WETLAND MITIGATION BANKING:

ANALYSIS & COMPARISION OF

MARKET MECHANISMS

By

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Abstract

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Federal regulation currently requires that wetland fills be offset by providing compensatory mitigation under a Clean Water Act Section 404 permit. This policy, often described as “no net-loss,” has facilitated the emergence of wetland mitigation banking. Wetland mitigation banking, a market oriented mechanism, works by allowing landowners to generate credits through restoring, enhancing, creating and/or preserving wetlands and selling them to those impacting wetlands for a cash return. Over the last several years, wetland mitigation banking markets have materialized as the preferable compensatory method of providing no net-loss.

Timing issues due to the ecological, economic, and regulatory conditions surrounding the credit market have created situations of credit “misses” or lags between permittees and suppliers. These misses can be characterized as credit shortages or excess demand in the compensatory market. In cases of credit shortages, permittees may provide

mitigation themselves. However, permittee-responsible has associated opportunity costs since permit review times are longer compared to mitigation banking.

In North Carolina, excess demand and increased permit review times provoked the creation of the Ecosystem Enhancement Program, a partnership between North Carolina's Department of Transportation and North Carolina's Department of Environment and Natural Resources. Under this program, credits are generated in advance of wetland impacts thus eliminating excess demand. Acting as a wetland credit broker, the Ecosystem Enhancement Programs coordinates the North Carolina Department of Transportation with credit suppliers promoting excess supply of wetland credits by investing early in credit generation.

This paper offers analysis of costs surrounding two wetland banking market mechanisms, conventional wetland mitigation banking and the Ecosystem Enhancement Program. The analysis provides information regarding the economic conditions surrounding both mechanisms, cost tradeoffs, and which mechanism is less costly at providing wetlands protection to society. The costs of excess supply and excess demand are modeled for the two market mechanisms and compared. Comparative statics derived from first order conditions, help to understand the circumstances and factors influencing low market cost mitigation.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF ACRONYMS

CWA	Clean Water Act
EEP	Ecosystem Enhancement Program
EPA	Environmental Protection Agency
MBRT	Mitigation Banking Review Team
MOA	Memorandum of Agreement
NCDENR	North Carolina Department of Environment and Natural Resources
NCDOT	North Carolina Department of Transportation
RFP	Request for Proposal
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
WMB	Wetland Mitigation Banking

CHAPTER 1

INTRODUCTION

Issue and Objective

Wetlands are transitional types of ecosystems that occupy a spectrum between land and water (Lupi, Kaplowitz, Hoehn 2002). These unique ecosystems directly support and provide goods and services to animal communities and those in outlining geographic areas (Barbier, Acreman, Knowler 1997). These goods and services include water storage, maintenance of ground water flows, biochemical cycling, dissolved material retention, etc. The benefits created by wetlands are enjoyed by many, yet wetlands are often converted to other uses (Heimlich, Wiebe, Claassen, Gadsby, House 1998).

Society values the many ecological, biological, and hydrological benefits provided by wetlands; however private wetland owners, unable to profit from their ecological services, covert wetlands to more profitable uses (Heimlich, Wiebe, Claassen, Gadsby, House 1998). Often these wetlands are converted to agricultural, industrial, or residential purposes not realizing their benefits until after they are lost (Turner 1991; Barbier, Acremand, Knowler 1997). Society often bears the full-economic costs of these losses, not the landowner. That is, the opportunity that society loses from wetland conversion is greater than that of the landowner. Thus, the private wetland market provides little incentive for landowner to preserve wetland resources.

Recent federal policy has helped to reduce incentives for wetland conversion. Section 404 of the Clean Water Act of 1972 has provided a permit process provisioning "no net-loss" of wetlands by requiring compensatory mitigation, wetland losses must be offset by a wetland gain elsewhere. The no net-loss framework, regulated in part by the United States Army Corps of Engineers (USACE), has allowed landowners to create returns by generating credits, a measure of offset quantity, through restoration efforts. Landowners may then sell credits to parties looking to mitigate wetland impacts, creating revenues for the landowner who might otherwise covert. The process of restoring privately held wetlands for profit is known as wetland mitigation banking (WMB).

Conditions governing the WMB process in some cases have caused the creation of thin markets and a shortage of credit supply (Shabman, Scodari 2004). High opportunity cost stemming from an extensive certification process and the regulatory factors used to employ quality standards on credit supply are thought to be reasons of reduced investment in WMB (Shabman, Scodari 2004). This lack of adequate supply can create "misses" in the market in which the permittee demands wetland credits but none are available. In these cases, misses or excess demand can create project delays among permittees, and permittees may have to carry out the mitigation themselves. In North Carolina, frustration over project delays sparked the creation of an alternative mechanism of WMB known as the Ecosystem Enhancement Program (EEP), which generates credits prior to impacts occurring, providing a large surplus of credits. Thus, two market mechanisms of WMB may be implemented to create wetland credit supply, conventional WMB and EEP

The objective of this paper is to determine which mechanism of WMB provides wetland protection at a lower cost. Characterizing the cost excess demand as the expenditure incurred due to project delays and the cost of excess supply as the opportunity lost on funds invested early, two cost models are created demonstrating the total costs under each WMB mechanism. These models are then used to create a net cost function outlining which mechanism is less costly at providing wetlands protection. Using comparative statics, results are given showing how factors help decide which mechanism to implement.

The results show several things. First, increases in the cost of delay will make wetland protection occurring through conventional WMB more costly. This suggests implementing EEP to reduce costs. Second, if the cost of early investment increases conventional WMB becomes less costly. Third, credit production cost increases make conventional WMB more costly suggesting that EEP be implemented. Finally, given the variance of excess demand within a particular market, whether the cost of delay and cost of early investment are large or small in comparison with each other dictates which mechanism is less costly at providing wetland protection.

This thesis comprises three chapters. Chapter one offers an overview of wetland issues describing the market failure face by private wetland landowners and the regulatory response to wetland losses. Chapter two gives an economic analysis regarding market failure, conventional WMB, and EEP along with cost comparisons. Chapter three contains the formal description of the market cost incurred under both mechanisms and the results indicating which mechanism is better at providing low cost wetland protection given market characteristics.

Wetlands issues

Wetlands are lands where water saturation is the dominant factor influencing soil development, plant type, and animal communities within the soil and its surface (EPA 2009). Within any particular wetland, there is an interface of both terrestrial and aquatic ecosystems providing important functions and services not only to the creatures inhabiting their biome but to the people within their watershed. It is for this reason that wetlands are considered to be a valuable resource, providing important ecosystem services such as flood control, water purification, nutrient recycling, recreation, wildlife population support, and carbon sequestration (Barbier, Acreman, Knowler 1997). These physical systems within nature provide an intrinsic value to those consuming the direct and indirect services produced.

Though wetland resources provide benefits to many, wetlands are often converted for agricultural or development purposes (Turner 1991). Historically, wetland owners converted wetlands to promote their productive value (Heimlich, Wiebe, Claassen, Gadsby, House 1998). In the past, Federal Acts such as the Swamp Lands Act of 1850 encouraged the drainage of wetlands in order to increase agriculture production (Connolly, Williams, Johnson 2005). Similarly, programs administered by the U.S. Department of Agriculture (USDA) also encourage the drainage of wetlands. In 1955, 103 million acres were organized into drainage systems through USDA assistance resulting in $900 million being spent to promote wetland conversion (Connolly, Williams, Johnson 2005).

In 1972, the creation of the Clean Water Act (CWA) provided a federal response to the large number of wetland losses. The CWA established a program to regulate wetland conversion, most notable the discharge of dredge or fill material into wetlands. Section 404 of CWA states that those who intend to dredge or deposit fill into navigable waters must apply for a permit from USACE (EPA 2009). Although Section

404 does not prohibit the unauthorized drainage of wetlands, drained wetlands which are later filled will need a permit (Connolly, Williams, Johnson 2005).[1]

Beginning in 1988, George H.W. Bush announced a campaign in which he pledged that there would be "no net-loss" of wetlands. Although legislation was never passed requiring no net-loss, compensatory mitigation was integrated into the Section 404 permit process. In order to achieve no net-loss, specific permit conditions outlined by USACE must be satisfied. These conditions often include actions in order to offset wetland losses; whereby losses in one geographically defined area are balanced by a gain elsewhere. Conditions of no net-loss are carried out during the permitting process which is called the mitigation sequence.

Mitigation Sequence

In order for dredged or fill materials to be discharged into a wetland, a 404 permit must be obtained authorizing the action. In such cases, a mitigation sequence is established in which the permittee must first avoid impacts to wetland resources by finding a practicable alternative with less destructive implications (USACE 2008). If impacts cannot be avoided steps must be taken to minimize impacts. Impacts which remain after avoidance and minimization must offset through compensatory mitigation. EPA (2009) offers the following breakdown of this process:

- Step 1. Avoid - Adverse impacts to aquatic resources are to be avoided and no discharge shall be permitted if there is a practicable alternative with less adverse impacts.

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[1] Within the Memorandum from Lance Woods to All Division and All District Counsels (1990), if USACE has reason to believe that someone intends to use, or is using pumps to remove water from a wetland or is removing wetland vegetation, or both, for the purpose of eliminating Section 404 jurisdiction, "the under normal circumstances" concept preserves 404 jurisdiction over the area notwithstanding the drainage or vegetation removal. Consequently, even if the pumping or vegetation removal might conceivably be accomplished without any regulated Section 404 discharge, the area still cannot be filled or developed in any manner which does involve a section 404 discharge unless a section 404 permit is obtained.

- Step 2. Minimize - If impacts cannot be avoided appropriate and practicable steps to minimize adverse impacts must be taken.

- Step 3. Compensate - Appropriate and practicable compensatory mitigation is required for unavoidable adverse impacts which remain. The amount and quality of compensatory mitigation may not substitute for avoiding and minimizing impacts.

During mitigation sequence, the quantity of offset to be provided is determined. Generally, the quantity of offset is described in terms of credits or acreage in some cases. Credits are a unit of mitigation measure which takes into account acreage and wetland function. Under the conditions of the permit, the permittee will be required to offset impacts by generating credits.

A permittee may generate credits through several forms. Considerations of practical/appropriate forms and of mitigation are generally determined during this process under conditions of a Section 404 permit. For example, if off-site mitigation is ecologically preferable, it must be determined whether the proposed site and form provides similar wetland function to those affected by the project (WADOE 2001). These forms include restoration, establishment, enhancement and preservation of wetland resources. EPA (2004) describes each form below:

- Restoration- Re-establishing or rehabilitating of a wetland or other aquatic resource with the goal of returning natural or historic functions and characteristics to a former or degraded wetland. Restoration may result in a gain in wetland function or wetland acres or both.

- Creation-The development of a wetland or other aquatic resource where a wetland did not previously exist, through manipulation of the physical, chemical and/or biological characteristics of the site. Successful establishment results in a net gain in wetland acres and function.

- Enhancement-Activities conducted within existing wetlands that heighten intensify or improve on one or more wetland functions. Enhancement is often undertaken for specific purpose such as water quality improvement, flood water retention or wildlife habitat. Enhancement results in a gain in wetland function, but does not result in a net gain in wetland acres.

- Preservation-The permanent protection of ecologically important wetlands or other aquatic resources through the implementation of appropriate legal and physical mechanisms. Preservation may include protection of upland areas adjacent to wetland as necessary to ensure protection or enhancement to the aquatic ecosystem. Preservation does not result in a net gain of wetland acres and may only be used in certain circumstances. For instance, when the resources to be preserved contribute significantly to the ecological sustainability of the watershed.

Figure 1.1 illustrates the proportion of forms used by permittees for compensatory mitigation. As indicated from the figure, restoration and enhancement are the most commonly used forms.

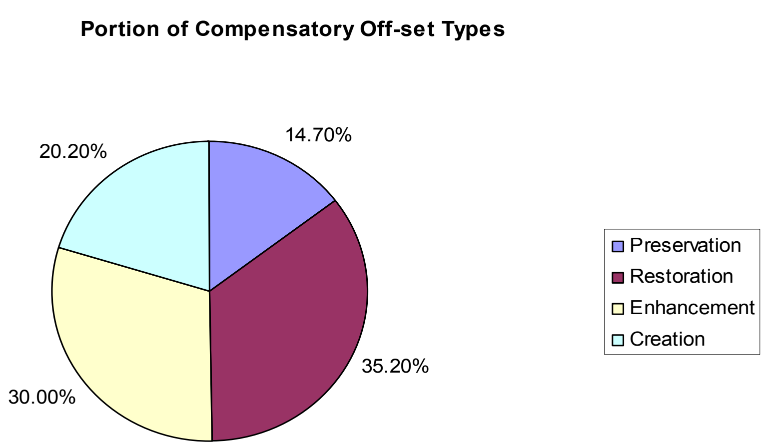

Figure 1.1 Compensatory off-set types (ELI 2005) [2]

<u>Methods for Compensatory Mitigation</u>

Along with the form of compensatory mitigation, there are several methods in which necessary wetland impacts may be offset. USACE and involved state regulatory

[2] Addition of percentages in Figure may not add to 100 due to rounding on the account of ELI.

agencies will determine the appropriate method during the mitigation sequence. Each method represents wetland mitigation liability that is either retained by the permittee or transferred to another party.[3] These methods include permittee-responsible mitigation, in-lieu fee (ILF) mitigation, and WMB.

Permittee-responsible mitigation entails offsetting impacts from a specific project either on-site or off-site. Under this method of compensatory mitigation, the permittee is responsible for the implementation and success of the mitigation including the design, construction, monitoring, and long-term protection of the site (EPA 2009). Permittees provide a mitigation plan outlining the actions and performance necessary to ensure mitigation success including the scale and scope of impacts and form of compensation to be carried out.

Mitigation may also occur under ILF mitigation, where the permittee transfers liability by providing funds to an ILF sponsor. ILF sponsors generally include a governmental or non-profit resource management entity which provides mitigation off-site and is responsible for the success of the mitigation project (EPA 2008). The sponsor may collect funds from multiple permits to pool financial resources and may execute mitigation after permitted impacts have occurred (EPA 2008). Usually credits needed to satisfy compensatory mitigation are advanced. That is, credits are available for sale prior to being fulfilled in accordance with a mitigation project. Sales are then pooled in order to complete mitigation projects on a larger scale.

Third party compensatory mitigation establishes an attractive feature to permittees who would otherwise be responsible for the site. The transfer of legal and

[3] This transfer occurs through the establishment of a mitigation instrument, a formal agreement between a mitigation sponsor and regulators. A wetland sponsor is defined as any public or private entity responsible for establishing, and in most circumstances, maintaining a mitigation site (USACE 2008).

financial responsibility of providing mitigation established mitigating for a cash return (Scodari, Shabman 2004). Permittees may pay a third-party to provide mitigation for offsetting impacts and thus transfer liability of mitigation success. This led to the development of the market oriented compensatory method known as WMB.

Over time two mechanisms for providing WMB have emerged. The first is conventional WMB, the second is EEP. Both are innovative approaches to wetland protection. Each mechanism offers unique characteristics in which a cash return may be earned by providing compensatory mitigation for those in need. The next two sections provide details regarding the operation of these two mechanisms.

Wetland Mitigation Banking

Wetland banks are sites, or a suite of sites, where wetland resources are restored, created, enhanced, and/or preserved for the purpose of providing compensatory mitigation for impacts authorized by a permit (USACE 2009). Banks have two components. The first is a physical place where wetland credits are generated by restoring, creating, enhancing and/or preserving wetlands. The second is an entity which creates a bank instrument and provides management for a wetland location where credit generation is performed. Credits can be used or "debited" to compensate for necessary impacts to wetlands within a designated geographic area.

Wetland banks can be broken down in three groups, public, private, and entrepreneurial. Public banks include those which were established by public entities for infrastructure projects such as roads, utilities, and municipal storm water management (EPA 2009). Private banks encompass corporations or private developers who wish to develop a WMB to address their own long-term development needs (EPA 2009).

Entrepreneurial banks include private individuals or firms who establish a wetland bank to sell credits to project proponents needing mitigation in a specified service area (EPA 2009). Entrepreneurial banks serve both public and private need for compensatory mitigation. Figure 1.2 shows the market breakdown by bank type. The figure indicates that entrepreneurial banking is the most widely used type of WMB. For the remainder of this paper, a reference to conventional WMB refers to entrepreneurial banking.

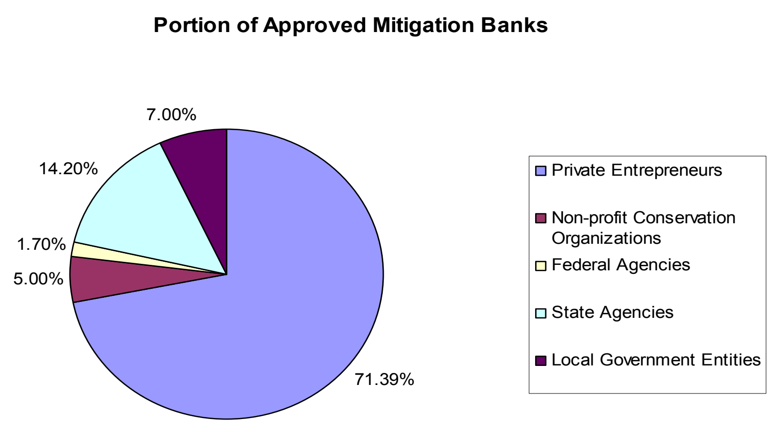

Figure 1.2 Portion of approved mitigation banks (ELI 2005)

Conventional WMB provides incentives for landowners to preserve wetlands. If approved during the permitting process, a permittee may buy credits, as a condition of government approval for offsetting in cases where impacts cannot be minimized or avoided practically (WADOE 2001). Since private owners will often convert wetlands due to lack of opportunity to capitalize on the benefits provided from preservation, WMB allows landowners to earn a cash return by selling credits to those impacting wetland resources. Therefore, society and landowners gain mutually.

In order to establish a wetland bank, those responsible for the bank site or the bank sponsor must be certified. The certification process relies on the formation of a Mitigation Banking Review Team (MBRT), made up of representatives from involved wetland public agencies which may include the EPA, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration Fisheries, and the Natural Resource Conservation Service (USACE 2008). The MBRT may also include state, local, and tribal representatives if appropriate. The primary role of the MBRT is to facilitate the establishment of the mitigation bank through the development of a mitigation banking instrument (USACE 2008).

The banking instrument is a contract between the bank sponsor and the regulatory agencies with jurisdictional authority over the bank. The instrument addresses the design, construction, monitoring, and long-term management along with the geographic service area of the wetland bank. The instrument determines how many credits will be generated and the financial assurances required. Plans must be submitted by the sponsor outlining credit generation, monitoring, and long-term management of the bank site. Sponsors are subject to the review of a pre-application prospectus, the mitigation banking instrument, public comment, and in some cases the requirements associated with state laws. For example, the bank certification process may include the participation and creation of an Environmental Assessment in accordance with the Environmental Protection Act of 1970 and State Environmental Protection Acts. The certification process is often complex and can take several years.[4]

Compensatory mitigation performed through a certified WMB has several advantages over traditional permittee-responsible mitigation (EPA 2009). WMB can

[4] As of 2006, it takes Washington State 24 months on average to certify a wetland bank (WADOE 2008).

reduce uncertainty over whether compensatory mitigation will be successful in offsetting wetland impacts (EPA 2009). This is due to wetland banks being certified to provide quality mitigation. Banks may provide extensive financial resources, planning, and scientific expertise not always available to many permittees (EPA 2009). Also, since banks are certified, banks reduce permit processing times and provide more cost-effective compensatory opportunities (EPA 2009). For example, under permittee-responsible mitigation, the permittee must submit a mitigation plan containing objectives, site selection, site protection, baseline information, determination of credits, mitigation work plan, maintenance plan, performance standards, monitoring requirements, long term management plan, adaptive management plan, financial assurances and other information (USACE 2008). However, permittees wishing to secure credits through a mitigation bank need only to submit information regarding baseline conditions and credit determination. Therefore, consolidation of permit review through the use of WMB enables efficient use of limited federal agency resources and compliance monitoring of compensatory mitigation (EPA 2009).

North Carolina's Ecosystem Enhancement Program

In North Carolina, project delays associated with the permitting process led to the implementation of an alternative WMB mechanism. During the mid-1990s, the North Carolina Department of Transportation (NCDOT) experienced increases in project delays within its transportation-infrastructure program due to compensatory permit review processes (NCEEP 2009; Shabman, Scodari 2004) Coincidentally, no entrepreneurial banks existed in North Carolina at that time (Voigt, Danielson 1996). Therefore, compensatory mitigation was carried out through internal staffing, North Carolina's Department of Environment and Natural Resources (NCDENR), and sub-contracting through the private sector (NCEEP, 2009) Most mitigation projects failed to meet their success criteria with mitigation failure rates being 60-80 percent (NCDENR et al. 2006). Later a cooperative improvement initiative of 10 state and federal agencies found that faulty communication and poorly synchronized mitigation/permitting processes had hindered project delivery and mitigation success (Greenways 2007). Their solution was the establishment of EEP.

Through a Memorandum of Agreement (MOA) between NCDENR and NCDOT, EEP was created as a refocused and renamed non-regulatory program. Under the MOA, EEP is to provide restoration, enhancement, and preservation to ecological functions within target watersheds addressing impacts from anticipated NCDOT transportation projects (NCDENR et al. 2004). That is, EEP provides mitigation well in advance of NCDOT projects. Thus, EEP acts proactively instead of reactively to mitigation efforts, as is not the case with permittee-responsible mitigation (NCEEP, 2009).

NCDOT pays EEP to plan mitigation, acquire land, construct projects, monitor progress, and handle remediation for compensating transportation impacts (Greenways 2007). That is, EEP generates credits for NCDOT projects. Taking advantage of upfront funding from NCDOT, EEP has the ability to implement mitigation for anticipated impacts in advance (NCENR et al. 2006). NCDOT each year provides updates and examines a seven year highway construction plan determining the projected type, amount and location of impacts to wetland resources. This forecast is provided to

EEP, which then assesses mitigation requirements and develops strategies for potential projects to meet mitigation needs (NCDENR et al. 2006). A biennial budget is then prepared in which NCDOT reviews the work plan before agreeing to the next funding cycle (Greenways 2007).

In order for EEP to fulfill the large quantity of credits needed to offset transportation impacts, EEP relies on both the public and private sector suppliers (D'Ignazio 2004). This includes credit generation in-house through design-build contracts and out-of-house full-delivery contracts. Design-build contract projects have several elements. Under this method, EEP provides planning and land acquisition for credit generation. Land acquisition often is administered through partnerships with local and regional land trusts or through the use of conservation easements (NCEEP 2009). EEP then may design the mitigation project itself or subcontract the design to the private sector. Construction, monitoring, and long-term management may also be sub-contracted.

Credit projects are also employed by WMB through full-delivery contracts. Under this method, EEP issues a Request for Proposal (RFP) defining the location, amount, and form of mitigation needed. Then credit providers bid for contracts by providing a sealed cost proposal and producing a technical proposal including a prospectus of credits, and the securing of the mitigation site (NCDENR et al. 2006). The RFP process acts as a WMB certification process in which financial assurances and mitigation plans are submitted to ensure quality. EEP then evaluates submitted proposals, conducts field investigations, and determines a technical score for each proposal (NCDENR et al. 2006). Sealed cost proposals that meet technical score criteria are then open and narrowed leading to awards based on site quality and cost (NCDENR et al. 2006).

Summary

Wetlands are important resources providing several benefits to those in outline geographic areas. Advances in ecological science recently have increased society's understanding of these unique ecosystems. Society values wetland benefits, but due to landowners not bearing the full-economic cost of their destruction, wetlands are converted to other uses in order to maximize returns. In order to provide landowner incentives to preserve wetlands, compensatory mechanisms such as WMB have allowed landowners to offer quality wetlands protection by generating credits and selling them to parties impacting wetlands.

WMB provides many benefits to permittees including a decrease in permit review processing times. Frustrated with delay times associated with the review process and mitigation failure, NCDOT and NCDENR created EEP and non-regulatory agency committed to wetland protection. NCDOT purchases wetland credits from EEP who generates credits through in-house production and contracting through credit suppliers. Credits are generated proactively before impacts to wetland resources occur. Credits are then used to offset NCDOT projects.

Although both conventional WMB and EEP demonstrate innovative ways of providing wetland protection, emphasis must be made as to which is more effective. That is, understanding which mechanism is less costly. This entails understanding the costs associated with each market mechanism. Minimizing the costs of achieving no net-loss is desirable from an economic perspective (Bonds, Pompe 2004). In order to minimize the costs to society associated with wetlands mitigation, implementing the appropriate low cost mechanism is necessary.

The next chapter provides an economic analysis regarding WMB mechanisms. The section gives the economic framework needed to understand the market setting surrounding conventional WMB. This helps to identify market conditions which led to EEP, and the foundation for comparison of these mechanisms.

CHAPTER 2

ECONOMICS OF WETLAND MITIGATION BANKING MECHANISMS

Market Failure

During colonial times, wetlands covered about 12 percent of the continental United States (Lupi, Kaplowitz, Hoehn 2002). Since then, approximately 45 percent of this area has been converted to other uses (Heimlich, Carey, Brazee 1989). These uses include agriculture, housing development, and commercial uses. Coincidentally, 82 percent of all wetlands and former wetlands in the continental United States are privately owned (Heimlich, Wiebe, Claassen, Gadsby, House 1998). These wetlands were often converted to increase their productive value (Heimlich, Wiebe, Claassen, Gadsby, House 1998).

Landowners will typically make decisions regarding converting wetlands to alternative uses by comparing the economic returns expected to be received from conversion to those gained by preservation (Heimlich, Wiebe, Claassen, Gadsby, House 1998). However, preserved wetlands provide public benefits extending beyond their boundaries (Heimlich, Wiebe, Claassen, Gadsby, House 1998). Often the public values wetland attributes such as habitat, but does not necessarily identify the functional benefits supplied until lost (Lupi, Kaplowitz, Hoehn 2002).Thus, when wetlands are converted, the value of their positive externalities is recognized (Turner 1991). For example, river diversions used for irrigation may reduce the amount of floodplains viable for grazing, contributing to arid rangeland zones, overgrazing, and pastoralist displacement (Turner 1991). Since the landowner does not bear the full-economic cost associated with wetland losses, there is market incentive to covert wetlands to more profitable land uses (BenDor, Brozovic, Pallathucheril 2008; Lant 1994). That is, wetland conversion affects society more than the individual landowner leaving weak incentive for preservation since returns may not be earned from preserving ecological functions.

Figure 2.1 provides a formal illustration of the private land market in relation to wetlands. The horizontal axis of Figure 2.1 represents the quantity of wetland acres owned privately such that $\overline{Q}$ represent the complete stock of wetland resources. The left vertical axis shows the value per acre, the right vertical axis implies the finite characteristic of wetland stock. The marginal benefit (MB) curve in the figure corresponds to the marginal benefits an individual landowner receives for protecting one additional acre. This may include the aesthetic value or recreational value. The marginal cost (MC) curve represents the marginal cost of preserving one additional acre of wetland or the opportunity cost of the next best use for that one particular acre. This includes forgone returns from farming or development. Therefore, the optimal private allocation of wetlands will be at Q. Where to the left of Q shows the quantity of acres allocated to preservation and the right shows the quantity allocated to conversion. This establishes the private equilibrium between preservation and wetland conversion. Still, as mentioned earlier, the social benefits of preservation extend beyond the wetland boundaries and are consumed by many.

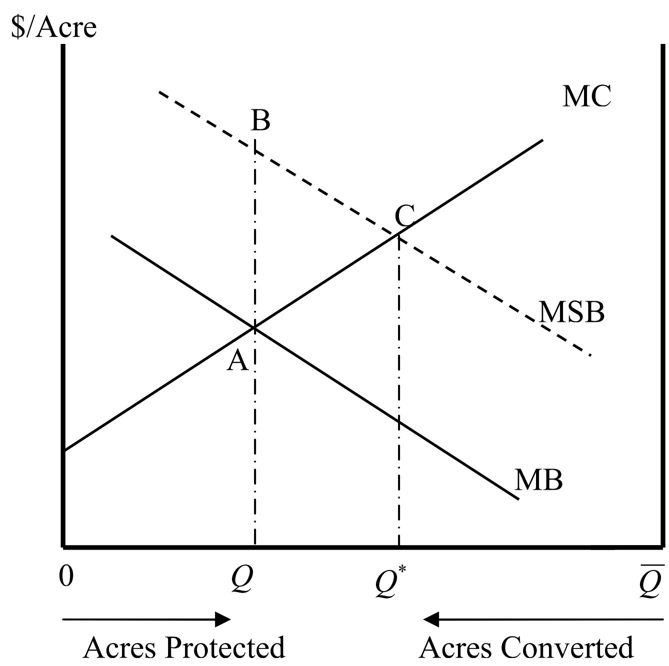

Figure 2.1 Optimal allocation of wetlands (Adapted; USDA 2005)

These benefits include the value of ecosystem services and functions such as flood control, water filtration, and wildlife habitat (Barbier, Acreman, Knowler 1997). This is represented by marginal social benefit (MSB) curve, which is the marginal social benefit associated with protecting one additional acre of wetland. Since landowners do not bear the full-economic cost associated with wetland losses, the MB curve is lower than the MSB curve. That is, the benefit earned from protecting an additional acre is less than that of society. Thus the graph indicates that the social optimal allocation of wetlands Q^* is greater than the private allocation Q.

Figure 2.1 demonstrates the weak incentives within the private market to preserve wetlands. As a result, welfare losses are incurred socially since the positive externalities wetlands provide are no longer received. This illustrated as the area *ABC* in the figure. This welfare loss offers motivation for policies to given preservation incentives to private landowners in order to move towards social equilibrium by shifting MB right to increase the preservation of individually owned wetlands. Policies such as WMB provide incentives to preserve wetlands since a cash return is earned through wetland preservation.

Economics of Conventional
Wetland Mitigation Banking

Mitigation banks sell credits to permittees who have an obligation to provide compensatory mitigation. Credits are generated by restoring, creating, enhancing, and/or preserving wetlands which are then protected in perpetuity. Credit sales provide incentives to landowners who would normally covert wetlands to more profitable uses. Thus, WMB provides returns for landowners and protects wetland resources.

Credit supply is influences by several factors. Changes in input prices and seasonal conditions alter the amount of credits supplied. Increases in input prices such as labor, machinery and land, decrease the quantity of credits produced. That is, as the cost of restoration increases the quantity of credit supply decreases (Fernandez, Karp 1998). Further, seasonal conditions which affects the time of planting, herbicide application and construction influence credit quantity. For example, seasonal conditions such as a long rainy season may increase the number of invasive species, reduce the success of vegetative plants, and reduce the ability to apply herbicides, thus influencing credit supply.

In the past, the credit supply from entrepreneurial banking was characterized as having large failure rates (King, Costanza 1994). That is, many of the credits produced did not provide any ecological value. Historically, the mitigation credit market was driven primarily by the demand for low cost permits (King, Costanza 1994). This provided incentive to keep costs low by under investing in credit quality. Since the permittee's concern is whether mitigation satisfies regulatory conditions, the permittee is price conscious not quality conscious (Shabman, Scordari, King 1994). Thus, deficient contract design execution between the regulator and bank sponsor can lead to underinvestment in credit quality, poor site selection, and credit failure (Hallwood 2006).

Supply risk factors such as poor site selection or invasive species infiltration which increase probability of ecological failure must be dealt with through the use of quality control measures monitored and enforced by relevant regulatory agencies. Often the rules of credit transactions and the units to be exchanged are determined by regulators in order to control the incentives which determine how credit suppliers make quality-cost tradeoffs (King, Costanza 1994). These often include extensive certification processes, financial assurances, credit ratios, maintenance requirements and credit release schedules in order to reduce the risk of failure.

In order to reduce supply risk a certification process is undertaken. The credit supplier must submit information regarding design, construction, monitoring, and long-term management to the MBRT who than reviews material and makes recommendations based on preferences regarding ecological conditions. This process ensures proper site selection along with the necessary performance standards needed to reduce ecological failure. These requirements may also include financial assurances, in order to provide incentive to suppliers to perform their obligations under the mitigation banking instrument.

Credit ratios refer to an acre-to-credit ratio in which the regulator requires that a certain amount of acres be restored, enhanced, created and/or preserved in order to generate one credit. Generally, a credit ratio acts as an aggregate index allowing the regulatory agency to adjust wetland credit quantity to account for differences in wetland quality resulting from inconsistency in ecosystem services expected to be provided over time (King, Price 2004). That is, ratios may account for the existing level of wetland function, the resulting level of wetland function, the length of time before mitigation is successful, the risk that the mitigation may not succeed, and the difference in location between impacted and mitigated sites (King, Price 2004). For example, it may be the case that 20 acres of preserved wetlands generates one credit which would constitute a 20:1 ratio regarding preservation. This is a relatively high ratio which may indicate that the wetland functions within these wetlands are rare, but do not add any additional acreage or function to net wetland stock. Also, since a credit supplier may generate credits using several forms of compensatory mitigation such as restoration or enhancement, different ratios will be assigned depending on the form. As mentioned, ratios may also be used as risk abatement in terms of site quality. For instance, if a site has a 50% rate of failure the regulatory agency may require a 2:1 ratio regarding restoration efforts.

Credit release schedules relate to the timing in which a credit may be sold. Typically credits are not to be sold until certain ecological and biological milestones have been achieved in order to ensure the success of a credit. This tool works by reducing supply risk. If credits are allowed to be sold prior to their production, such as in the planning phase, there may be little incentive for credit supplier to ensure credit success since a return has already been made.

Demand for credits is generated from regulatory requirements associated with development pressure (Shabman, Scodari 2004; Shabman, Scodari, King 1994)). Most notably, demand is created from development which leads to land-use changes. Land-use change is the most pervasive socioeconomic force driving degradation of watershed ecosystems (Dale et al. 200). Permits needed to offset impacts regarding land changes stemming from public work projects, commercial and industrial land-uses, and residential development will create credit demand (Shabman, Scodari, King 1994). Often development patterns, influenced by local land-use regulations, such as zoning ordinances, development guidelines, and property acquisition programs will often dictate location of projects (Langpap 2006). These patterns may also dictate the location of wetland banks.[5]

During the mitigation sequence, the amount of compensation needed in order to offset impacts is determined. In order for credits to be provided by a wetland bank the regulator must determine if off-site mitigation is appropriate. For instance, it may be the case that due to the rarity of hydrological functions provided by a particular wetland that on-site mitigation is required whereby the mitigation bank may not provide a similar function. Thus, in this case no credits will be demanded. If off-site mitigation is appropriate, regulators will often use credit ratios in order to determine the appropriate compensation. For example, an acre-to-credit ratio of 1:2 may be employed which implies that for every acre impacted two credits must be secured.

The availability of other compensatory methods will also influence demand. A permittee may compensate wetland impacts by providing permittee-responsible

[5] There is also a pattern associated with the redistribution of wetlands. In their 2006 paper, Ruhl and Salzman found that land prices will often dictate the location of wetland banks to areas with lower land prices therefore indicated a transfer of wetland resources from urbanized area into rural ones.

mitigation, participating in ILF mitigation, or creating a wetland bank themselves. This implies the existence of several substitutes for wetland credits. Thus, credits will only be demanded if credit prices are less than substitutes (Shabman, Scodari, King 1994). For example, economic theory suggests that increases in the price of wetland credits will increase demand for off-site permittee-responsible mitigation.

Demand is also influenced by the risk of regulatory change (Shabman, Scodari 2004). Changes in regulation surrounding compensatory mitigation and section 404 of CWA influence shifts in demand. For instance, legislative ambiguity as to what constitutes a wetland or navigable water suggests the future of wetlands permitting is still being shaped. Interpretation of laws will increase or decrease the quantity demanded by regulators. That is, established banks may experience shifts in demand due to court interpretations regarding the definition of wetlands.

Land-use change, mitigation substitutes, and regulatory uncertainties create demand risk. Since it is often difficult to predict land development patterns, which affect wetlands, future demand expectation are often uncertain (Shabman, Scodari 2004). Furthermore, uncertainty concerning the regulator's tastes and preferences is unknown to the credit supplier. That is, the individual regulator's preferences of wetlands function will in-turn influence the decision allowing for credit purchase since it may be the motive of the regulator to reduce functional tradeoffs between wetland sites. If a regulator believes a particular function to be rare, then compensation may need to be provided on-site whereby no credits are demanded. Further, use of credit ratios may amplify the quantity demand in the mitigation sequence process as well. Thus, regulatory uncertainty can create future demand uncertainty.

Measures such as the credit release schedule may also create demand risk. Credit schedules can create time lags between the permittee and supplier. As discussed, the regulator will decide the time frame between production and release. However, opportunity is lost if a permittee demands credits but none are available due to the supplier not yet meeting ecological criteria. Thus, the supplier endures the opportunity cost of waiting until credit maturity and the risk of biological failure (Shabman, Scodari, King 1994). In some cases, the credit supplier is allowed to sell a portion of credits prior to generation in order to finance bank construction. Still, even if a percentage of the credits are allowed to be sold the remaining credits may take 10 to 25 years to develop required functions (Mitsch, Wilson 1996; Simenstad, Thom 1996; Craft et al. 1999).

Using Figure 2.2, the relationship between ecological risk and economic risk involving credit release is shown. More so, the figure demonstrates the tradeoffs between supply risk and demand risk. If the horizontal axis represents time and the vertical axis represents risk, it is shown that as time increases the ecological risk of mitigation failure decreases but the economic risk increases since the supplier incurs the risk of failure and the opportunity lost from forgone credit sales. T* represent an optimum equilibrium of credit release between the planning phase of credit production and the maturing of a particular wetland credit. Total risk endured by the supplier is shown as area *0R*AT** on the graph, this includes the ecological risk of credit failure and the risk of lost sales prior to credit release.

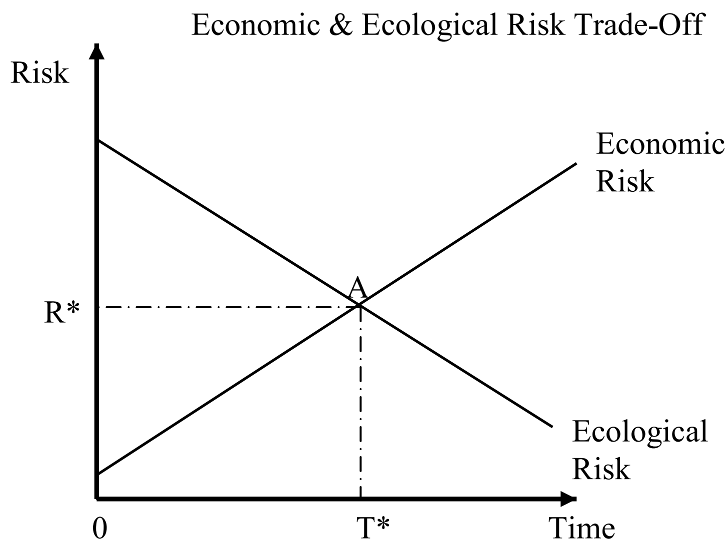

Figure 2.2 Economic & ecological risk trade-off (Brumbaugh 1995)

Issues relating to both supply and demand can have significant impact on credit prices. Supposing that a credit supplier is operating under perfect competition and demand is known, then prices would reflect the marginal cost of production. Though opportunity cost of regulation, may raise the cost of supplying credits beyond what is necessary to secure ecological success (Shabman, Scodari 2004). The uncertainty of when a credit supplier will be able to sell a particular credit will likely increase prices simply because of the risks involved in producing the credit (Shabman, Scodari 2004). This can be generalized as a risk-return trade-off, where the seller will not take on added risk unless an additional return is expected. Figure 2.3 illustrates this risk-return relationship. The horizontal axis represents risk and the vertical axis represents the expected returns received from credit sales. Suppliers require higher expected returns in order to be willing to accept higher risk. Thus, the credit market prices reflect the costs of credit production, the regulatory costs of gaining credit sales approval, and the risk associated with future demand uncertainty (Shabman, Scodari 2004; Shabman, Stephenson, Scodari 1998).

Risk-Return Relationship

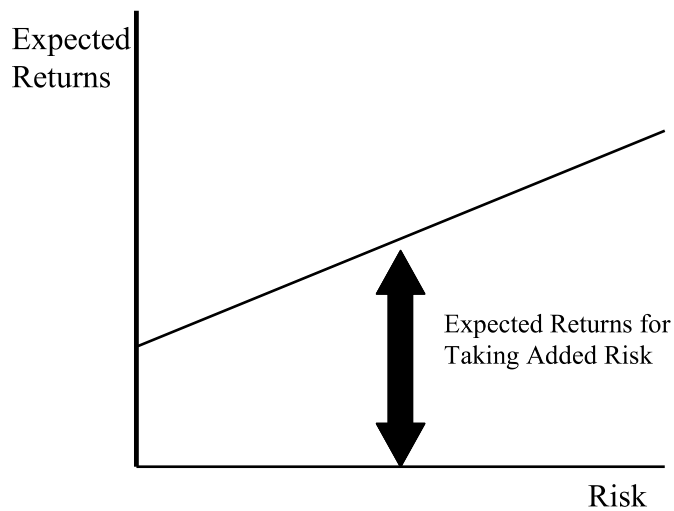

Figure 2.3 Risk return trade-off (Adapted; Keown 2006)

The market conditions surrounding the credit market influence investment in conventional WMB. The nature of land-use change, mitigation substitutes, and mitigation sequencing makes investment in WMB improbable, since entrepreneurs faced with demand uncertainty will typically not make an investment in producing a product that may not be sold (Shabman, Scodari 2004). Further, the certification process creates a large opportunity cost for those wishing to invest in WMB (Shabman, Scodari 2004). Environmental assessments including soil, vegetative, hydrological, and other functional assessment which must be carried out, make navigating the process complex and time consuming. Also ambiguity of legislation may create uncertainty of future credit demand leading to a decrease in WMB investment (Shabman, Scodari 2004). How courts interpret such laws makes investment in credit production a high-risk activity since judicial rules may limit the wetland area or wetland types for which credits will be required (Shabman, Scodari 2004). Case studies show that regulation within WMB is not a simple unidirectional force, but instead a multi-scaled position with internal conflicts and interests (Robertson 2009). Disharmonies between different scales of government such as state and local may be difficult for banks to manage (Robertson 2009).

The timing of credit investment and credit release in conventional WMB creates costs. If the credit market is characterized by lags or misses in credit supply due to underinvestment, time constraints regarding credit releases, and time of bank certification then there are associated costs. For example, lack of adequate supply increases delay costs due to longer review processes associated with alternative methods of compensation such as permittee-responsible mitigation. Therefore, delay costs may be incurred anytime there are increases in the quantity of excess demand. That is, anytime credits are demand but none are available due to credit release, underinvestment, or slow certification processes costs are incurred. In North Carolina, widespread dissatisfaction with delays associated with permit approval for North Carolina's Department of Transportation highway projects motivated the creation EEP (Shabman, Scodari 2004).

Economics of Ecosystem Enhancement Program

EEP acts as a liaison between the buyer and sellers of wetland credits; or rather EEP is a wetland credit broker. Like any broker, EEP possesses information about the credit market. NCDOT submits a yearly updated construction plan to EEP, in which

EEP then determines the required quantity of wetland credits thus demanding such quantities from producers. EEP coordinates NCDOT with potential supplier by gathering information regarding mitigation requirements and transferring this information to potential suppliers thereby reducing the costs of delay to NCDOT.

By coordinating NCDOT with potential supplier EEP offers an increase in the quantity supplied and certainty of future sales. By transferring demand information to credit suppliers EEP has potential to increase the number of willing WMB participants. Economic theory suggests that expectation regarding future sales may increase the number of potential suppliers and thus the quantity of credits supplied. However, this quantity may only be increased to levels demanded by NCDOT.

Certainty of future sales reduces credit prices. As mentioned earlier, conventional WMB credit prices reflect the costs of credit production, the regulatory costs of gaining credit sales approval, and the risk associated with future demand uncertainty (Shabman, Scodari 2004). In the case of EEP, the uncertainty of future sales does not exist due to the information distributed to producers in the form of RFPs reducing price. Also, since RFP process increases competition amongst producer due to the bidding process, prices could be expected to reflect the marginal cost of production. Thus, the EEP structure not only acts as a broker but also a price stabilization service to NCDOT. However, it should be noted that prices may also reflect the costs of participating in the RFP process.

In order to ensure a quality supply of credits under the RFP framework, several supply risk tools are implemented. Technical reviews within the RFP are aimed at ensuring proper site selection. These reviews are performed every time the supplier enters into the RFP. Winning credit suppliers are subject to credit release schedule in which suppliers are paid on the bases of the credits reaching ecological milestone. That is, every time a credit meets ecological criteria, the supplier is paid a portion of the bid.

Transaction costs associated with EEP also exist. These costs include the administrative costs as consequence of NCDOT partnering with EEP. For example, NCDOT bear the cost of creating a highway construction plan and reviewing EEP's biennial budget. Transaction costs also include the costs of the RFP process face by credit suppliers. Technical reviews, credit release schedules, and financial assurances required to ensure quality imply an incurred cost as a consequence of the RFP process (Shabman, Scodari 2004).

Given that NCDOT provides EEP with funding to provide the construction of credit projects prior to impacts occurring, NCDOT increases its opportunity costs. That is, NCDOT loses the opportunity of using funds for other uses. Further, NCDOT loses the interest on funds invested early. For example, since NCDOT has chosen to participate in the credit market though the use of a broker, a decision has been made to reduce delay costs by investing in wetland mitigation early, however, NCDOT incurs the costs of early investment.

Comparison and Summary of Costs

Both wetland credit mechanisms provide an interesting tradeoff between market costs. Market conditions surrounding conventional WMB have reduced investment and therefore the creation of robust markets in WMB (Shabman, Scodari 2004). However, shortages or excess demand may be consequence of the unique timing aspects of the credit market. The presence of excess demand has in some cases created increases in project delay. For example, NCDOT suffered large mitigation failures due to lack of a synchronized permit process and execution related to permittee-responsible mitigation (NCDENR et al. 2006). These delays were often amplified by large mitigation failures (NCDENR et al. 2006). The combination of project delays and increased mitigation failure provoked collaboration between NCDOT and NCDENR allowing for the creation of EEP, an innovative approach to compensatory mitigation.

EEP generates credits through several methods in order to create a surplus of credits, thus excess supply. EEP does this by producing credits through in-house credit production and the RFP process. However, the creation of excess supply is not without its cost. By choosing to invest early in credit production, NCDOT forgoes the compounded interest earned on invested funds as consequence of credit surplus or excess supply. Thus, conventional WMB and EEP demonstrate a cost tradeoff between early investment costs and delay costs.

Both mechanisms are innovative ways of providing wetland protection. However, emphasis must be placed on choosing the mechanism which provides protection at the lowest cost to society. The next chapter offers an analysis of market costs associated with each credit supply mechanism. By characterizing the costs associated with excess supply and excess demand, two cost models are created and then used to determine the best mechanism based on costs. Evaluating the costs incurred by these mechanisms provides understanding regarding the cost of securing wetland protection.

CHAPTER 3

COST ANALYSIS OF WETLAND MITIGATION BANKING MECHANISMS

Theoretical Framework

In order to compare conventional WMB practices with EEP, several assumptions are made. First, assume that there are no quality differences between credits produced through conventional WMB and EEP. Although the qualities of wetland functions and wetland attributes will vary, it is assumed that neither EEP nor conventional WMB consistently produces higher quality credits. Thus, both provide quality credits on an equal basis. Second, suppose that both mechanisms operate in two distinct time periods. One period consists of the production process regarding credits and the other period comprises of the mitigation sequencing procedure. If the decision of how many permits to fulfill is made at the beginning of the production process, then the end of the first period would give the number of credits supplied within the market. If the second period encompasses the mitigation sequence where impacts are avoided and minimized, then the end of the second period would give the number of credits supplied. Thus, if not enough credits are produced to satisfy permit demand, excess demand would exist. Similarly, if too many credits are produced excess supply would exist. To simplify, Equation (3.1) shows that at the end of the second period where the market is left with x, the quantity of excess demand. If x is positive it implies the presence of excess demand, If negative it implies the presence of excess supply.

(3.1) $x = x_d - x_s$

where x = Excess demand of wetland credits

x_d = The quantity demanded

x_s = The quantity supplied

However, if x is zero it implies that excess demand is zero such that there are no costs associated with project delays or early investment. The creation of Equation (3.1) now gives the framework to formally define the total costs of excess demand and excess supply.

Since different costs are incurred based on whether x is positive or negative, that is $x > 0$ or $x < 0$, a measure of the costs conditional on the value of x is needed. Assuming that x approximates a normal distribution such that $x \sim N[\mu, \sigma^2]$, a Truncated Normal Distribution can be employed to generate the expected values:

(3.2) $$E[x|x<0]\ \mu + \sigma\left[-\frac{\phi\left(\frac{a-\mu}{\sigma}\right)}{\Phi\left(\frac{a-\mu}{\sigma}\right)}\right]$$

$$E[x|x>0] = \mu + \sigma\left[\frac{\phi\left(\frac{a-\mu}{\sigma}\right)}{1-\Phi\left(\frac{a-\mu}{\sigma}\right)}\right]$$

where: μ = The mean of excess demand

σ = The standard deviation of excess demand

$\phi(.)$ = The standard normal probability density function

a = The point of truncation

$\Phi(.)$ = Then standard normal cumulative distribution function

Equations (3.3) can be concisely written as:

$$(3.3) \qquad E[x|x>0] = \mu + \sigma\lambda^{+}(\alpha)$$

$$E[x|x<0] = \mu + \sigma\lambda^{-}(\alpha)$$

where: $\alpha = \dfrac{a-\mu}{\sigma}$

$$\lambda^{+}(\alpha) = \frac{\phi(\alpha)}{1-\Phi(\alpha)}, \text{ if } x>0$$

$$\lambda^{-}(\alpha) = -\frac{\phi(\alpha)}{\Phi(\alpha)}, \text{ if } x<0$$

Multiplying the expected values for excess demand and excess supply by their respected marginal costs and probabilities of existence will yield the total cost of delay and early investment within the credit market. Hence, the conventional WMB total cost function can now be obtained.

Conventional Wetland Mitigation
Banking Total Cost Function

Using the information and definitions for variables obtained from Equation (3.1) to (3.3), it is possible to create total cost equation for the conventional WMB mechanism shown as:

(3.4) $$C_w = C_D \cdot \left(E\left[x \middle| x > 0\right]\right) \cdot prob(x > 0) + C_{ws} \cdot \left(E\left[x \middle| x < 0\right]\right) \cdot prob(x < 0) + bx_s$$

$$C_w = C_D\left(\mu_w + \sigma_w \lambda^+(\alpha_w)\right)\left(1 - \Phi_w(\alpha_w)\right) + C_{ws}\left(\mu_w + \sigma_w \lambda^-(\alpha_w)\right)\Phi_w(\alpha_w) + bx_s$$

where: C_D = The marginal cost of excess demand or the cost of project delay

$1 - \Phi_w(.)$ = The evaluated probability of the existence of excess demand

μ_w = The mean excess demand for conventional WMB

σ_w = The standard deviation of excess demand for conventional WMB

α_w = The evaluated values of the point of truncation, mean, and standard deviation of excess demand

C_{ws} = The marginal cost of excess supply or the cost of early investment in credit production

$\Phi_w(.)$ = The evaluated probability of the existence of excess supply

b = The marginal cost of credit production

x_s = The quantity of credits supplied

Under the framework provided by Equation (3.4), several assumptions are made regarding variables. Within the model, both C_D and C_{ws} are parameters. Within conventional WMB, no one particular wetland bank or permittee may alter the market costs of excess demand and excess supply. To further explain, C_d depicts the cost for an additional unit of delay or the minimum opportunity cost of time associated with the use of permittee-responsible mitigation per credit. For instance, if no credits are available it is assumed that the permittee will fulfill required compensatory mitigation itself.[6] As discussed in the previous chapter, credit purchases are streamlined compared to permittee-responsible mitigation. Regulators will often require several actions to be performed by the permittee such as a mitigation plan which includes the design, construction, monitoring, and long-term management, of the site. These requirements have already been fulfilled by the bank during certification, so the permittee does not face such an extensive permit review process. Therefore the costs of delay can be shown as the present value of the opportunity cost of delay per credit summed across time periods:

(3.5) $$C_D = \sum_{i=1}^{i} \frac{OC_i}{(1+r)^i}$$

where: OC = The opportunity cost of delay associated with permittee-responsible mitigation

x = The quantity of excess demand

r = The discount rate

i = The number of time periods

C_S depicts the cost of early investment. If the permittee purchases credits prematurely before impacts occur, then the permittee loses the opportunity to earn compounded interest on the funds used to purchase one additional credit. Thus, the cost

[6] The permittee may have several options at its disposal when credits are not available such as waiting for credits to become available, use ILF mitigation, or provide Permittee-responsible mitigation. Each option has its associated cost of delay. For example, the costs of delay associated with ILF are the benefits loss to society from the purchase of credits to the time of credit generation since ILF programs pool funds and then execute mitigation. For the sake of convenience, this paper simply assumes that delay costs exist when credits are not available permittee provide mitigation themselves.

of excess supply can be shown as the opportunity cost of funds invested early. This is shown formally in Equation (3.6).

(3.6) $$C_{ws} = \sum_{i=1}^{9} b_i \left(1 + \frac{r}{n}\right)^{ni}$$

where: b = The marginal cost of credit production

r = The rate of interest

i = The number of time periods

n = The number of times interest is compounded per period

It is assumed that no permittee or supplier may alter the costs of production. This is due to interest rates and production costs being outside the control of the permittee and supplier. For example, no agent within the market may influence the cost of investment by increasing or decreasing their respective outputs. Thus, the cost of excess supply is also exogenous.

It is also assumed that marginal cost of production, b, is a parameter. Credit transactions from a particular bank or permittee cannot alter the price of credits. It is argued that uncertainties regarding regulatory controls maintain the production costs no matter what the output. For instance, no one particular wetland bank may exhibit economies of scale in order to reduce the price of credits. It is assumed that even though suppliers may be limited the costs of regulatory credit approval maintain production costs no matter the output.

That being said, the marginal cost of production within the model may be described as the sum of factors contributing to per unit credit cost. This includes per unit costs of property tax, input factor wages, and regulatory credit approval (Shabman, Scodari 2004). This is expressed in Equation as the present value of credit costs (3.7).

(3.7) $$b = \sum_{i=0}^{1} \frac{m_i}{(1+r)^i}$$

where: m = The sum of all marginal costs retained from elements within credit production

r = The discount rate

Given certain characteristics of the conventional WMB market, it assumed that within Equation (3.4) that μ_w is zero over the long run. Though in the short-run, the market may exemplify misses such that excess demand exists. That is, it is argued that the conventional WMB market is characterized by misses where timing issues create lags in credit supply. Extensive certification processes, release schedules, or not having an adequate supply of credits demonstrates short-run excess demand. However, economic literature has shown that increases in credit supply do occur in cases of decreased restoration costs, interest rates, or increased biological uncertainty and the value of wetland credits (Fernandez, Karp 1998). Thus, over the long-run, taking these lags and investments into account, it can be assumed that the mean of excess demand is zero. Since these misses can not be controlled by any given supplier or permittee the mean of excess demand is considered to be exogenous.

Further, it is assumed that σ_w is exogenous. The standard deviation of excess demand relates to the variance of the credit market. If the market variance of excess demand is zero it implies that the dispersion of credits within the market is small, indicating that excess demand does not exist and the quantity of credits demanded is satisfied. If conventional WMB excess demand variance is defined as:

(3.8) $$\sigma_w^2 = \sigma_d^2 + \sigma_{ws}^2$$

where: $\sigma_d^2 =$ The variance of credit demand

σ_{ws}^2 = The variance of credit supply

Then it is argued that neither permittee nor credit supplier may alter the value of credit demand variance or credit supply variance. That is, no agent within the market may alter the dispersion of credit supply or demand in the market by influencing the credit supply or demand. Therefore, all variables within Equation (3.8) are exogenous

Ecosystem Enhancement Program
Total Cost Function

Similar to the conventional WMB cost function, it is possible to develop a cost function for the EEP mechanism. Again, using information from the Truncated Normal Distribution, a cost function is developed by multiplying the costs of excess demand and excess supply by their respected expected values and probabilities of existence and adding the total cost of credit production yielding:

(3.9) $$C_e = C_D \cdot \left(E\left[x \middle| x > 0\right]\right) \cdot prob(x > 0) + C_{es} \cdot \left(E\left[x \middle| x < 0\right]\right) \cdot prob(x < 0) + bx_{es} + R$$

$$C_e = C_D\left(\mu_e + \sigma_e \lambda^+(\alpha_e)\right)\left(1 - \Phi_e(\alpha_e)\right) + C_{es}\left(\mu_e + \sigma_e \lambda^-(\alpha_e)\right)\Phi_e(\alpha_e) + bx_{es} + R$$

where: $C_{es} =$ The marginal cost of excess supply under EEP

μ_e = The mean of excess demand under EEP

$1-\Phi_e(.)$ = The evaluated probability of the presence of excess demand

σ_e = The standard deviation of excess demand under EEP

α_e = The evaluated values of the mean excess demand and standard deviation of the truncated normal distribution under EEP

$\Phi_e(.)$= The evaluated probability of the presence of excess supply

x_{es} = The quantity of credits supplied under EEP

R = The fixed transaction cost associated with EEP

Several things are assumed regarding Equation (3.9). Both C_D and b are parameters. Like conventional WMB, no supplier or permittee may alter their value. The cost of excess demand are determined by factors outside the control of the permittee or credit supplier such as the amount of time projects will be delayed or the quantity of excess demanded credits. Furthermore, the production cost reflects the marginal cost associated with in-house production and their respected supply risk such as the transaction costs of the RFP process. Therefore, they are considered to be exogenous since the costs may not be altered intentionally by EEP or NCDOT.

This model assumes that C_{es} is endogenous. Given the market information EEP holds regarding demand, EEP may choose the amount of investment it whishes to pursue. Thus, the cost of excess supply is a variable in which EEP chooses the amount it is willing to incur. This implies that EEP may also control the quantity of credits produced. Making use of the NCDOT seven year highway construction plan, EEP possesses the information needed to make approximations regarding credit production.

Since EEP may increase the quantity of credits supplied by increasing or decreasing in-house credit production or issuing and delaying issue of RFPs, then it is argued that x_{es} is endogenous.

Equation (3.10) shows how the EEP's ability to change the quantity of credit supply influences other variables in Equation (3.9).

(3.10) $$x = x_d + x_{es}$$

where: x = The mean of excess demand

x_d = The quantity of credits demanded

x_{es} = The quantity of credits supplied

If EEP alters the quantity of credits supplied it in-turn alters the value of the mean of excess demand. This suggests that EEP may increase or decrease the quantity of excess demand within the market and therefore it can be assumed that μ_e is endogenous as well.

Unlike the market costs under conventional WMB, σ_e is endogenous. Similar to equation (3.8) an equation referring to the variance of excess demand under EEP is created yielding:

(3.11) $$\sigma_e^2 = \sigma_d^2 + \sigma_{es}^2$$

where: σ_d^2 = The variance of credit demand

σ_{es}^2 = The variance of credit supply within EEP

Using Equation (3.12), one could argue that EEP has the ability to reduce the variance of credit supply since it may choose the quantity of credits produced. For instance, in reality EEP creates a steady surplus of credits. In 2008, net wetland credit assets were 9,678.2 (NCEEP, 2009). And, in 2006 net credit assets totaled 11,495 (NCEEP, 2009). Thus, EEP may decrease the variance of excess demand by controlling the dispersion of credit supply.

However, EEP may not alter variance of credit demand. That is, as in conventional WMB, it is assumed that EEP may not influence demand patterns or dispersion within the market. It is assumed that decisions of how many credits are needed to offset impacts are the decisions of regulators alone, and therefore demand dispersion is not controlled by EEP. Further, neither EEP nor NCDOT may alter the dispersion of credits by influencing development patterns. Thus, comparing Equation (3.12) and (3.8), it is implied that neither EEP nor conventional WMB has the ability to alter the variance of the credit demand.

Since Equation (3.9) holds several endogenous variables, these variables can be optimized in order to minimize market costs regarding EEP. Plugging the optimal values for the costs of excess supply, quantity of credits supplied, the mean of excess demand, and the standard deviation of excess demand, into Equation (3.9) a minimum value function can be obtain shown as:

(3.12)

$$\begin{aligned} C_e = {} & C_D\left(\mu_e^*(C_D,b) + \sigma_e^*(C_D,b)\cdot\lambda^+(\alpha_e^*(C_D,b))\right)\left(1-\Phi_e\left(\alpha_e^*(C_D,b)\right)\right) \\ & + C_{es}^*\left(\mu_e^*(C_D,b) + \sigma_e^*(C_D,b)\cdot\lambda^-(\alpha_e^*(C_D,b))\right)\Phi_e\left(\alpha_e^*(C_D,b)\right) + bx_{es}^*(C_D,b) + R \end{aligned}$$

where:

where:	$\mu_e^*(C_D, b)$	=	The optimal mean of excess demand
	$\sigma_e^*(C_D, b)$	=	The optimal standard deviation of excess demand
	$\alpha_e^*(C_D, b)$	=	The optimal evaluated values of the mean excess demand and standard deviation within the truncated normal distribution
	$C_{es}^*(C_D, b)$	=	The optimal cost of early investment.
	$x_{es}^*(C_D, b)$	=	The optimal quantity of credits supplied

which can be rewritten concisely as:

(3.13) $$C_e^* = C_D\left(\mu_e^* + \sigma_e^* \lambda^+(\alpha_e^*)\right) + C_{es}^*\left(\mu_e^* + \sigma_e^* \lambda^-(\alpha_e^*)\right) + bx_{es}^* + R$$

Equation (3.13) now represents the total cost function of EEP evaluated at its optimal.

Results

The Truncated Normal Distribution has allowed for the creation of expected values for excess demand and excess supply. These expected values helped to establish the total cost functions for conventional WMB and EEP. Each total costs function represents the market costs incurred associated with a WMB mechanism. By using Equations (3.4) and (3.13), it is now possible provide analysis as to which mechanism is less costly at providing wetlands protection. Subtracting the conventional WMB cost from EEP cost function, a net cost solution can be obtained indicating the better choice:

(3.14) $$NC = C_w - C_e^*$$

Thus, if $NC > 0$ conventional WMB is more costly, and if $NC < 0$ EEP is more costly. However, since a numerical solution for each mechanism has not been obtained, it would be more appropriate to provide comparative statics on Equation (3.14) in order to determine how factors influence implementation choice.

In order to do so, notice that Equation (3.13) is an indirect objective function made up of parameters. Given that, using the envelope theorem, it is possible to employ comparative statics by taking the first order condition of Equation (3.13) yielding the direct effects of parameter changes. For example, Equation (3.13) can be rewritten generally as:

$$(3.15) \qquad C_e^*(C_D, b) = f(\mu_e^*, \sigma_e^*, C_{es}^*, C_D, b)$$

Differentiating with respect to parameters yields the following first order conditions:

$$(3.16) \qquad \frac{\partial C_e^*}{\partial C_D} = f_{\mu_e} \frac{\partial \mu_e^*}{\partial C_D} + f_{\sigma e} \frac{\partial \sigma_e^*}{\partial C_D} + f_{Ces} \frac{\partial C_{es}^*}{\partial C_D} f_{es} \frac{\partial x_{es}^*}{\partial C_D} + f_{C_D}$$

$$\frac{\partial C_e^*}{\partial b} = f_{\mu_e} \frac{\partial \mu_e^*}{\partial b} + f_{\sigma e} \frac{\partial \sigma_e^*}{\partial b} + f_{Ces} \frac{\partial C_{es}^*}{\partial b} + f_{es} \frac{\partial x_{es}^*}{\partial b} + f_b$$

Since it the first order conditions suggest $f_{\mu_e} = f_{\sigma_e} = f_{C_{es}} = 0$, it possible to reduce the result to:

$$\frac{\partial C_e^*}{\partial C_D} = f_{C_D}$$

$$\frac{\partial C_e^*}{\partial b} = f_b$$

Thus, the envelope theorem implies that it does not matter whether the optimal values vary or are held constant, changes with respect to parameter values will give the same result. Meaning, the derivative of the objective function is identical as the derivative of the indirect objective function with respect to the parameters. This result now provides a framework to compare conventional WMB to EEP.

By performing comparative statics on Equation (3.15) with respect to exogenous variables, insights may be attained as to the characteristics within any given conventional WMB market which may influence the choice of market mechanism. For example, performing comparative statics with respect to the standard deviation of excess demand may provide insight as to how excess demand dispersion within the market increase or decreases net costs. However, referring back to Equation (3.8) and (3.12) it is in fact the standard deviations of credit demand and credit supply which will provide insight. Therefore taking the square root of Equation (3.8) and (3.12) gives the standard deviations of credit demand and credit supply for their respected mechanism:

(3.17) $$\sigma_w = \sigma_d + \sigma_{ws}$$

$$\sigma_e = \sigma_d + \sigma_{es}$$

Plugging the information obtained in (3.17) into Equation (3.14), it is possible to provide comparative statics as to how changes in parameters and exogenous variables within any particular conventional WMB market affect mechanism choice. The comparative static results may be found in Appendix A.[7]

In order to determine whether comparative statics are increasing or decreasing preceding assumptions are used. First, since EEP creates a large supply of

[7] The results are written formally showing the probability density functions along with the Gaussian distributions in order to ensure sign accuracy.

credits we can further assume that $x_{es}^{*} < x_{s}$ and $\mu_{e}^{*} < \mu_{w}$. Second, it was discussed that $\mu_{w} = 0$, therefore it is assumed that $\mu_{e}^{*} < 0$,

Using these assumptions, the results show that increases in the cost of delay increase net costs, $\frac{\partial NC}{\partial C_D} > 0$.[8] That is, for every additional unit of delay conventional WMB becomes more costly. For instance, if the opportunity cost of permittee-responsible mitigation rises, it would in-turn raise the cost of conventional WMB. This suggests that increasing credit supply, which reduces the use permittee-responsible mitigation, will lower the cost of wetland protection. However, in cases where permittee-responsible mitigation is necessary, such as cases where wetland functions are rare, a streamlined permit process is important in order to reduce delay costs.

Comparative statics show that net costs decrease as the cost of excess demand increases, $\frac{\partial NC}{\partial C_S} < 0$.[9] That is, investing in large amounts of credits reduces the effectiveness of EEP. If interest rates increase the cost of excess supply, investing early becomes less practicable. As this result points out, the quantity of investment must be managed in order to reduce costs. For instance, in the case of EEP, emphasis must be placed on forecasting the optimal quantity of credits needed to offset impacts. Investing too much in future impacts may increase the costs of wetland protection.

The comparative statics also show that increases in production costs increase net costs, $\frac{\partial NC}{\partial b} > 0$.[10] That is, for every additional unit increase in costs associated with

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[8] This result is presented in Appendix A as Equation (3.18)
[9] This result is presented in Appendix A as Equation (3.19)
[10] This result is presented in Appendix A as Equation (3.20)

credit generation, conventional WMB becomes more costly. Increase in production costs stemming from demand risk will provide an incentive to implement an EEP mechanism. These risks include those associated with credit release schedules, ecological risk, and opportunity cost from participating in bank certification. Thus, increases in risks of credit approval will enhance the effectiveness of EEP.

The results also indicate that it is unclear how the standard deviation of credit supply influences net costs, $\frac{\partial NC}{\partial \sigma_{ws}} \Rightarrow Ambiguous$.[11] However, if the marginal cost of excess demand is less than the marginal cost of excess supply within conventional WMB, then an increase in the standard deviation of credit supply will decrease net costs, thus conventional WMB becomes less costly. That is, if it costs more to invest early in credit production than maintaining the status quo, then in a thin market where credits are widely dispersed the costs incurred by society are reduced by maintaining conventional WMB. On the other hand, if maintaining the status quo costs more than investing early in credit production, then in a market that is thin with credits it is better to implement EEP. Therefore, given a market where the dispersion of credits is large, high delay costs, which suggest increases in ecological failure or increases in permit-review times, indicate that EEP should be implemented to reduce cost.

This can be illustrated using Figure 3.1. The horizontal axis represents the standard deviation of credit supply and the vertical axis show the total market cost. Each structure is graphed over the standard deviation of credit supply. Notice that the line representing the total cost of EEP is constant. The standard deviation of credit supply is

[11] This result is presented in Appendix A as Equation (3.21)

an exogenous variable in conventional WMB which is not the case in EEP. Since the standard deviation of credit supply in minimized under EEP and is not identical the exogenous standard deviation of credit supply under conventional WMB, EEP's total cost line remains constant.

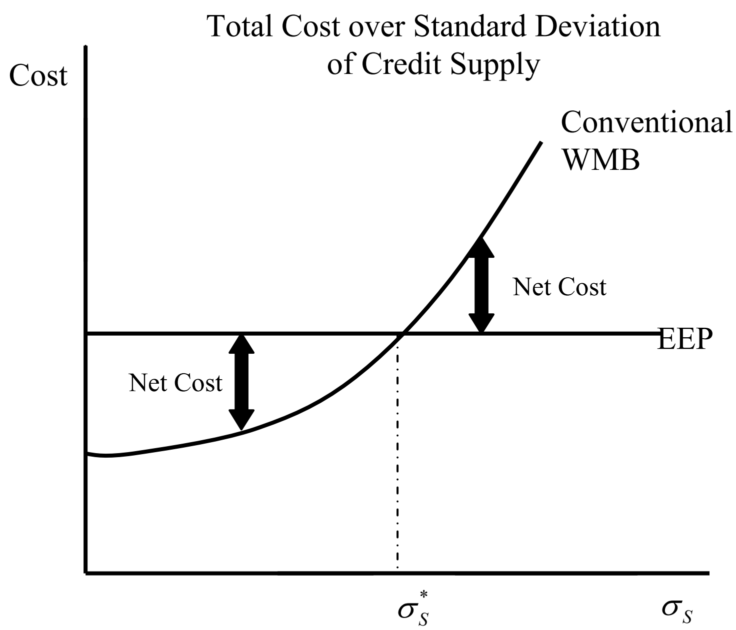

Figure 3.1 Total cost over standard deviation of credit supply

The graph shows cost differences between the two market mechanisms depicted as the net costs. As the results indicate, if the marginal cost of delay is relatively high, increases in the dispersion of credit supply make it less costly to implement EEP. That is, once total costs of conventional WMB surpass σ_e^*, maintaining conventional WMB is less effective. Vice versa, a smaller standard deviation would indicate a smaller dispersion of supply within the conventional market implying no change is needed.

The comparative static results give an ambiguous result regarding the influence the standard deviation of demand has on net costs, $\frac{\partial NC}{\partial \sigma_d} \Rightarrow Ambiguous$.[12] Though, if the marginal cost of early investment is relatively large in comparison to the marginal cost of delay, then as demand dispersion thins net costs decrease. That is, if investing early in credit production is more than not investing at all, then an increase in the dispersion of demand, perhaps due increases in mitigation substitutes, rarity of wetland functions, or changes in development patterns, will indicate that maintaining conventional WMB is less costly. However, if it is less costly to invest early than not to invest at all, then EEP is less costly to implement as demand dispersion thins.

The comparative statics for the standard deviations of supply and demand provide insights as to how market variance influences implementation. Referring back to Equation (3.17), since the standard deviations of supply and demand influence the standard deviations of excess demand in both mechanisms, the results provide several implications. First, whether the marginal costs of delay and early investment are relatively large or small in comparison to one another will help to determine mechanism choice. That is, whether it costs more to invest early than not investing. Second, whether the market is characterized by having a large variance of excess demand which indicates large short-run misses or a small variance of excess demand suggesting optimal coordination of supply and demand will determine mechanism choice. If it costs more to invest in early credit production, a large excess demand variance would suggest maintaining conventional WMB practices. However, if it cost more not to invest, a large excess demand variance would suggest implementing EEP.

[12] This result is presented in Appendix A as Equation (3.22)

Conclusion

The reality of WMB is that regulation surrounding the credit market is not a unitary whole, but different scales of federal, state, and local governments which control in uncoordinated ways (Robertson 2009). The credit market is complex whereby participants must navigate the regulatory, economic, and ecological terrain (Robertson 2009). Understanding how these scales influence costs regarding excess supply, excess demand, and production is important in wetland protection. For example, the results suggest that the mitigation sequences which determines the dispersion of credit demand can have an affect on banking costs.

Furthermore, the WMB market is characterized by the complexity of timing. Certification time, credit release, permit review processes, and even seasonality influencing wetland planting can alter the quantity of credits supplied sequentially altering the quantity of excess demand and the mean of excess demand. Understanding the timing issues surrounding compensatory mitigation which influences these variables will better help to provide wetland protection at a low cost to society.

More so, understanding the market conditions will help to determine which mechanism is better at providing wetland protection. Market costs such as the marginal cost of delay and marginal cost of early investment largely influence the implementation decision given the market variance of excess demand. Whether it is more costly to invest early in credit production than not investing will dictate which mechanism is best given the variance of excess demand. Thus, understanding what drives market variance of excess demand will also provide the framework for choosing a mechanism which reduces mitigation costs.

Choosing the better mechanism given market conditions provides an opportunity for an increase in WMB practices. Retrospective studies have shown permittee-responsible mitigation programs are usually poorly designed, inadequately implemented, and infrequently monitored (Ruhl 2008; National Research Council 2001; Ruhl, Salzman 2006; Salzman, Ruhl 2000). Lack of regulation over ecological risks would often result in a series of disconnected mitigation sites providing no functional value (Ruhl 2008; Freeman 2007). Providing WMB practices at low costs offers market incentives to purchase wetland credits rather than using other methods of compensation such as permittee-responsible mitigation. Moving away from such alternatives may entail benefits such as streamlined credit purchases. Given that existing wetland banks and programs such as EEP operate under a banking instrument, the permit review process is less time consuming. Meaning, that since these methods have been certified by regulators the permittee saves time by not having to participate in the process of site selection, design, construction, and long-term management. The permittee benefits by transferring the risk of ecological failure to those with the technical knowledge to provide effective resource management increasing the probability of mitigation success.

In summary, wetlands are an important resource providing benefits to many. Large numbers of wetland losses led to a regulatory response and the creation of WMB, providing market incentive to restore, create, enhance and/or preserve wetlands. Due to the regulatory conditions surrounding WMB market, two credit supply mechanisms emerged. Both conventional WMB and EEP are innovative prescriptions for protecting wetland resources. Each WMB mechanism provides a unique tradeoff between the costs of excess demand and excess supply. Understanding the costs associated with WMB mechanisms allows for lowered market costs incurred by society and wetlands protection in perpetuity.

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APPENDIX A

RESULTS OF COMPARATIVE STATICS

RESULTS OF COMPARATIVE STATICS

(3.18) $$\frac{\partial NC}{\partial C_D} = -\frac{e^{-\frac{\mu_e^{*2}}{2(\sigma_d + \sigma_{es}^{*})^2}}(\sigma_d + \sigma_{ws})}{\sqrt{2\pi}} + \frac{(\sigma_d + \sigma_{ws})}{\sqrt{2\pi}} - \frac{1}{2}\mu_e^{*}\left(-2 + Erf\left[\frac{\mu_e^{*}}{\sqrt{2}(\sigma_d + \sigma_{es}^{*})}\right]\right)$$

(3.19) $$\frac{\partial NC}{\partial C_S} = -\frac{\sigma_d + \sigma_{ws}}{\sqrt{2\pi}}$$

(3.20) $$\frac{\partial NC}{\partial b} = -x_{es}^{*} + x_s$$

(3.21) $$\frac{\partial NC}{\partial \sigma_{ws}} = -\frac{C_D - C_{es}}{\sqrt{2\pi}}$$

(3.22) $$\frac{\partial NC}{\partial \sigma_d} = \frac{C_D - C_{es} + (C_D + C_{es}^{*})e^{-\frac{\mu_e^{*2}}{2(\sigma_d + \sigma_{es}^{*})^2}}}{\sqrt{2\pi}}$$