parcels	12,333	9%
Priority 2- Critical Parcels	44,212	33%
Priority 1	2,260	2%
Priority 2	0	0%
Priority 3	0	0%
Total Acres	58,805	43%
B4: Under-represented Natural Communities		
Upland Glade (G1)	0	0%
Pine Rockland (G1)	10	<1%
Scrub (G2)	1,096	1%
Tropical Hardwood Hammock (G2)	32	<1%
Dry Prairie (G2)	0	0%
Seepage Slope/Bog (G3)	0	0%
Sandhill (G3)	876	1%
Sandhill Upland Lake (G3)	223	<1%
Upland Hardwood Forest (G4)	0	0%
Pine Flatwoods (G4)	11,672	9%
Total Acres	13,909	10%
B5: Landscape-sized Protection Area (Yes/No)		
Priority 1	yes	
Priority 2	yes	
Priority 3	yes	

MEASURES (continued)	Acres[a]	%[a]
C4: Natural Floodplain Function		
Priority 1	9,969	7%
Priority 2	1,385	1%
Priority 3	4,407	3%
Total Acres	15,761	12%
C5: Surface Water Protection		
Priority 1	7,153	5%
Priority 2	27,896	21%
Priority 3	11,040	8%
Total Acres	46,089	34%
C7: Fragile Coastal Resources		
Uplands	2	<1%
Wetlands	3,725	3%
Total Acres	3,727	3%
C8: Functional Wetlands		
Priority 1	24,467	18%
Priority 2	26,279	19%
Priority 3	17,764	13%
Total Acres	68,510	51%
D3: Aquifer Recharge		
Priority 1	604	<1%
Priority 2	3,310	2%
Priority 3	12,380	9%
Total Acres	16,295	12%
E2: Recreational Trails		
(prioritized trail opportunities from Office of Greenways and Trails & U. Florida)		
Priority 1	17	
Priority 2	17	
Priority 3	7	
Total Acres	41	
F2: Arch. & Historical Sites (number)	79	sites
G1: Sustainable Forestry		
Priority 1	14,456	11%
Priority 2	5,831	4%
Priority 3	10,652	8%
Total Acres	30,939	23%
G3: Forestland for Recharge	604	<1%

[a]Number of acres of each resource in mitigation sites and percentage represented are listed except where noted. Only Priorities 1 - 3 included. Some resources priorities are 1-6.

The fact that existing mitigation banks only include 14% of FNAI Habitat Conservation Priorities, 10% of Under-represented Natural Communities or 3% of Fragile Coastal resources is not surprising, as these values were not considered in any way in identifying potential mitigation areas, although there is little doubt that a much higher percentage of each of these values could have been obtained if incentives for including them were included in the Department of Environmental Protection's rules. It is more disturbing that in the areas in which related wetland functions should be strongest, such as aquifer recharge and surface water recharge, only 12% of the area of banks occur within any of the top three priority areas, while only 34% occur in locations that provide priority surface water protections. Barely half occur in areas with locations that were identified as priorities for wetlands functions. Clearly the existing mitigation banks, regardless of whether they are meeting their regulatory objectives, miss a great opportunity to expand the ecological and economic benefits available by locating mitigation in the right places.

The Department of Transportation's Efficient Transportation Decision Making (ETDM) web-based permitting system may actually create barriers to taking advantage of the additional ecosystem services provided by a more ecoregionally-based mitigation approach. One of the most direct costs of implementing transportation projects is the cost in both staff and delays related to the acquisition of the necessary permits. Florida's ETDM is an award winning web-based tool designed to streamline the process of planning and implementing transportation projects, and over the last seven years since its implementation, it has been shown to be remarkably effective in shortening the time for permits and project implementation (Roaza 2007).

However, the ETDM does not build in the necessary information and interagency buy-in necessary to implement an ecoregionally based mitigation approach. To create the interagency agreements needed to build the ETDM, or any other programmatic measures, it is necessary to complete complex and intense negotiations with the regulatory community, which also takes both time and money (Venner et al. 2010). Many view the benefits in speed and cost of transportation project implementation over the benefits of developing these, and almost any programmatic regulatory agreement, particularly if mitigation is involved (Achterman et al. in press). However, the ETDM is an example of when the initial costs of implementing a program can limit its long-term effectiveness and expandability. In other words, the inherent cost due to negotiation of a complex programmatic system for permitting, especially if it is web based, provide incentives for not including new information and not updating existing information.

For example, much of the information on threatened and endangered species used in ETDM came directly from the Florida Natural Areas Inventory (FNAI) program. The data used was the best available at the time, approximately 2003, but extensive and much improved information has been developed by FNAI since that time. In particular, FNAI has been working with NatureServe to create species distribution maps (SDM) for at-risk and threatened and endangered species, identified in recent studies (Achterman et al. in press) as critical data which can improve both the ability to avoid endangered species early in the planning process, and to target areas with endangered species during mitigation planning. Developing SDMs is not without initial costs, but in Florida FNAI has developed initial SDM for all priority species, to assist in conservation planning. With ETDM, the existence of a methodology that speeds transportation project implementation without considering the ecological or economic benefits of using new data or methodologies, removes any incentives they have for adopting them, or even for evaluating their utility.

6.3. Minnesota: "Midway" Compensatory Mitigation Approach

Regulations governing Minnesota's state-run, comprehensive freshwater wetland program stipulate certain preferences and necessary components of wetland compensation sites to promote ecologically suitable and sustainable mitigation. The regulations prefer that wetland replacement is "located and designed … to be self-sustaining," located where it can maximize natural hydro-geomorphology and necessitate little landscape alteration, and require that it be "accomplished according to the ecology of the landscape area." Minnesota's wetland regulations further specify that compensation projects must consider "landscape position, habitat requirements, development and habitat loss trends, sources of watershed impairment, protection and maintenance of upland resources and riparian areas, and provide a suite of functions." The regulations also specify upland buffer requirements for all wetland replacement projects. Finally, Minnesota requires that wetland compensation follow detailed siting procedures based on an impact's minor watershed, major watershed, county, bank service area, and metropolitan area; these siting requirements vary based on the percent of pre-settlement wetlands intact in a county/watershed. Counties with a higher percentage of intact pre-settlement wetlands receive higher spatial flexibility for replacing wetland impacts.

The state uses the Minnesota Routine Assessment Methodology (MnRAM) for evaluating wetland functions, which provides on-site measures useful for evaluating wetland mitigation performance criteria as well as off-site measures of a wetland's surrounding landscape. MnRAM is particularly conducive to social benefits analysis and, in fact, includes some metrics that incorporate judgments of the value or opportunity associated with a particular function. MnRAM allows regulators to assess a site's performance for the following categories of functions/values: "vegetative diversity and integrity, maintenance of characteristic hydrologic regime, flood and stormwater storage/attenuation, downstream water quality protection, maintenance of wetland water quality, shoreline protection, management of characteristic wildlife habitat structure, maintenance of characteristic amphibian habitat, aesthetics/ recreation/ education/ cultural/ science, commercial uses, groundwater interaction, wetland restoration potential, wetland sensitivity to stormwater input and urban development, and additional stormwater treatment needs" (Fennessy 2004). MnRAM also allows site assessments to utilize GIS analysis when appropriate. Minnesota additionally accepts functional assessments that utilize HGM.

Minnesota maintains data tracking overall costs of mitigation bank credits in the state. When reported voluntarily by a permittee or mitigation provider, the state posts the prices of completed mitigation bank transactions on the website of the state's Board of Water and Soil Resources (BWSR). Prices are currently posted for transactions from 2005-08. BWSR also runs a state mitigation banking program and the state uses a legislatively-set formula to derive prices for credits sold in each county in the state. The formula and calculations of credit prices in each county are also available on the BWSR website. ELI (2007) reports past credit prices for BWSR's public banking program. BWSR also oversees a publicly-accessible database of available wetland bank credits that is updated on a daily basis; this database allows users to group wetland credits by county, watershed, service area, and wetland type, though it does not post the prices for available wetland credits. This database also provides contact information for bankers supplying credits.

Minnesota has one of the most ambitious statewide efforts to inventory native plant communities and species of conservation concern through the County Biological Survey in the Minnesota Department of Natural Resources (MNDNR). Spatially explicit data are produced that document sites of biodiversity significance, natural habitats, wetlands, and at-risk species distribution across the state. These data are available as GIS files and have been used by DNR, local governments and NGOs in statewide, regional and local planning processes to identify conservation priorities. However, there is currently no statewide map of conservation priority areas that is utilized by all conservation interests (Bonita Eliason, MNDNR, personal communication).

Minnesota has a section of the Wetland Conservation Act (WCA) rules pertaining to "Local Comprehensive Wetland Protection and Management Plans" (Minn. Rules Chapter 8420.0830). This part of the program is more closely aligned with the theme of "progressive mitigation." The rule states:

> "The ultimate goal of a comprehensive wetland protection and management plan is to maintain and improve the quality, quantity, and biological diversity of wetland resources within watersheds through the prioritization of existing wetlands and the strategic selection of replacement sites. The purpose of developing a plan is to provide a watershed and ecosystem-based framework to make wetland impact and replacement decisions that meet state standards and locally identified goals and support the sustainability or improvement of wetland resources in watersheds while providing local flexibility as allowed under subpart 4."
>
> "The comprehensive wetland protection and management plan must include the establishment of watershed goals based on an analysis of the existing ecological conditions of the plan area and the development of corresponding goals for maintaining and improving those conditions. The ecological condition of the plan area should be based on inventories of historic and existing wetland resources, including identification of degraded wetlands, existing high-quality wetlands, and immediate and long-term resource needs within the plan area."

Also, there have been a number of large watershed projects in which an integrated watershed approach to conservation and mitigation was developed in large watersheds in Minnesota. Of particular interest were large watershed projects in the Sunrise Watershed and the St. Croix–Lino Lakes Watershed. The Sunrise Watershed project involved modeling and GIS work to develop a vulnerability assessment, did some public outreach, used available data, including data from the Total Maximum Daily Load (TMDL), so wetlands, water quality and endangered species were all included in the analysis. Table 2 below shows some of the results of the Sunrise River Watershed analysis, particularly those related to wetland types which are most in need of mitigation banks. The authors of the presentation from the U.S. Army Corps noted that these recommendations, such as the types of wetland habitats most needed for mitigation, were provided as potential guidance to the banking community. They stated that providing this information to the bankers could potentially make it easier for bankers to sell credits with the most desirable wetland communities, based on the in-kind anticipated losses. This is different from the efforts in Oregon and Maryland described below, which provide either actual financial incentives or regulatory mandates for working in priority areas, or focusing on priority species or habitats.

Table 2: Calculated demand for wetland types with greatest losses as incentives to mitigation banks in Sunrise River Watershed (Smith 2010).

	Deep Marsh	Shallow Marsh	Sedge Meadow	Wet Meadow	Shrub Carr	Hardwood Swamp
Existing credits	0.03	5.97	0	4.96	8.77	0.1
Average annual demand	0.05	0.73	0.66	1.61	0.24	0.05
Projected date of deficit	2010	2018	2010	2012	2036	2012

Calculated demand for wetland bank credits by types based on Section 404 permit impact data from 1999 - 2009

The concept of working with local stakeholders to develop a progressive approach to restoration, conservation and mitigation has obvious benefits, many related to being able to introduce local stakeholder interests and priorities. However, there are also some obvious limitations to the approach, as shown in Minnesota. First, the developers of the Sunrise River Watershed project from the Corps noted that while the methods these watershed studies developed appear to improve the results of conservation and mitigation, the Corps does not have the resources to implement them widely in the St. Paul District, given their relatively high costs to complete (Smith 2010). Second, even when developed by regulatory agencies such as the Corps or the Environmental Protection Agency, standards are not used, so that individual regulators have to evaluate the effectiveness of each of the proposed mitigation projects. So, while Minnesota is in some aspects the most progressive state of any evaluated, the lack of a standard method to integrate conservation, restoration and mitigation of wetlands, endangered species, and overall biological resources prevents the development of a statewide, progressive approach to the selection of compensatory mitigation sites.

6.4. Oregon: Progressive Compensatory Mitigation Approach

Oregon has a number of ongoing efforts to improve the quality and implementation of compensatory mitigation in the state. These include recent programmatic agreements for vernal pool wetlands and endangered species in the Agate Desert portion of the Rogue Valley, comprehensive restoration and mitigation activities in the Klamath Basin, and widespread efforts in the Columbia Basin by the Bonneville Power Administration to compensate for wildlife losses from the construction of the major dams on the Columbia River. However, the focus of this study will be on a group of related projects to improve restoration and mitigation in the

Willamette Basin, and some extensive research recently completed or underway to characterize this work.

One of the most relevant projects underway represents a series of coordinated efforts to restore ecosystem function in the Willamette Basin. The area has extensive urban, suburban and residential development, prime agricultural lands, highly productive forests, and numerous endangered species populations and extensive wetlands. The Willamette Basin is home to most Oregonians, and has been the focus of extensive conflict between environmental conservation and economic development forces (Talis and Polasky 2009). The Willamette Basin also has had extensive study to characterize the distribution of diversity and barriers to conservation, best summarized in the Willamette River Basin Atlas (Hulse et al. 2002), which summarized an almost 10 year, multi-University and agency research project called the Willamette Ecosystem Research Consortium. This data and an understanding that the Basin and its rivers provide critical ecosystem services, led to the creation of the Willamette Basin Partnership and a number of efforts to restore the basin.

The General Crediting Protocol for the Willamette Basin Partnership references priority areas for ecological improvements to salmonoid habitat, prairie habitat, wetland habitat, and water temperature impairments (Willamette Partnership 2010). The Partnership identifies priority rivers and streams for improved salmon habitat based on National Marine Fisheries Service (NMFS) data, priorities for investment in prairie habitat and thermal pollution mitigation based on the Willamette Basin Synthesis Map, and priorities for wetland mitigation based on the wetland priorities identified in the Synthesis Map or areas surrounded by high-function wetlands as determined by Oregon Wetland Assessment Protocol (ORWAP).

The Synthesis Map was produced by a mix of conservation groups, academics, and government agencies, including Oregon State University and the Willamette Partnership, to identify priority terrestrial and freshwater sites for conservation and restoration. Two endangered species recovery efforts were also incorporated into the syntheses. The first was a multi-species recovery plan for three endangered plants and an endangered butterfly which occur on wetlands and upland prairies in the Willamette Valley, and the prairie habitat crediting protocols integrate these species needs. This included INR developing species distribution maps identifying the probable distribution of these listed species, which were used in prioritizing areas for recovery and avoidance (Achterman et al. in press). The second are the recovery efforts for threatened fish in the basin, most notably salmon.

Important for Clean Water Act mitigation, the Synthesis Map integrates priority wetland sites for conservation and restoration developed cooperatively by the Wetlands Conservancy (TWC) and the Institute for Natural Resources (INR). To address wetlands compensatory mitigation priorities, in the Willamette Basin, TWC and INR updated the wetlands dataset for the basin, and then identified the priority conservation areas with extensive wetlands and with restoration needs, within each subwatershed of the basin.

Since the primary wetlands mitigation activity is wetlands restoration, the project also developed a Wetlands Restoration Planning Tool (Oregon State University 2010) that helps users identify the most appropriate sites to implement restoration, and what wetland habitats should be targeted for restoration. Datasets used in the tool include the statewide wetland layer, rare wetlands, restoration targets based on HUC4s, locations of wetland mitigation banks and Wetland Reserve Program sites, wetland priority sites for the Willamette Valley, and hydric soils.

It generates information in two tables showing acreage by Cowardin type that could be impacted if the site is fully developed, suggested restoration targets by Cowardin type based on acreage of historical losses for the given HUC4, and links to plant materials recommended for restoration.

However, perhaps the primary emphasis of the Willamette Basin Partnership is developing scientifically valid ecosystem service accounting protocols that can measure and register the functions and values associated with improvements and impacts to unbundled ecosystem services. The Partnership is currently developing credit/debit protocols for wetland habitat, prairie habitat, salmanoid habitat, nitrogen and phosphorus loadings, and thermal pollution offsets. Approved site assessment metrics include Counting on the Environment's Salmon Credit Calculation Method, Counting on the Environment's Prairie Credit Calculation Method, the Oregon Wetland Assessment Protocol (ORWAP), and the Shade-a-Lator (for water temperature); all of these measures are conducive, and within the framework of the Partnership, intended to be used for ecosystem services valuation. It is worth noting that the Willamette Partnership was funded primarily with NRCS Conservation Innovation Grant dollars meant to help create markets for ecosystem services. Mitigation activity and planning were thus driven by a "markets" approach, which tends to demand both transparent credit/debit criteria and an assessment of benefits associated with alternative mitigation outcomes.

The stream and aquatic habitat restoration efforts are being coordinated by the Freshwater Trust along with the Willamette Partnership. The Freshwater Trust has developed and is working to implement a web-based stream restoration and mitigation tool called Streambank, and has worked with Parametrix to develop the salmanoid habitat measures. Using Light Detection and Ranging LiDAR high resolution data for the Willamette Valley, INR has developed riparian maps to assist The Nature Conservancy, Ducks Unlimited, and the American Bird Conservancy in efforts to prioritize riparian conservation. The new data created a very high resolution DEM which allowed for detailed hydrological flows mapping in very low gradient areas, to improve the measurement of Clean Water Act services in the basin (Nielsen and Kagan 2011).

The Natural Capital Project's has evaluated ecosystem service values throughout the Willamette Basin. Nelson et al. (2009) was one of the first published applications of a spatially explicitly modeling tool for ecosystem services valuation. The paper uses the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) to assign monetary values to ecosystem services in the Willamette Basin. While the paper does not model the economic value of ecosystem services associated with a particular compensatory mitigation program, the researchers modeled three stakeholder-defined scenarios of land cover change in InVEST, one of which was a "conservation" scenario. A second paper published by Natural Capital further expounds how use of modeling tools such as InVEST can inform natural resource management (Tallis and Polasky 2009).

While the extensive data and research in the Willamette Basin makes it an excellent laboratory for understanding methods for accounting for ecosystem services and planning for successful compensatory mitigation, this level of detailed information is not critical for progressive mitigation implementation. In Oregon, the critical components were the development of comprehensive wetland and endangered species data and an accepted REF. The costs to develop the wetland mitigation and most of the endangered species programmatic data were modest.

6.5. Maryland: Progressive Compensatory Mitigation Approach

The Watershed Resources Registry (WRR) developed in Maryland is a geographic information system based mapping tool designed to support the development of a watershed profile by integrating information from various stakeholder including federal and state agencies, NGOs and others. The result is a system that can easily identify priority resources and resource goals including water quality, habitat, storm water management, land management, existing watershed plans, etc. By integrating information from multiple resource agencies and NGOs into one system WRR supports the identification of high priority resources for mitigation in Maryland and the development of conservation goals utilizing a standard, scientifically based and repeatable process that is encapsulated in the WRR.

Information on resource type and quality, quantitative and qualitative descriptions of land cover, land use, soil types, wetlands, streams, forest hubs and corridors, endangered species, critical birding habitat are included. The focus is to provide spatial data on the health and needs of the watershed. Utilizing the information in the WRR, local scientific experts and conservation professionals document recommended actions in the watershed profile that support conservation goals in the watershed. The WRR maps those areas in the watershed that would benefit from the actions identified in the watershed profile. The WRR creates eight ecological maps using logical and arithmetic processes that include opportunities for: 1) wetland preservation, 2) wetland restoration, 3) wetland enhancement, 4) riparian zone preservation, 5) riparian zone restoration, 6) upland preservation, 7) upload reforestation, and 8) stormwater management. The maps show areas that scored high for each opportunity type. WRR utilizes widely available and accepted datasets like USGS watershed layers, NRCS soils data, and §303(d)-listed impaired streams as well as locally developed priority areas. The WRR can easily identify areas that can provide multiple benefits if targeted for mitigation.

Prior to the development of the WRR, the Conservation Fund worked with federal and state agencies in a very in-depth environmental data integration and assessment process – including species and ecological communities. It appears that the data analyses results and the data itself was integrated into the WRR and likely made the tool much more effective. Although the WRR case study did not mention performance measures, and only recommended that monitoring protocols be developed, the standard, scientifically based evaluation and method of selecting mitigation sites included specific factors and site-specific goals that could be translated into measures for monitoring the success of these goals in the areas selected for mitigation.

In addition to overlaying many datasets in order to 'score' sites that could be targeted for restoration or preservation, they developed a benefit-cost optimization tool to help identify parcels that would bring the most conservation benefit with the least amount of monetary investment. The ecological metrics were used to create an overall parcel conservation score, which was then compared with land costs to choose conservation sites under hypothetical budget scenarios of $15 million and $5 million. The model that ran with a $15 million limitation was compared with a rank-based prioritization method, with the benefit-cost optimizer resulting in 15% more green infrastructure area and a 7% higher net ecological score. Under the $5 million budget scenario, the optimizer resulted in a 14% higher overall ecological score as compared with a ranking method, although it did result in 28% less green infrastructure area since there were more parcels selected for their enhanced ecological value. Unfortunately, Weber and Allen's empirical model results were limited to conservation prioritization and did not extend to restoration, though the framework is established for such analysis by comparing restoration potential with cost (Weber and Allen 2010).

The registry was initially developed using information from four watersheds in the Chesapeake Bay southeast of Washington, D.C., including portions of Charles and Prince George's Counties: Mattawoman Creek, Port Tobacco, Zekiah Swamp and the Piscataway Creek. The registry database and tools have been expanded to cover the entire state of Maryland (Bryson et al. 2010). The registry focused on how it could be a national pilot, particularly be identifying the national datasets from the rich Maryland specific datasets. However, Bryson et al. were not specific about recommending which rich datasets would be most important to develop across the country. Much of the work was based on the Green Infrastructure Network Identification (Maryland Department of Natural Resource - MDDNR), based on Green Infrastructure methodology, which as discussed below, may have limitations in applying it nationally. Also, while WRR is very focused on functions, it does not really address services, aside from assuming that they are derived from improved function. However, it remains as one of the only national examples that provides a methodology for statewide implementation of a progressive mitigation strategy.

7. Traditional and Progressive Mitigation Compared

The traditional and progressive approaches to mitigation differ along two dimensions: one relates to the goals of mitigation and how those goals are assessed and measured. The other relates to the *process* of planning, scoring, and approval.

7.1 Assessment, Criteria, and Outcomes: Traditional Versus Progressive

As noted above, traditional and progressive approaches to mitigation are distinguished by the degree to which they evaluate mitigation in the context of (1) systems of ecological production, and (2) the social factors that affect the value of ecosystem services produced by mitigation. In general:

- Traditional approaches tend to evaluate only site-specific features and processes. Progressive approaches evaluate the role of mitigation in a larger biophysical systems context.
- Traditional approaches place less emphasis on spatial configurations. Progressive approaches place more emphasis on the role of spatial biophysical production relationships.
- Traditional approaches do not evaluate the production or delivery of ecosystem goods and services (ecological outcomes that are directly valuable to households, businesses and communities). Progressive approaches evaluate mitigation at least in part on the basis of their contributions to economic and social improvements.

A criticism of traditional mitigation assessments, scoring, and targeting is that they focus on outcomes that – while they may lead to a narrow replacement of features or functions – do not guarantee the attainment of ecological goals, or the replacement of lost ecosystem goods and services. In other words, traditional planning criteria can be poor proxies for more socially and ecologically valuable mitigation/restoration goals. Progressive mitigation planning seeks the delivery not of these on-site features and functions, but of a broader and more valuable bundle of ecosystem goods and services. A central reason traditional mitigation criteria may be poor proxies is that they do not permit the evaluation of off-site, watershed or regional scale biophysical processes or they may ignore important spatial phenomena such as the role of connectivity and contiguity of land cover types in the production of ecological outcomes.

> **Summary: The spatial nature of ecological production means that sites that are equivalent in terms of "on-site features and functions" are *not* equivalent in terms of their ability to deliver ecological outcomes, including goods and services.**

In contrast, because progressive assessment seeks the attainment of ecological outcomes (goals) that differ from simple "input measures," it leads to assessments more capable of evaluating ecological and economic outcomes that are truly desired and beneficial. In practice, this means that progressive assessment relies on spatial configuration of natural resources and processes and that eligible mitigation sites are defined and prioritized based on landscape-level biophysical analysis.

> **Key Assumption: Progressive assessment and planning will lead to improved quantities and qualities of ecological production (NRC 2001), because the sites' role in the broader biophysical production system is evaluated. When higher quantity/quality ecological outcomes are sited in areas with adequate social demand these outcomes, they lead to greater production of economic value associated with ecosystem goods and services.**

An additional benefit of progressive mitigation planning is that spatial analysis of the configuration of natural resources and processes is likely to identify mitigation locations where "on-site" functional replacement is most likely to succeed.

> **Key Assumption: Even if the goal remains narrowly focused on "replacement of site-specific features and inputs," the success of that replacement is likely to be improved via progressive biophysical planning and evaluation (Achterman et al. in press).**

> **Summary: Progressive evaluation and planning, by design, explores the role of individual mitigation projects in the context of larger systems of ecological production. Also, progressive mitigation favors the delivery of socially valuable ecosystem goods and services delivered by those systems.**

7.2 The Planning Process: Traditional Versus Progressive

The traditional mitigation planning process identifies eligible sites only *after* a mitigation need is expressed, and does so on an individual permit by individual permit basis.

A criticism of the traditional approach is that seeking approval for compensation projects on a project-by-project basis can lead to duplicative, rather than coordinated permitting practices, which in aggregate increase administrative and evaluation costs, relative to a more coordinated, systematic spatial approach. Another disadvantage of ex post permit-by-permit approvals is the significant possibility of permit delays, given the absence of an accepted mitigation plan. These delays can impose significant economic costs on permit applicants.

Another criticism, related to the discussion in 7.1 is that ecological production of ecosystem services is very difficult to accomplish through mitigation or restoration without a comprehensive spatial plan. Ex post and one-off approvals will thus tend to imply that scoring and targeting rules will focus on site-specific features and functions, rather than the production of valuable ecosystem services. As a result, studies show in existing mitigation programs (Fennessy et al. 2004; Reis and Brown 2007) and general analysis of wetlands within developed areas, a decline in functions over time (Kentula et al. 2004).

In contrast, a progressive planning *process* identifies (and may prioritize) eligible mitigation sites based on (1) their different contributions to ecological production, (2) the likelihood of functional replacement, based on biophysical assessment of the broader spatial configuration of natural resources and processes, and (3) their contributions to off-site ecosystem services delivery.

Summary: Progressive mitigation planning takes into account a broader range of biophysical processes and outcomes. This means that progressive planning requires up-front investment in this more sophisticated – and socially desirable – planning activity.

By focusing on spatial configuration, and with specific ecological goals in mind, progressive planning identifies or prioritizes eligible mitigation sites in terms of their ability to deliver the greatest ecosystem service benefit. By design, progressive approaches direct mitigation to more specific sets of parcels than a traditional approach. Traditional approaches will tend to "allow" mitigation on any parcel that meets simpler, site-specific feature and function criteria.

Summary: Progressive planning, because of its ability to identify the *best* rather than just equivalent mitigation sites, may or may not steer mitigation toward higher cost lands than traditional approaches.

7.3 The Progressive Planning Hypothesis: Cost and Benefit Factors

The hypothesis explored by this report is that progressive mitigation planning yields net overall social benefits relative to traditional mitigation approaches.

The cornerstone of our hypothesis is that mitigation planning divorced from analysis of mitigation's role in larger systems of ecological production *will necessarily* lead to fewer ecosystem services benefits than progressive planning. This is true whether or not explicit connection to monetary benefits is included in the planning activity, and for purely biophysical reasons. Biophysical production is determined not just by the atomistic contribution of individual sites. Because spatial biophysical production functions can either thwart or amplify ecosystem services production, progressive analysis will yield desirable ecological outputs in greater quantity and of higher quality. When these increased, more effective ecological outcomes are located in areas with adequate social demand for the resultant ecosystem goods and services, they will produce more economic value. But progressive planning can go further and attempt to site mitigation in ways that target beneficiary populations with the explicit purpose of maximizing economic benefits.

Quantifying the magnitude of these additional benefits is difficult, to be sure. Section 8 of this report describes ways in which such quantification can be developed. But managing a system in order to deliver socially desirable outcomes is likely to yield greater ecological and economic benefits than an approach that ignores biophysical and economic factors that affect mitigation's ability to deliver those outcomes.

When it comes to the costs associated with traditional versus progressive mitigation there is greater ambiguity. First, progressive planning can and should constrain the location of acceptable mitigation projects by identifying which yield the greatest ecological and economic benefit. Ideally, progressive planning chooses sites with the greatest *net* benefit, meaning land acquisition costs are taken into account. However, it is possible that the cheapest lands will not yield the largest net benefit, which implies that acquisitions costs may be higher under a progressive planning approach. Nevertheless, with a net benefit approach to site selection, the gains from progressive planning will be greater than any additional land acquisition costs.

Two other cost categories will yield differences between traditional and progressive: evaluation and planning costs and the costs of the permitting process itself. Because progressive mitigation planning – by design – involves more and better analysis, the costs of analysis under progressive approaches will be more expensive. There is no free lunch if we are to do a better job of understanding biophysical production and economic outcomes. However, these higher up-front planning costs may yield long-run cost savings associated with expedited and coordinated permitting. Pre-approved regional mitigation plans can avoid duplication of effort, analysis, and bureaucracy. They also provide greater regulatory certainty to permittees and mitigation operators. Perhaps most important, pre-approved mitigation plans reduce long-run permit analysis costs and reduce permit delays. Reduced permit delays have a huge potential economic value to mitigation demanders and operators.

> **Key Assumption: The economic and ecological benefits of progressive planning, combined with potential process cost savings and savings associated with reduced permit delays, are likely to outweigh the additional (and upfront) analytical costs.**

8. Making the Connection between Ecological Assessments and Economic Value

Progressive planning uses knowledge of spatial biophysical systems to evaluate the mitigation actions most likely to yield ecologically and economically valuable outputs across the system. This requires more sophisticated (progressive) ecological evaluation, which we have been referring to as spatial biophysical production analysis. In this section we describe in more detail the properties of this kind of analysis. In particular, we focus on the kinds of biophysical analysis that are necessary for evaluation of economic benefits associated with ecological improvements.

Economic evaluation of ecosystem service outcomes requires two basic things: (1) biophysical outcome or evaluation measures that allow for economic interpretation, and (2) the application of economic valuation or evaluation methods to assess the benefits of a change (gain or loss) in biophysical outcome.

If mitigation planning is to feature economic assessment, development of economically interpretable biophysical outcome measures is necessary. This section proceeds as follows. First, we describe the properties of economically interpretable biophysical outcome measures. Second, we discuss data and methods needed to relate these measures to mitigation interventions and existing ecological outcome measures. Third, we review economic data and tools available to evaluate the benefits (or costs) that arise from gains (or losses) in these outcome measures.

8.1 Biophysical Outcomes Suitable for Economic Evaluation

A threshold issue for ecosystem services analysis is therefore: What are the biophysical quantity units we should measure in order to subsequently facilitate economic valuation and other forms of social evaluation?

The centerpiece of ecosystem service-oriented mitigation policy is the definition, measurement, and evaluation of *ecological endpoints*. Ecological endpoints are a distinct subset of the larger universe of biophysical outcome measures. In general, natural systems can be thought of as collections of features, things, and qualities that interact via physical processes with other physical features, things, and qualities. Accordingly, almost anything we can measure in nature is an “outcome” of some underlying process or function. Ecological endpoints are a special set of biophysical outcomes: those that are meaningful and understandable to communities, businesses, households, planners, and other stakeholders.

> **Definition: Ecological Endpoints are biophysical outcome measures that require little further biophysical translation in order to make clear their relevance to human welfare. These endpoints are the essential bridge between biophysical and economic assessment. The term “endpoint” is used in many ways and refers generically to any modeled or measured outcome of a process, function, or relationship. We use the term more narrowly, to draw attention to the need for biophysical outcome measures that facilitate social evaluation.**

One way to think of these measures is that they are ways to describe nature in terms that your next-door neighbor (or some other beneficiary) would understand. Examples include water availability, species populations, viewable or accessible open space, flood risks, and air, soil, and water quality – all in particular places at particular times.

Economic planning and assessment requires us to measure outcome qualities or quantities whose value or importance can be meaningfully debated by stakeholders or detected by social scientists. In practice, this means choosing outcomes that are comprehensible and meaningful to non-scientists. Outcomes like biotic integrity indices, chemical water quality concentrations, hydrogeomorphic classifications, and rotifer productivity are of scientific interest, and establish the scientific basis for accurately modeling ecosystem functions and services, but without tangible measures of these benefits, stakeholders cannot evaluate their social value.

Many things we can measure in nature, and that are important features of the ecological system, do not share these properties. The dissolved oxygen level in water, for example, is not directly experienced, nor is it typically the subject of household choice, nor is it tangibly meaningful to most non-experts. But there are direct inputs to home production dependent on dissolved oxygen as an input. Dissolved oxygen, for example, can affect fish populations, water clarity, and odor. These outcomes are much more likely to be directly experienced, bear directly on households choices, or be identified as intuitively important to utility.

To convey the distinction between ecological endpoints and biophysical outcomes that are not endpoints consider the examples in Table 3 below.

Table 3: The distinction between general ecological measures and endpoints.

General Ecological Measures	Biophysical Process	Ecological Endpoint
Surface water pH	Habitat and toxicity effects	Fish, bird abundance
Acres of habitat	Forage, reproduction, migration	Species abundance
Wetland acres	Hydrologic processes	Reductions in flood probability & severity
Forest acres	Shading and sequestration	Air quality and temperature
Vegetated riparian border	Erosion processes	Sediment loadings to reservoirs

Consider a firm or household asked to place a value on the commodities on the left-hand side of Table 3. Are lower surface water pH levels valuable to households? Yes, but not directly. Why is lower pH valuable? One reason is that it allows for habitats more suitable to fish and bird species. If a household directly values more fish and birds, they indirectly value lower pH levels. But households cannot themselves place a value on lower pH levels. The reason is that the value of lower pH must be inferred from two pieces of information (1) the value of the fish and birds to households, and (2) the production relationship between surface water pH and fish and bird abundance. It is the second part of that equation that prohibits economic valuation by households. How are they to know the quantitative relationship between pH and the fish and birds they care about? In contrast, the abundance of fish and birds requires no further biophysical transformation in order to make its role in household production clear. Thus, fish abundance is an endpoint.

Consider another example from Table 3. A household or firm owning real estate in a floodplain may understand that wetlands are valuable because they reduce the severity of flood pulses and property damage. But the value of the wetland must again be inferred from the hydrological processes that relate wetlands to the probability, height, speed, and location of flooding (the hydrograph). In this case, the hydrograph is the directly consumed nonmarket good (and thus by our definition an ecological endpoint). Wetlands' role in this toy example is as a valuable, but indirectly valuable, commodity. *Qualitatively* households can say "wetlands are beneficial because they reduce my flood risk." Quantitatively, however, households cannot value wetlands in this way because it requires knowledge of the biophysical relationship between wetlands and the flood risks that are of tangible concern to the household.

Similarly, measures of "suitable habitat" do not, on their own, facilitate economic assessment. Qualitatively, households understand that "more habitat means more abundance." Quantitatively, however, they can only place a value on what they directly experience as relevant to the welfare: abundance.

As a final example, consider almost any biophysical condition that is defined in technical or scientific terms. It is common in ecology to measure things like dissolved oxygen, turbidity, benthic disturbance, trophic change, etc. Technical outcome measures like these almost always signify the need to subsequently translate the measure into outcomes that are more meaningful to non-technical audiences (i.e., firms and households) in order to convey their economic importance. Is less benthic disturbance valuable? Yes, but because it is an indicator of the health of fish and amphibian species in the river. A benthic disturbance measure, by itself, is almost meaningless to firms and households. It is thus not an outcome measure amenable to economic interpretation.

Summary: Many of the most common mitigation outcome and assessment measures in current regulatory use do not directly facilitate or allow for economic evaluation.

8.2 Data and Methods Needed to Relate Mitigation Interventions to Ecosystem Service Measures

Data and Assessment Needs 1: Economic assessment of ecosystem service priorities and delivery requires development and collection of biophysical measures that are interpretable by social science evaluations.

Many common ecological outcome measures do not satisfy the characteristics of ecological endpoints, meaning their relationship to economic welfare is unclear, ambiguous, or qualitative, rather than quantitative in nature.

If we are to assess mitigation's ability to produce (and maximize) ecosystem service benefits, it will be necessary to (1) monitor ecological endpoints, and (2) relate them to existing ecological measures that are already routinely collected. Methodologically, this will require analysis that "translates" known outcomes (e.g., hydrogeomorphic classifications, biotic integrity and habitat equivalency scores) into their subsequent implications for endpoint changes. Consider a known relationship between land cover and a chemical water quality measure such as nitrogen concentration. Nitrogen delivery is relatively well studied. The question is: how does surface water nitrogen translate into ecological endpoints relevant to social evaluation such as species abundance, risk of water-borne disease, or aesthetically desirable water conditions?

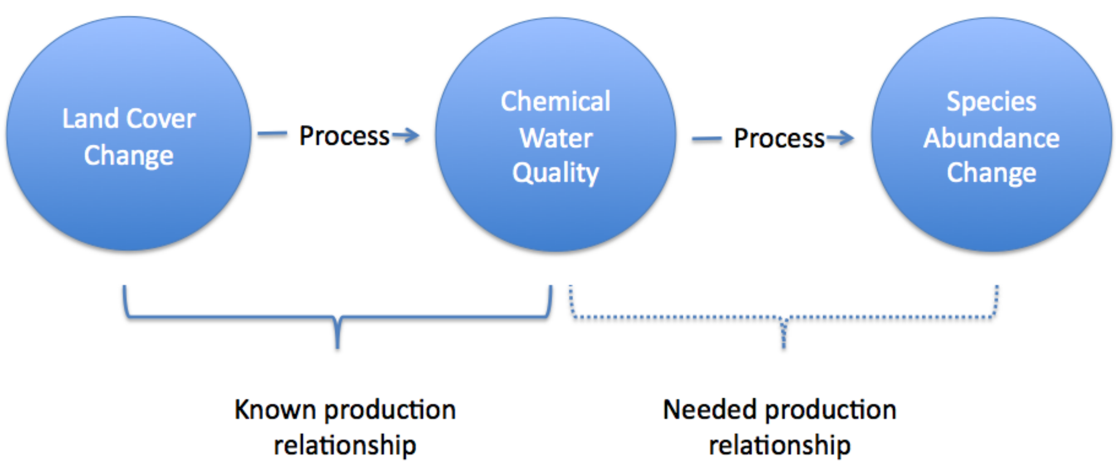

Figure 3: Translation of existing production function to endpoint change.

Figure 3 depicts this kind of empirical strategy, which builds on known relationships between mitigation actions and non-endpoint outcomes. Often, existing models and monitoring can tell us about the relationship between interventions and proxies for, or precursors to, endpoint changes. The challenge, in this case, is to empirically relate the proxy or precursor to endpoints of interest to social evaluation. This can be done with a combination of new monitoring and modeled relationships.

> **Data and Assessment Needs 2: Economic assessment of ecosystem service priorities and delivery will require new data and modeled relationships that translate existing outcome measures into ecological endpoints suitable for economic and social evaluation.**

To provide concrete examples of the modeled relationships that are necessary for progressive evaluation, consider Table 4 below. The table provides simplified, but concrete, examples of biophysical production relationships that link mitigation actions to socially meaningful ecological outcomes, i.e., ecological endpoints.

Table 4: Relationships linking mitigation to ecological outcomes.

Mitigation Action	Biophysical Production Functions	Ecological Endpoint
Pollutant reduction	Toxicity and habitat	Fish, bird abundance
Habitat protection	Forage, reproduction, migration	Species abundance
Wetland restoration	Hydrologic	Expected reduction in flood probability, severity
Reforestation	Sequestration and shading	Air quality and temperature
Riparian vegetation protection or restoration	Erosion	Reduced reservoir sediment loadings

This is an illustrative, not a complete, list of the relationships to be evaluated. Note again that some outcomes may be delivered locally, for example, the effect of forest cover on temperature. But in many, if not most cases, mitigation's value is delivered off-site, as in the case of migratory fish and bird abundance, flood risk reductions, and downstream sediment loadings.

The analytical architecture for progressive mitigation planning thus involves several elements.

- Biophysical production functions that relate mitigation actions to both local and off-site biophysical outcomes.
- A systems-based depiction of interactions between these production functions across the relevant region (watershed, habitat and migratory area, etc.).
- New monitoring and modeling efforts to relate existing, conventional biophysical outcome measures to ecological endpoints that facilitate social, economic, and policy interpretation.

While some of these elements will already be in place, depending on a state or program's existing investments in such analysis, in many situations it will require new investments and efforts. It is therefore useful to remind us of why these investments are likely to be worth their cost.

With these analytical elements in place, mitigation planning can target mitigation interventions and locations that yield the greatest ecosystem service benefits (for a given cost). Failure to use such analysis means that ecosystem services outcomes will be haphazard, random, and unlikely to be the most socially beneficial.

8.3 Economic data and tools to evaluate the benefits that arise from Improvements in Ecological Endpoints (Ecosystem Service Outcome Measures)

Economic and social evaluation is built around analysis of biophysical production, more specifically *changes in* biophysical production. If ecological evaluation can describe the relationship between mitigation interventions and the suite of subsequent changes, the economic benefits (or costs) of those endpoints changes can be evaluated. Recall that, by design, endpoints are meaningful to decision-makers and society generally. This means that changes in those endpoints can more easily lead to economic evaluation. There are several ways to approach economic analysis of endpoint changes.

Economic studies derive monetary benefit estimates using hedonic, travel cost, contingent valuation, and other econometrically sophisticated methods. Non-market valuation techniques fall into two general categories: revealed and stated preference methods (Freeman 1993).

Revealed preference studies look at the price people are willing to pay for marketed goods that have an environmental component. From those prices, inferences about the environmental benefits associated with the good can be made. For example, when people purchase a home near wetlands or other aesthetically pleasing natural resources home prices reflect that environmental amenity (Mahan et al. 2000). Alternatively, when people spend time and money traveling to recreational locations they reveal a willingness to pay the time and travel costs to access the recreational services. "Travel cost" studies, often using hedonic analysis are used to make a benefit estimate based on those expenditures (McConnell 1992). The travel cost method requires data and analysis linking the number of trips to a site with the quality, size, or location of a site. Changes in these attributes can be valued if there is a perceptible change in the number, length, or cost of trips taken to the site.

Of course, not all environmental benefits are captured in market prices or in observable individual choices. One way around this problem is to move away from reliance on preferences revealed in markets. Stated preference studies are one such alternative. Stated preference studies ask people, in a highly structured way, what they would be willing to pay for a set of environmental improvements. Contingent valuation studies are an example (Kopp et al. 1997). Stated preference methods can be controversial, but they are a distinct improvement relative to evaluation techniques that ignore social preferences (Carson et al. 2001).

It deserves emphasis that our ability to conduct such analyses is dependent on an ability to relate mitigation actions to economically-relevant biophysical changes, hence the need for biophysical evaluation of endpoint changes.

8.4 Do Monetary Wetland and other Mitigation Estimates Reflect the Full Value of Mitigation-Related Ecosystem Services?

There is a fairly large set of economic valuation studies that place dollar values on wetlands, open space, and other types of land use affected by mitigation. These studies use the aforementioned techniques, in some cases looking at property values in proximity to wetlands or open space, or evaluating travel and expenditure behavior to recreate in a particular type of resource area. These types of valuation studies are an important piece of the evaluation puzzle, because they (1) reveal that wetlands and other mitigation resources are economically valuable, and (2) can help identify areas where they are *most* valuable.

Unfortunately, the amenity value of open space to recreators who travel to visit it or commuters who enjoy the view on the way to work will not be capitalized into housing values. Nor will the value of the open space as an input to production of services (species, water quality) that are enjoyed further afield. It is therefore important to understand that “wetland valuation studies” capture only a fraction of these resources’ total value. They only capture the benefits to particular user groups (neighboring households, hunters and birders) and only capture the direct, on-site benefits of the wetland.

> **Summary: Traditional mitigation valuation estimates only capture direct, on-site benefits. They do not measure benefits that arise from mitigation’s contributions to off-site ecosystem services delivery.**

Consider again the following simplified depiction of ecosystem service production. Traditional valuation studies will detect the value of the mitigation site itself to neighboring households or businesses (in the case of hedonic analysis) or recreators who travel to the site (in the case of travel cost methods). In other words, they capture a part of the on-site benefits generated by mitigation. They do not, and cannot, measure the ecosystem service benefits associated with the mitigation’s role in spatial biophysical production.

Consider a hedonic analysis that finds a price premium for houses in proximity to a wetland. Are all of the wetlands benefits (those associated with open space, water quality improvements, and crab abundance) reflected in the hedonic premium? In the case of housing, the example system would identify the wetland’s open space endpoint as being likely to matter to the utility of nearby homeowners. In effect, there is a clear linkage between the market commodity (housing) and related consumption of open space. In contrast, the other two wetland endpoints are less likely to appear in the value of the market good. This is true for several reasons. First, wetlands’ role in the production of less flashy hydrographs and crabs may not be known to homebuyers. Second, even if they are known, the benefits they produce may not be enjoyed by local households. Improved flood risk profiles, or water quality, or crab abundance may occur far from the households in question (e.g., far downstream) in which case the value will not appear in home values and thus not be detected as benefits.

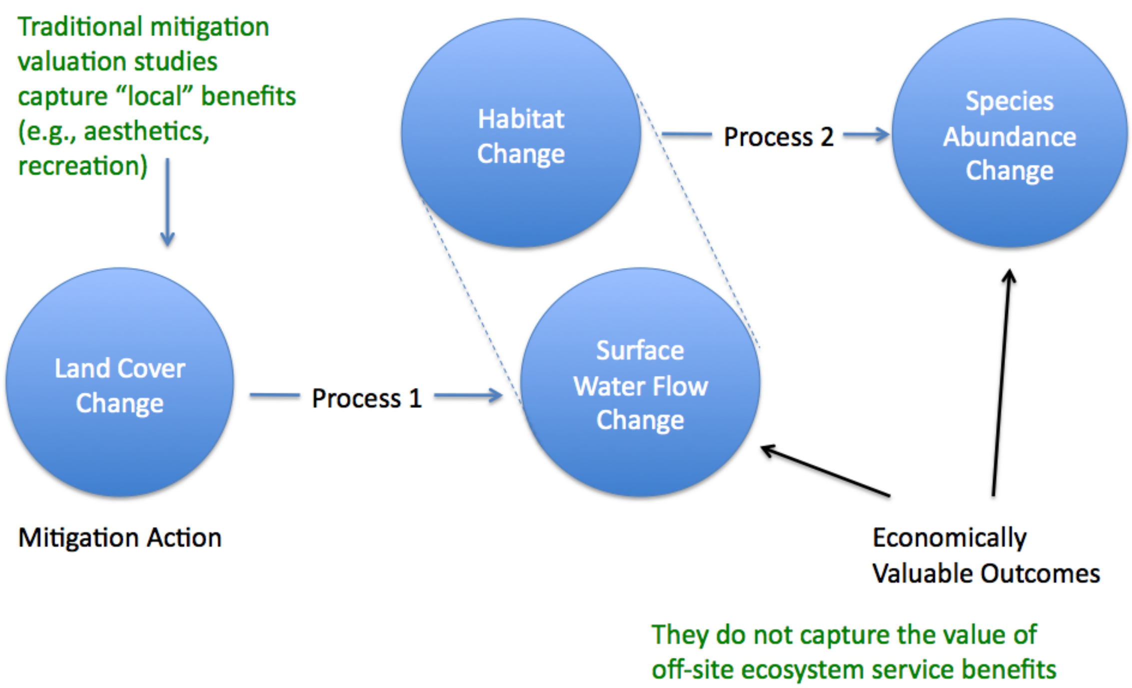

Figure 4: Mitigation evaluation measures linking to economic outcomes.

To be clear, the value of off-site ecosystem endpoint improvements can be valued economically. But they must be evaluated via a progressive approach to ecosystem service analysis: where spatial biophysical production is taken into account. Economic valuations that capture only on-site benefits are akin to "traditional" mitigation assessment. They capture only a part of what is beneficial about mitigation.

8.5 Endpoints and Benefit Transfer Methods

Original monetary benefit studies may not always be practical because they are expensive, time-consuming, and require special econometric skills. Broadly, there are two alternatives to original econometric studies of revealed or stated preference. The first are so-called benefit transfer studies. The second are quantitative, but non-monetary, benefit evaluations.

"Benefit transfer" studies are one way to harness the benefits of econometric estimation while minimizing the need for costly new analyses (Water Resources Research 1992; Kirchoff et al. 1997; Kopp and Smith, 1993). The benefit transfer method takes the result of a pre-existing monetary study and translates it into a new environmental context. For example, if a study of trout fishing in Colorado yields a per-person benefit of $100 a day, this result can be transferred, with some adjustments, to say something about the value of a fishing day in California.

The challenge for benefit transfer methods is that the value of environmental goods and services is highly dependent upon the physical and social context in which they arise (and a core aspect of the progressive mitigation concept). It requires methodological and conceptual sophistication to credibly transfer values across the landscape. Chapman and Hanemann (2001) found:

> It is sometimes claimed that the benefit transfer approach provides a convenient solution when the requisite data are lacking. But in this case there was considerable disagreement over basic issues, such as whether or not beaches in Florida are 'substantially dissimilar' from beaches in Southern California. If this benefits transfer is problematical, how much more so others! It is striking that, although both parties initially decided to use benefits transfer, as the trial approached they each felt compelled to undertake original research to re-analyze the data and re-estimate the models used in the benefits transfer studies.

In order to judge the relevance of a particular study to a particular new site, it is necessary to know how comparable those sites are (Rosenberger and Loomis 2000; Loomis and Rosenberger 2006).

Like any benefits, ecosystem service benefits are a function of scarcity, substitutes, and complements. Environmental benefits are often not fungible precisely because substitutes and complements in the economic production function are themselves not fungible. This is a common complication in benefit transfer studies (Ecological Economics, Special Issue 2006). If a beautiful vista is to yield social value people must have access to it. In other words, the vista must be spatially bundled with infrastructure (roads, trails, parks) that are themselves not transportable. Recreational fishing and kayaking require docks or other forms of access. Substitutes for a given recreational experience depend on a recreator's ability to reach them in a similar amount of time. Thus, the location of non-fungible substitutes is important. An important issue in travel cost studies, for example, is the definition of relevant substitutes for the sites in question. Arrow et al. (1993) note that "omitting the prices and qualities of relevant substitutes will bias the resource valuations." The value of surface water irrigation is a function of the location and timing of alternative, subsurface water sources. If wetlands are plentiful in an area, then a given wetland may be less valuable as a source of flood pulse attenuation than it might be in a region in which it is the only such resource.

> **Data and Assessment Needs 3: Social evaluation of ecosystem services delivered across the landscape requires spatial data on beneficiary populations, the presence of protected or enhanced property values, and complements to and substitutes for the ecosystem services.**

Accordingly, social evaluation and economic valuation of mitigation options requires exploration of these spatial factors. Wetlands, for example, have been found to increase the value of homes in urban areas (Mahan et al. 2000), but lower them in rural areas (Bin and Polasky 2005). We call these factors "benefit indicators," metrics that depict the scarcity of, substitutes for, and complements to the biophysical endpoints being evaluated. These benefit control variables are described in more detail below.

8.6 Non-Monetary Approaches to Benefit Assessment

Monetary valuation requires the use of data and methods that substantially add to the assessment burden. Typically, each benefit or cost stream arising from the natural landscape must be analyzed with different data and econometric methods. It is common in studies to see only a single environmental benefit monetized, due to the costs of such studies.

Also, econometric tools are opaque to most decision-makers. And some audiences reflexively reject the monetization of benefits related to nature. These issues can undermine trust in economic assessment and limit the application of economic arguments in certain decision contexts.

It is thus useful to ask: is it absolutely necessary to conduct econometrically sophisticated studies to estimate the value and importance of ecosystem goods and services? An alternative (or complement) to econometric analysis is the use of quantitative ecosystem benefit indicators (EBIs).

> **Definition: Ecosystem benefit indicators (EBIs) are countable features of the physical and social landscape that relate to and describe the value of endpoint changes. They can usually be derived easily from existing geospatial datasets.**

Benefit indicators are quantitative, countable features of the physical and social landscape. They are environmental and social features that influence, positively or negatively, ecosystem services' contributions to human wellbeing. EBIs convey information about the production of benefits involving ecological inputs.

EBIs relate to the ways in which ecological endpoint changes produce changes in human welfare. Like analysis of *biophysical production*, analysis of *economic production* describes how inputs combine to produce an output, in this case human welfare.

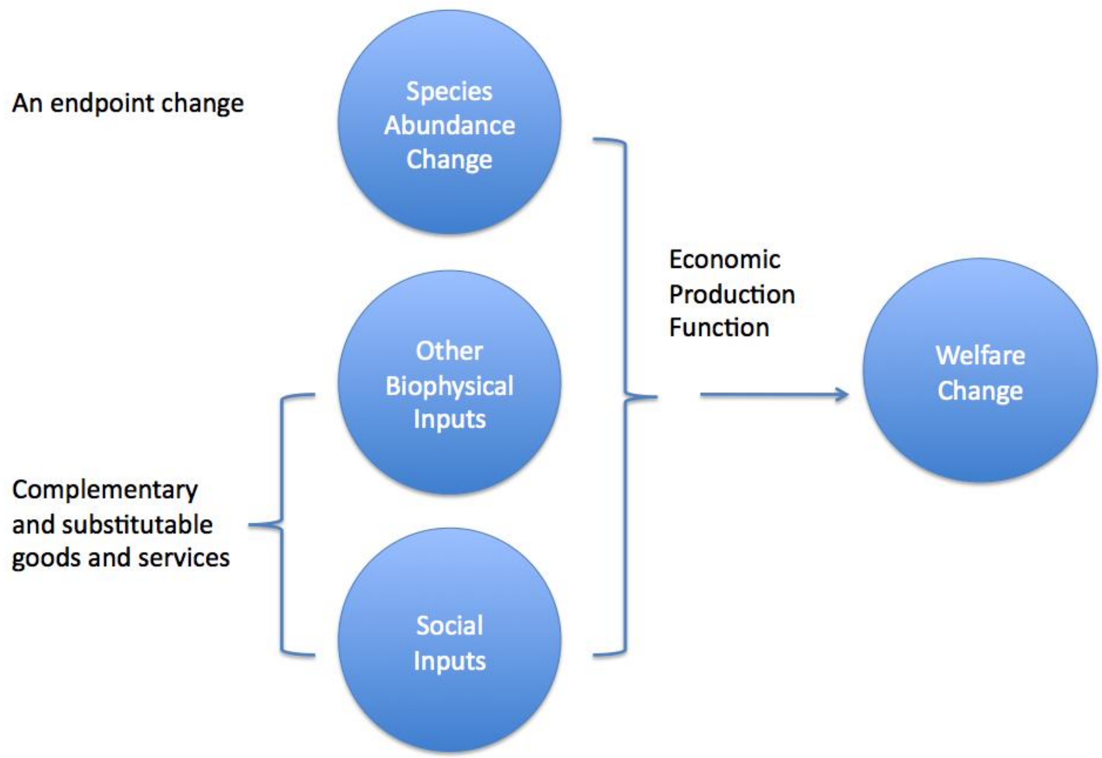

Figure 5: A simplified economic production system.

In some cases, we can draw economically significant conclusions even without knowledge of underlying preferences for ecosystem goods and services. This is true because economic production obeys certain fundamental properties, or principles. For example, all else equal, we can always say the following:

- The scarcer an ecological feature, the greater its value.
- The scarcer are substitutes for an ecological feature, the greater its value.
- The more abundant are complements to an ecological feature, the greater its value.

The scarcity of, substitutes for, and complements to many ecosystem goods and services are relatively easy to assess. In many cases, metrics can be derived from social and biophysical GIS data (Boyd and Wainger 2003).

Depending on the ecological feature we can often go further than this. For example, the social value of some environmental features is often a direct and increasing function of the number of people with access to them. Similarly, the social value of some environmental features is often a direct and increasing function of the economic value they protect or enhance. Accordingly, we can often, but not always, say the following:

- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic value protected or enhanced by the feature, the greater its value.

Relative to econometric benefit estimation, EBIs are relatively simple measures to develop. They provide useful economic information in a cost-effective way. Linked to specific ecological endpoints, they can quickly inform decision-makers and allow for more comprehensive evaluation of multiple goods and services given limited budgets for analysis.

Summary: EBIs are also useful control variables for – and thus an important complement to – stated and revealed preference studies.

Recall that benefit transfer studies are a way to harness the benefits of econometric estimation while minimizing the need for costly new site-specific analyses. In essence, the benefit transfer method takes the result of a pre-existing monetary study and translates it into a new environmental context. To do so credibly, however, requires the calibration of a benefit transfer function. This is because the value of environmental goods and services is highly dependent upon the physical and social context in which they arise. Calibration controls for variation in ecological and social features across study sites. EBIs can be thought of as the location-specific independent variables necessary to transfer dollar-based valuations. Accordingly, EBIs should not just be thought of as a standalone approach to evaluation, but also as an important complement to conventional monetary benefit estimation.

8.7 Illustrative Benefit Data and Evaluation

To illustrate the types of benefit data available to planners, and relate them to ecosystem service evaluation we present here several examples of data that is broadly available to planners and the relationship of that data to benefit evaluation. This is not a complete list of possible data and analyses.

Water quality threats addressed: Identifying mitigation projects likely to address significant water quality threats. As noted earlier, for mitigation to generate water quality benefits, there must be a water quality problem in need of improvement. Locational indicators should reflect the quality of waters received by the wetland. The more impaired the received runoff, the greater the mitigation project's benefits. Measurable indicators that speak to the likelihood of such problems include:

- Percent of crop or pasture land in vicinity of mitigation project;
- Percent of source watershed in crop or pasture land;
- Percent of impervious land cover in vicinity;
- Percent of source watershed in imperious land cover; and
- Existence of specific water quality threats in vicinity or watershed, including, combined animal feeding operations, landfills.

It is also important to explore the degree to which wetland functions are scarce in the site's vicinity. If there is a great abundance of nearby wetlands the loss of one area may not lead to a significant loss of water quality benefits. If wetlands are scarce, the benefits lost will tend to be more significant. Measures that speak to this include:

- The percentage of land cover in wetland, locally and across the watershed; and
- The percentage of non-agricultural natural land cover across the watershed.

Drinking water quality services delivered: mitigation projects likely to yield the greatest social benefits associated with improved groundwater quality used for drinking. Potential sources of water contamination are a necessary, but not sufficient condition for there to be drinking water quality benefits. The water must also be used for drinking, or commercial or agricultural use. The following kinds of data can be used to identify areas where groundwater quality improvements are likely to be most beneficial:

- Population density associated with aquifer hydrologically connected to mitigation project; and
- Permitted, public supply, and private residential wells drawing from the aquifer.

Note that similar types of data can be collected for surface water quality impacts. Mitigation projects likely to deliver the most valuable water quality services will be those where surface water impacts affect the larger number of beneficiaries.

Again, the purpose of these indicators is to reveal characteristics of the sites' landscape that are likely to affect both the production and delivery of ecosystem service benefits. For drinking water quality improvements, the importance of landscape is clear, both because landscape relates to water quality threats that mitigation projects can address, and landscape relates to the presence of beneficiaries of that water quality.

Flood threats addressed: mitigation projects that provide desirable flood-related hydrological functions will be most valuable when situated in areas where flooding is a threat. Various types of data can be used to assess flood risks in a given watershed, including:

- Floodplain assessments, maps, and historical gage data;

- Percentages of watershed that are in developed land use or in impervious landcover;
- Quality and extent of built flood control infrastructure (e.g., dams, levees, coastal barriers); and
- The scarcity of wetlands providing similar function.

Flood protection benefits delivered: wetland mitigation projects can decrease the likelihood and severity of flood-related damages. The following data relate to property characteristics in floodplains where a given mitigation project is presumed to have an effect on flood pulses:

- Number of housing and commercial units;
- Value of those housing and commercial units;
- Presence and value of other infrastructure subject to flood damage (e.g., roads, bridges);
- Presence and value of crops vulnerable to flooding; and
- All else equal, the greater the number and value of properties protected, the greater the value of the service delivered.

Wetlands or other mitigation projects that are hydrologically relevant to a larger watershed system prone to flooding will clearly be more valuable in terms of flood avoidance benefits than hydrologically isolated wetlands. The social value of flood reduction services is also clearly related to the value of property protected. Spatial data is available to evaluate these conditions.

Species abundance threats addressed: mitigation projects that complement regional land and water resources necessary to predation, forage, reproduction, and migration processes will yield more ecologically beneficial outcomes by promoting particularly productive species-support functions. In general, the goal is a pattern of mitigation that corresponds to conservation planning designed to maximize the avoidance of threats to key habitat features and that promote connectivity and contiguity of habitat areas. Habitat mosaics capable of producing particularly diverse and sensitive biological communities are of particular interest. The relationship of a given mitigation project to a larger pattern of natural land uses will determine its habitat-related benefits. The following types of data relate to these patterns.

- Proximity to, and contiguity with, existing preserves and high-priority conservation areas;
- Proximity to globally rare, or more locally rare, species occurrences and high-value habitat types (seagrass beds, prairie, woody riparian zones); and
- Land cover patterns where mitigation would address a particular migratory or forage need (corridors, minimum habitat size).

Species abundance benefits delivered: while the objective of species support may be purely regulatory in nature (attainment of critical habitat goals for threatened and endangered species) social benefits from greater abundance take additional forms, relating to recreation, in particular.

The location of abundance relative to recreational and aesthetic opportunities can have a significant effect on social benefits. The relationship between improvements in abundance or biodiversity and proximity to recreators can be assessed using the following types of data:

- Location of public lands, including parks, beaches, forest, and navigable waters;

- Proximity to forms of access, including trails, roads, boat ramps;
- Usage rates and populations within walkable, drivable distances of the resource; and
- Proximity to residential areas and population density with visual or recreational access to the species.

These kinds of landscape indicators provide a more complete understanding of the portfolio of changes associated with mitigation. Viewed in isolation, a given indicator is useful information that can almost always inform decisions. Certainly, landscape analysis yields a richer description of the site's impact on social benefits than functional assessments limited to on-site features and functions. First, the analysis fosters an appreciation of the way in which on-site functions are related to the biophysical characteristics of the larger landscape, such as watershed hydrology, floodplain characteristics, and species communities. Second, landscape analysis highlights the human dimension of the surrounding environment. Ecosystem services can be described only if we have data on both the physical and social environments. Third, these kinds of landscape factors can help reveal both extremely good and extremely poor landscape scenarios. From a landscape perspective, certain potential mitigation locations will, for example, be in a poor position to provide flood protection and drinking water benefits – a result that would not necessarily be clear from an examination of purely on-site functions and features. Other mitigation locations, largely by virtue of the location relative to other biophysical and social features, will be identifiable as both contributing to (1) the avoidance of clear water quality, flood, or species threats, and (2) the provision of ecological outcomes that are particular valuable to human populations.

The ability to distinguish mitigation sites in this should matter to regulators and land use planners. If the social value of ecosystems, not just acreage or on-site function, is to be preserved, then sites' relative ability to generate benefits must be explored. Data and methods already exist to foster appreciation of landscape characteristics. If applied, these data and methods will yield greater ecological and social welfare. The additional ecological and economic benefits that can be achieved is a core motivation for progressive planning.

9. Costs and Potential Savings of Progressive Planning

The relative costs of traditional versus progressive planning can be evaluated across several categories of costs. Progressive planning will by definition increase the up-front costs of planning and evaluation. However, it may also lead to cost savings in the long run.

9.1 Land Acquisition

As noted earlier, traditional and progressive approaches, by steering mitigation toward different sites will lead to different land acquisition costs. When site-specific contributions to ecosystem services benefits are not taken into account (or taken into account in a more rudimentary way) mitigation siting tends to be predominately driven by land acquisition costs (Ben Dor et al. 2006). In contrast, progressive planning steers mitigation toward sites that yield the highest net benefit, taking into consideration the provision of ecosystem service benefits. An illustrative application of this kind of analysis is Weber and Allen (2010), though one applied to conservation planning rather than mitigation planning.

Will land acquisition costs be higher under a progressive approach? Perhaps, since progressive approaches will are more selective in their identification of eligible mitigation locations. Progressive approaches, in effect, narrow the set of acceptable sites and thus may lead to higher land acquisition costs. However, within a progressive planning exercise site costs can obviously still be taken into account, with preference given to those that yield that greatest net benefit (the difference between ecosystem service benefits and land costs). Since progressive planning is expected to yield greater social benefits, the net value of mitigation can and should be greater than the net value of traditional mitigation, even though progressive planning *may* site mitigation on lands that are more expensive.

We emphasize that it is by no means a foregone conclusion that land costs will necessarily be higher under progressive planning. In fact, they could be lower if ecologically productive sites correspond with lower cost tracts. To the extent progressive planning allows for greater spatial flexibility in the siting of mitigation projects, all else equal, this will lead to lower acquisition costs (simply because the set of eligible properties will be larger and thus likely to include a larger number of lower cost sites. This is related to the concept of abatement cost heterogeneity, with more heterogeneity implying greater cost savings (Newell and Stavins 2000).

Summary: Progressive planning may lead to higher or lower land acquisition costs.

9.2 Mitigation Construction and Long-Term Management

Progressive planning will not necessarily alter mitigation project construction and long-run management costs. The goal of progressive planning is not to change mitigation technologies or practices associated with particular sites. Rather, it is to change the location and spatial configuration of those sites.

It is possible, though, that progressive planning may could lead to lower construction and management costs (Templeton et al. 2008). Our hypothesis is that progressive planning may lead to larger areas of "connected" mitigation activity, where a larger number of mitigation credits is associated with, and directed toward, a particular location on the landscape. It is possible that this could lead to "economies of scale" in mitigation construction and management, relative to more isolated, traditional mitigation projects. A pertinent study of wetland mitigation in Michigan found that the state was able to achieve economies of scale via a consolidated mitigation plan, reducing costs from $75,000-100,000 per acre to $25,000-30,000 per acre (Venner 2010a).

In other words, it is possible that the co-location of mitigation activities will lead to cost savings. (For the same reason that larger banks may on a per-credit basis, yield mitigation at lower cost than a collection of smaller banks.)

Key Assumption: Progressive planning may lead to lower construction and long-run management costs.

9.3 Planning and Permitting Process Costs

Progressive planning, by definition, involves greater investment in up-front analysis of mitigation siting. The costs of progressive planning are associated with the need to conduct the kinds of spatial analysis described in our report. Against, these up-front costs should be weighed a cost-savings that can arise from having a pre-approved watershed or regional mitigation plan in place (Venner 2010a).

With a pre-approved mitigation plan in place, the analytical and process burden on subsequent individual permit requests is reduced. The comparison is between a coordinated pre-approved mitigation plan and uncoordinated, project-by-project site approvals. The traditional approach to permitting places permittees in a more uncertain regulatory environment and one in which permit-specific delays can slow approvals. As an example, a motivation for North Carolina's Ecosystem Enhancement Program (EEP) was reduction in such delays and EEP has already demonstrated its ability to reduce them (Anderson, 2005).

Uncertainty and delay are costly to permittees. In other regulatory contexts where permit and planning reforms have been instituted, reductions in uncertainty and permit delays have been a significant motivation. As an example, consider EPA's Project XL, which established pre-approved permits for industrial facilities subject to Clean Air Act regulations (Ginsburg and Cummis 1996). In exchange for a tighter overall cap on air emissions, firms were granted pre-approved permits that allowed for facility and process changes that otherwise would have required regulatory review and a continuous process of re-permitting. Firms found it in their interest to accept the tighter overall emission cap because the regulatory process cost savings were so significant (Boyd et al. 1998; NAPA 1997). Project XL did not involve mitigation regulations, but does provide an example of how permit reforms, based on ex ante negotiation and approval, can lead to both environmental benefits and lower costs for the business sector.

A final example is the Oregon Bridge Project, in which the Oregon Department of Transportation developed programmatic wetland and endangered species mitigation agreement with wetland and endangered species regulators to assist in the implementation of an over 1.3 billion dollar program to repair or replace over 300 bridges in Oregon. The initial planning included the development of a mitigation strategy that addressed the entire mitigation needs for all the bridge projects, along with the environmental assessments (Oregon Department of Transportation 2011).

ODOT completed a cost benefit analysis (ODOT 2008) which indicated an almost 20 percent savings in project implementation cost, a very substantial savings given the billion dollar investment. And for this project, the programmatic agreements were specifically developed for the project, meaning that ODOT was not able to take advantage of the extensive conservation and mitigation planning work which has taken place via the state's Wildlife Conservation Strategy planning process, an Eco-Logical project, and wetland mitigation prioritizations developed through EPA's State Wetlands Development Grants program.

Summary: Progressive planning will require up-front investment in analysis and planning, but has been demonstrated to lead to long-run permit cost savings.

Currently, there are no progressive programs which have attempted to characterize or collate the actual costs of implementing the programs. Most have been developed either by agencies attempting to test new methods to improve environmental outcomes from mitigation, from research studies, or from projects with a broader restoration or conservation objectives, such as the Willamette Partnership.

10. Conclusions

The research team's goal was to find good examples of 'traditional', 'midway', and 'progressive' compensatory mitigation site selection methods from around the country that had been independently evaluated as to their effectiveness in achieving 'successful' compensatory mitigation. In some cases, these examples were regional efforts within a state (Minnesota, Oregon, Maryland), and in some cases they were state-wide efforts (Ohio and Florida). We did not comprehensively evaluate all regional and state-wide mitigation efforts in the five states selected for the evaluation.

The purpose of reviewing different programs and projects was not to rate the effectiveness of a state or a program's compensatory mitigation efforts. Rather, it was to identify practices and rate their relative success in improving the ecological, social and/or economic outputs of compensatory mitigation. Finding 'evidence' of success, in this case, supports our efforts to further explore similar methods in other parts of the country and help improve the compensatory mitigation outcomes nationally.

In Ohio and Florida there is useful academic and research literature that provides examples of data and analysis that could play a role demonstrating the effectiveness of progressive planning. In some cases, researchers have evaluated mitigation outcomes that could be used to generate economic benefit estimates. In other cases, more work needs to be done to "translate" measures such as biotic integrity scales into their social implications. In general, non-governmental evaluations emphasize and illustrate the ability to evaluate spatially-explicit outcomes, even if they fall short of the kinds of models and metrics needed to place dollar values on the ecosystem service benefits of alternative mitigation plans. We also identified some clear opportunities for regulatory planning to build upon existing conservation plans such as updating Florida's EDTM to reflect changes in the Florida Natural Areas Inventory.

Minnesota's protocol is noteworthy because of its evaluation of socially and economically relevant outcomes, including for example flood and storm water storage/attenuation capacity, downstream water quality protection, shoreline protection, delivery of aesthetic and cultural outcomes, and relationship to storm water treatment needs. Also, because of the way their state Wetlands Conservation Act regulations require mitigation sites to evaluate site suitability, landscape position, habitat requirements, hydrogeomorphology, and other values, the program strives towards the progressive methodologies. While Minnesota's program has not been funded to deploy progressive planning systematically, MnRAM's design has the potential to facilitate future progressive planning activities.

Oregon and Maryland have the most extensive progressive planning approaches in place. At this point, the registry in Maryland appears to have advantages over the approach taken in the Willamette Valley of Oregon in its focus on obtaining local inputs, and by the intimate involvement of two of the three key regulatory agencies in its development. The registry includes endangered and at-risk species information where relevant.. It may be that in Maryland, the limited number of federally listed species in their pilot watersheds makes initial involvement of U.S. Fish and Wildlife (USFWS) or NOAA Fisheries regulatory staff unnecessary, although the USFWS website shows 7 listed plants, a turtle, a mussel, two mammals, two fish species and two beetles listed as threatened or endangered in Maryland. Certainly, in California, Oregon, Arizona, Florida and a number of other states, Endangered Species Act mitigation issues appear to be just as complex as Clean Water Act mitigation issues, although the U.S. Fish and

Wildlife Service may have been adequately involved. So, it may be that to implement this methodology in western or southern states with larger numbers of listed species, more Endangered Species Act initial agency involvement may be required.

There is a need to conduct an evaluation of how well the various national conservation blueprint efforts could work as a methodology for prioritizing compensatory mitigation sites (Achterman et al. in Press). Methodologies for developing priority conservation areas vary widely, with some of the most widely used being:

1. A complex analysis of all species and habitats, such as developed in Australia for their national conservation law;
2. The use of MARXAN (Watts et al 2009) by The Nature Conservancy in their ecoregional conservation strategies;
3. The Conservation Fund's Green Infrastructure Network methodology;
4. The Trust for Public Lands' Greenprint methodology; and
5. Development of a Regional Ecosystem Framework using various datasets including species and habitats and other land use information in conjunction with a decision support software such as NatureServe's Vista or OSU's ENVISION (NatureServe 2011, Oregon State University 2011)

In particular, some standard protocols, or at least minimum standards may be exceptionally useful, especially in regard to how the projects address the regulated resources: water quality, wetlands and endangered species.

While working in the right place is clearly the most critical factor leading to ecological success and meaningful ecosystem services outputs, it is also essential that sufficient areas be identified so there are always locations in which to work. Bulluck noted in describing a recent mitigation catalog pilot, that the initial Virginia Mitigation Catalog had been so focused on identifying the areas that were most ecologically significant and vulnerable that there were often no potential locations for sites (Bulluck 2010). Even a network such as the one developed in the Willamette Valley with multiple, very large priority wetland mitigation areas identified may not provide sufficient opportunities given the need for bankers or agencies looking for a bank to find a willing seller. Also, as previously noted, with limited choices the cost of establishing banks in priority areas can be higher. As a result, the progressive models - such as Maryland's and Virginia's work - to evaluate all potential mitigation sites, and then rank them as to their suitability, based on anticipated environmental outputs. All that is needed is to assure that positive incentives are high enough to adequately value the added inputs.

Our review of state programs shows the broad range of planning practices: From those that do little or no evaluation of landscape-level ecosystem services assessment to those where landscape and social evaluation is a driving principle. The review also identified a wide range of approaches – data, models, outcome measures – that have been deployed by researchers outside the regulatory programs we reviewed. This literature provides a set of concrete examples for how progressive planning can be approached in practice and in many cases demonstrates the "proof of concept" for more effective compensatory mitigation outcomes.

To illustrate the 'value' of progressive planning, an investment in evaluating the outcomes of this type of planning effort is needed. Taken as a whole, the reviewed cases and literature suggest that such investment can build upon existing analytical approaches. We did not find any single state - or academic study, for that matter - where the full range of benefits and costs associated with alternative mitigation plans was conducted. We also found relatively little monetary evaluation of the benefits of ecosystem services delivered. However, our review did identify place-specific and service-specific examples of how such evaluation can be conducted. Going forward, the best – and most practical – examples can and should form the basis for mitigation planning that targets the most socially, ecologically and economically beneficial mitigation locations.

Transportation agencies have demonstrated that they can make significant improvements in the delivery of new projects when programmatic agreements such as the Oregon Bridge Program are developed. Significant improvements in transportation project implementation have also been shown using decision support programs built on programmatics such as Florida's ETDM. In this report, we attempted to demonstrate the significant increase in both economic, social, and ecological outputs that can be gained if mitigation can be focused in areas in which these benefits are most efficiently generated. It appears that there are fewer and fewer regulatory impediments to implementing progressive mitigation approaches. However, it is less clear that sufficient incentives exist for transportation agencies to support these progressive approaches. The lack of incentives coupled with the initial implementation costs, and the additional agency and public coordination that may be required in implementing an progressive approach to compensatory mitigation, both need to be addressed to support better social, economic and ecological outcomes nationally.

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