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Evaluation of Wetland Mitigation Measures

Volume I: Final Report

U.S. Department of Transportation
Federal Highway Administration

Research and Development
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FOREWORD

The United States Department of Transportation (DOT) now has a policy under DOT Order 5560.1A, "Preservation of the Nation's Wetlands," which states "transportation facilities and projects should be planned, constructed and operated to assure the protection, preservation, and enhancement of the Nation's wetlands to the fullest extent possible." This policy is based on numerous laws, regulations, and Executive Orders. The study reported conclusions about the effectiveness of 17 varied wetland mitigation projects examined in 14 States across the country. Evaluations were made by a single evaluation crew in 1989 on created, restored, and enhanced wetlands considering natural control wetlands and regulatory framework of assessed projects. Conclusions were developed and recommendations and guidance for wetland mitigation are presented.

The study "Evaluation of Wetland Mitigation Measures" is primarily presented in Volume I (Final Report). This report will be of interest to environmental scientists and highway planners and designers concerned with wetland regulation and management. It contributes to the growing body of information on the design and creation of wetland mitigation sites.

Sufficient copies of this publication are being distributed by memorandum to provide three copies to each Region and at least three copies to the Divisions. Additional copies for the public are available from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

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Operations Research and Development

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FHWA Contracting Officer's Technical Representative: Howard A. Jongedyk (HNR-30). State departments of transportation from California, Florida, Illinois, Iowa, Maryland, Michigan, Minnesota, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Washington and Wisconsin cooperated in supporting this study.

16. Abstract

This report presents the results of an evaluation of the performance of wetland mitigation efforts taken by several State departments of transportation around the country. These mitigation efforts, taken in response to State and Federal requirements to protect wetland values, have attempted to compensate for wetland impacts directly and indirectly related to highway construction projects. The FHWA and State participants in this "pooled research study" were concerned that little had been done to monitor the various mitigation projects to determine whether or not the desired goals had been met, or whether there had been any unforeseen impacts (positive or negative) which have occurred as a result of the mitigation.

This report analyzes 17 mitigation projects in 14 States, comparing them to natural control wetlands to evaluate the effectiveness of the mitigation to perform wetland functions and values. Mitigation projects include six sites where existing wetland systems were enhanced, six sites where wetlands were created from uplands, two sites which were combinations of enhancements and creation, and three sites where existing wetlands were restored. The efficiency of a wetland to perform a number of functions and values was evaluated to determine success. Field biologists used a number of assessment techniques, including the Wetland Evaluation Technique (WET 2.0) and the Hollands-Magee assessment models. Conclusions and recommendations for wetland mitigation are made. Success was found to be less related to mitigation type (i.e. enhancement, restoration or creation) than the adequacy of Planning, Design Elements and Implementation/Follow-through.

FHWA-RD-90-084, Volume II: Field Data Sheets, contains WET 2.0 and Hollands-Magee data sheets, as well as plant species list from sites studied.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

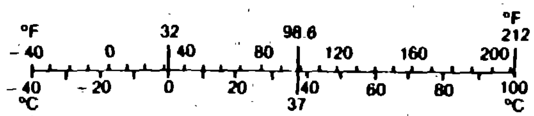
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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PURPOSE AND SCOPE

In October 1988 the Federal Highway Administration (FHWA) began a study of selected wetland mitigation efforts taken by several State Departments of Transportation around the country. These mitigation efforts were designed to compensate for wetland impacts, directly and indirectly related to highway construction, in response to State and Federal laws, regulations, policies and Executive Orders. The FHWA and State participants in this "pooled research study" were concerned that little had been done to monitor the various mitigation projects to determine whether or not the desired goals had been met, or whether there had been any unforeseen impacts (positive or negative) which had occurred as a result of the mitigation. The FHWA estimated that there were several hundred significant wetland mitigation efforts that were over 5 years old, and felt that it was desirable to evaluate some representative projects to determine the effectiveness of the mitigation, as a guide for future efforts in this area.

Wetlands occur in all 50 States, and highway projects have affected a wide range of wetland types. Representative of the range of geography and wetland types, 15 States participated in the "pooled research study" with the FHWA including the Department of Transportations of Florida, North Carolina, Maryland, New Jersey, New York, Pennsylvania, Ohio, Michigan, Illinois, Minnesota, Wisconsin, Iowa, Washington, Oregon and California. Of 58 sites nominated by the participating States, 17 primary and 6 secondary mitigation projects were selected in 14 of the 15 participating States.

The study was designed to accomplish the following:

- Review and evaluate wetland mitigation types and methods associated with selected highway construction projects.
- Determine the relative effectiveness of selected types of wetland mitigation to the extent possible with the sites studied.
- Document the results of the study.
- Provide guidelines directed at enhancing effectiveness, including cost effectiveness, of various methods of wetland mitigation.

The study was also intended to provide a field test of the Wetland Evaluation Technique (WET), Version 2.0. This study provided an opportunity to evaluate the practicability and effectiveness of this model for assessing wetland functions and values in a variety of wetland types and biomes. At each primary site another functional assessment model, the Hollands-Magee model, was also performed in order to compare and contrast to the WET 2.0 method.[1,2]

BACKGROUND INFORMATION

1. Mitigation Policy and Regulatory Policies

Providing a safe, economical and reliable transportation system is one of the responsibilities of State departments of transportation and highway agencies. The construction, operation and maintenance of highways to meet this requirement requires these agencies to comply with a number of Federal, State and sometimes local environmental statutes, procedures and policies. Some of these environmental regulations are aimed specifically at the protection of wetland resources that may be directly or indirectly affected by highway routing and construction.

Wetland Regulation

Wetland regulation has been evolving for about the last 15 years, as has the science of defining, delineating, categorizing and assessing wetlands and their functions and values. Considerable attention has been directed at predicting and evaluating wetlands impacts and mitigating wetland losses, although the science of wetland replacement is still in a developmental stage.

There are a number of different definitions of wetlands. Two commonly cited definitions originate from the U.S. Fish and Wildlife Service and the Clean Water Act.[3,4]

The U.S. Fish and Wildlife Service defines wetlands as:

> "..lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.... Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Wetlands are defined in section 404 of the Federal Water Pollution Act of 1972 (33CFR328), as amended by the Clean Water Act of 1977:

"The term 'wetlands' means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

The Clean Water Act's objective is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. Section 404 of the Clean Water Act is the primary Federal mechanism regulating wetlands. It authorizes the Corps of Engineers (COE) to establish a permit system to regulate the dredging and filling of materials in "waters of the United States" which include freshwater wetlands in or adjacent to navigable waters such as lakes, rivers, and streams. Anyone who proposes to discharge dredge or fill material into waters of the United States must first obtain a Federal permit. The COE dredge and fill regulations provide specific guidance (33 CFR 320 - 330), although the Corps reviews wetland permits on a case-by-case basis since wetland systems are unique and different impacts result from different types of developments.

The U. S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service, and the Environmental Protection Agency (EPA) provide comments and input to the Corps 404 regulation. The EPA has promulgated environmental guidelines under Section 404(b)(1) of the Clean Water Act which provide guidance for the issuance or denial of permits by the COE.

Other Federal requirements which directly or indirectly regulate wetlands include, but are not limited to:

- Section 10 of the Rivers and Harbors Act.
- Presidential Executive Order 11990, Protection of Wetlands.
- U. S. Environmental Protection Agency 40 CFR 230, Interim Regulations on Discharge of Dredged or Fill Material Into Navigable Waters.
- Coastal Zone Management Act.
- National Environmental Policy Act and implementing procedures of the Council on Environmental Quality (CEQ).
- Clean Water Act Section 401, water quality certification.

Highway projects which impact wetlands through discharge of fill are regulated by Section 404 and permits may be required. In addition, the U.S. Department of Transportation has issued policies to address wetland protection and mitigation. Order 5560.1A, Preservation of the Nation's Wetlands, states that "transportation facilities and projects should be planned, constructed, and operated to assure the protection, preservation, and enhancement of the Nation's wetlands to the fullest extent possible."

Mitigation

The mitigation of wetland impacts is an integral part of the regulatory process. The Council on Environmental Quality has defined mitigation (40 CFR 1508.20) as actions that avoid, minimize, reduce, rectify, or compensate for the adverse impacts of development. These have been combined in the February 1990 Memorandum of Agreement (MOA) between the Corps of Engineers and Environmental Protection Agency into three general types: avoidance, minimization and compensatory mitigation.

Under this MOA, every effort must be made by parties seeking 404 permits to first avoid wetland impacts, and then to minimize impacts (e.g. - by project modifications and/or permit conditions). Compensatory mitigation will be allowed only for unavoidable adverse wetland impacts. While restoration, enhancement and creation are all possible compensation, on-site mitigation is preferable to off-site, and in-kind is preferable to out-of-kind (i.e. - wetland functions and values).

The Federal Highway Administration and the Fish and Wildlife Service have issued policies to address wetland mitigation:

- FHWA Policy 23 CFR 777, Mitigation of Environmental Impact to Privately Owned Wetlands.
- U. S. Fish and Wildlife Service Wetlands Mitigation Policy, FR46(15): 7644-7663.

Current national directions of wetland protection are reflected in the final report of the National Wetlands Policy Forum, a policy review convened by the Conservation Foundation.(5) The Forum recommended that:

> "...the nation establish a national wetlands protection policy to achieve no overall net loss of the nation's remaining wetlands base, as defined by acreage and function, and to restore and create wetlands, where feasible, to increase the quality and quantity of the nation's wetland resource base."

In addition to these Federal regulatory requirements, several States have established strong wetland protection programs (e.g. - Maryland, New Jersey, Washington, New York) and others are being revised. In most States, wetland permits must be obtained in addition to Section 404 permits, or the State may protect wetlands through a State environmental review program, Section 401 Water Quality Certification or a coastal zone management program. The State permits and requirements that affected the 17 study wetland projects are discussed under the individual site descriptions.

Taken together, these Federal and State regulations are indicative of the evolving focus on wetland protection, with mitigation of wetland values as a major component of these regulations. The 17 wetland mitigation projects evaluated for this study were completed generally in the 1984 through 1988 time period. They were built before the 1988 "no net loss" recommendations and the 1990 COE-EPA MOA, but nevertheless represent techniques and methods which are current state of the art in wetland mitigation science.

2. Mitigation Definitions

The continual evolution of wetland regulation and wetland science have contributed to a number of different definitions to describe the various aspects of wetland mitigation. The broad term mitigation, according to the CEQ regulations (40 CFR 1508.20), includes avoidance, minimization, reduction, rectification, and compensation. For purposes of this study, however, wetland mitigation sites selected were in the rectification and compensation area of mitigation that CEQ defines as follows:

- Rectifying the impact by repairing, rehabilitating or restoring the affected environment.
- Compensating for the impact by replacing or providing substitute resources or environments.

In the interests of standardization, this study has attempted to use the following definitions of mitigation by Lewis.[6]

- Restoration - "returned from a disturbed or totally altered condition to a previously existing natural, or altered condition by some action of man. Restoration refers to the return to a preexisting condition. It is not necessary to have complete knowledge of what those preexisting conditions were; it is enough to know a wetland of whatever type was there and have as a goal the return to that same wetland type. ...It is...important to define the goals of a restoration project in order to properly measure the success."

- Rehabilitation - "the conversion of uplands to wetlands where wetlands previously existed....the goal is...conversion to a new or altered wetland that has been determined to be "better" for the system as a whole...."

- Creation - "the conversion of a persistent non-wetland area into a wetland through some activity of man. This definition presumes the site has not been a wetland within recent times (100-200 years) and thus restoration is not occurring. Created wetlands are subdivided into two types: artificial and man-induced. An artificial created wetland exists only as long as some continuous or persistent activity of man (i.e., irrigation, weeding) continues. Without attention from man, artificial wetlands revert to their original habitat type. Man-induced created wetlands generally result from a one-time action of man and persist on their own. The one-time action might be intentional (i.e. - earthmoving to lower elevation) or unintentional (i.e., dam building). ...."

- Enhancement - "the increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values. ...The intentional alteration of an existing wetland to provide conditions which previously did not exist and which by consensus increase one or more values is enhancement. The diking of emergent wetlands to create persistent open-water duck habitat is an example; the creation of a littoral shelf from open water habitat is another example. ..."

3. Mitigation Goals

The regulatory permits under which the 17 projects studied were authorized and built often did not have specified goals. Permits were often non-specific, without restoration plans or conditions.

This lack of permit conditions and goals matches observations that "most wetland restoration and creation projects do not have specified goals, complicating efforts to evaluate 'success'".(7) Quammen noted that "The common reason for the difficulty in defining successful habitat and functional replacement was the lack of clearly stated restoration objectives in the permits conditions or restoration plans. The permit conditions...often stated only that the habitat lost be restored or created elsewhere, but failed to; clearly define what was lost; acknowledge the variability among natural marshes; or identify the functions or habitats most in need of replacement or restoration. The failure of permit conditions to state restoration objectives or provide sufficient technical detail about restoration design makes it difficult to develop success evaluation criteria."[8] Josselyn, Zedler and Griswold reviewed wetland mitigation along the Pacific Coast and noted that in the popular view, success was often "...a function of permit enforcement [i.e. was the project finished] rather than the effectiveness of the restoration or enhancement plan."[9] Another common measurement of wetland success amounts to measuring vegetation establishment (species and percentage of the site covered) for a defined period of time.

Kusler and Kentula recommend that "Ideally, success should be measured as the degree to which the functional replacement of natural systems has been achieved."[7] This additional definition by Lewis is germane:[6]

- Success - "Achieving established goals. ...success in wetlands restoration, creation, and enhancement ideally requires that criteria, preferably measurable as quantitative values, be established prior to commencement of these activities. However, it is important to note that a project may not succeed in achieving its goals yet provide some other values deemed acceptable when evaluated. In other words, the project failed but the wetland was a "success"....In situations where poor or nonexistent goal setting occurred, functional equivalency may be determined by comparison with a reference wetland, and success defined by this comparison..." [emphasis added].

Because the goals of the mitigation were often non-specific this study attempted to utilize Lewis' recommendation, as well as other available information. Therefore to evaluate the "success" of the mitigation efforts at the 17 sites, this study relied on both the informal goals and expectations of the biologists who worked on these projects, as well as a comparison of wetland functions and values in the mitigated wetland and the original undisturbed wetland where ever possible to determine if a measure of success was achieved.

TECHNICAL APPROACH

1. Site Selection

The study was intended to provide specific case examples of the relative effectiveness of various types of mitigation in different geographic settings, in order that the results of the study would have the widest possible applicability to future wetland mitigation efforts. Sites were nominated by participating pooled States for inclusion in the study. These sites represented a wide spectrum of ages, sizes and mitigation methods. There were a number of freshwater tidal wetlands and salt water sites, with the largest number being inland freshwater wetlands.

A preliminary sort was made from the 49 initial nominees. Using a customized database, sites were sorted and reviewed according to a predetermined set of selection criteria, including:

- Location by State and region of the country.
- Availability and completeness of preconstruction and construction data.
- Representativeness of wetland type and mitigation type.
- Proximity to suitable Natural Control Sites and other sites studied in the State and region.

Criteria were based on experience with wetland mitigation, as well as the results of an EPA study.(10)

Recommended sites were initially identified as potential primary or secondary sites. Primary sites were to undergo the most detailed and extensive evaluation, and would be paired whenever possible, with natural control sites to allow a comparison of the mitigated wetland's functions and values with those of a local, natural wetland. Secondary sites were selected as backup locations, as well as sources of subjective wetland information.

Location

In selecting primary sites, every reasonable attempt was made to establish at least one site in each of the participating States. This was felt important in discerning differences between States regarding regulatory influences, methods used, as well as providing feedback to participating State agencies.

The most appropriate natural control site would be the original wetland disturbed by the highway construction if it were available. In some cases where the disturbance was confined to a small portion of a large wetland, it was appropriate to use the present original wetland as the Natural Control for that project (e.g. - the Rancocas Creek, NJ site).

Availability of Data and Site Background

The recommended sites where the most complete background information was available were preferred. In addition to the essential items, such as aerial coverage, ground photos, topographic maps and soil surveys, the preconstruction base line measurements or studies were vital to the study. Similarly, information on soils, water levels, grading plans, planting and top-dressing specifications, costs, weather records, outside influences (e.g. - stream flows, mowing, spraying) were all important. Environmental Impact Statements (EIS), Environmental Assessments (EA) and/or other environmental reports were helpful in compiling related natural resources, such as fisheries and waterfowl.

Postconstruction monitoring, photographic control points, sample transects, etc. were also important in assembling a packet of information on each site. Permit conditions and contracts, if any, were solicited. If the site was built with a goal in mind, or a goal incorporated in a permit, then the chances were much better that there would be good documentation and information on follow up studies.

Age was a limiting factor. Generally, the older and more stabilized a wetland site was, the better. If a site was younger than two growing seasons, it was generally felt not mature in vegetative growth to provide an indication of success.

Representativeness

An attempt was made to select sites most representative of the mitigation methods and techniques used most often in each State. This was based on the projects submitted by the cooperating States, discussion with State representatives and experience of the wetland scientists. For this reason, the number of salt water sites was restricted, while there were a large number of enhancement/creation projects, especially borrow pit conversions.

Proximity

In addition to the proximity of primary sites to appropriate natural control sites, logistic considerations influenced the selection process. Sites were grouped or clustered in a region of the country as much as possible to maximize on-site time.

Final Selection

The 49 initially nominated sites were narrowed down to 12 and divided into categories by mitigation type and geographic representation. Recommended at this second cut were three enhancements, two restorations, and seven creations (or what appeared at this stage to be creations) - two from borrow pits and five from upland. These were further divided into east coast, midwest, and west coast.

In April 1989 representatives of each of the pooled States, the FHWA, EPA, COE and the contractor met to review the first round selections and to discuss the goals of the study in view of these recommended sites. This discussion of study goals took a considerable amount of time because of the different perspectives that each State brought to the study. For example, several eastern States felt that any effort to study enhancement would be unproductive, since ratios for enhancement set by the regulators that they had to deal with were so high as to make that mitigation technique prohibitive.

States introduced additional nominees for study, and had an opportunity to defend their preferred sites. Fifty-eight sites were eventually nominated. Of these, 15 primary sites were selected in 14 States, with 9 secondary sites. Later, as the principal investigator (PI) and the field team visited each site, additional judgements were made, and 2 additional primary sites were studied, for a total of 17 primary sites and 6 secondary sites.

To the extent possible, wetland mitigation sites were selected to be representative of typical mitigation opportunities for a wide selection of States. Also, the mitigated wetland sites were chosen so that there was an undisturbed portion of the original wetland nearby to contrast to the mitigation project using the two functional assessment techniques. The intent of the comparison was to determine if the new wetland achieved a functional equivalency with the reference wetland.

When the study was concluded, 17 primary sites had been studied, including 6 creations, 6 enhancements, 2 combination creation/enhancements, and 3 restorations. Primary sites were located, one each, in Florida, North Carolina, New Jersey, Pennsylvania, New York, Michigan, Minnesota, Wisconsin, Iowa, Washington and California. Two sites each were studied in Maryland, Illinois and Oregon. Six secondary sites in six States were also studied.

2. Data Collection

Data collection took place in three phases. From the information gathered on each site, preparations were made in the office to identify potential problems, data gaps, and to anticipate the review of the site with the WET 2.0 technique.

The principal investigator then visited primary and secondary study sites, usually in company with a representative of the State DOT. Additional information was obtained from the State and other agencies, and an effort was made to identify local wetland experts and regulatory contacts for later interviews by the field team. Selected changes in study sites and/or control sites were made at this point, as well as later during the field team's data collection visits, when it appeared that the original study plan could not be carried out as planned.

Following the PI's initial visit, a team of two to three wetland scientists visited each primary/control site pair, spending up to a week interviewing State and Federal officials, completing a level 1 and 2 WET 2.0 analysis, a Hollands-Magee assessment, preparing a plant species list, photographing and videotaping the site, and generally assessing the success (or lack thereof) of the planned mitigation measures. The secondary sites were also visited and subjective evaluations were made of the success or failure of mitigation.

3. Data Analysis

Following the field collection, information gathered was analyzed to determine, among other things, (1) whether the mitigation was necessary; (2) if the mitigation was successful in accomplishing the desired goal; (3) whether there were unanticipated impacts, either positive or negative, to the wetland due to the mitigation; (4) if the mitigation effort went further than required to achieve the desired goal; (5) the relative cost of the mitigation; and (6) if there were other alternatives to the mitigation which would have been as or more effective.

4. Functional Assessment

In order to evaluate the effectiveness of mitigation measures, this study was designed to compare the functions of enhanced, created or restored wetlands with the functions of those wetlands that they were intended to replace, irrespective of wetland type (i.e. forested, emergent, etc.). Two sets of models were used to aid in the functional assessment of the mitigation and the impacted wetlands in this study: the Wetland Evaluation Technique and the Hollands-Magee wetland assessment models. This section presents an introduction to these models and the assumptions on which they are based.

Wetland Evaluation Technique (WET 2.0)

The Wetland Evaluation Technique, Version 2.0 is a revision of the Method for Wetland Functional Assessment, Volume II published by the Federal Highway Administration.[1,11] A computer program for model analysis was developed by the Wetland Research Team at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) for use with Version 2.0.

WET 2.0 (hereafter referred to as WET) is a set of models that process 'yes' or 'no' answers to questions designed to relate a wetland's physical, chemical, and biological characteristics to the body of scientific literature dealing with wetland functions. A list of these questions for the evaluation levels used in this study is in appendix B. The result for each function is a qualitative rating (High, Moderate, or Low) of the probability (in non-statistical usage) that the wetland serves that function. In other words, the model assesses only the likelihood that a function is provided at all by the wetland, not the degree to which it is provided. The proper interpretation of WET results relies on that important distinction. The WET authors acknowledge that assessment of the actual capability of a wetland for serving a function will usually require quantitative data and the professional judgement of technical experts.

Wetland functions are evaluated by WET in terms of Social Significance, Effectiveness, and Opportunity. The Social Significance Models assess the likelihood that actual social or economic benefit will accrue if a function is performed by the wetland. The models focus on features in the downstream waterbodies and floodplains, and general ecological and social characteristics of the immediate locale and the region as a whole. The Effectiveness Models assess the physical and biological characteristics of the wetland itself and its immediate surroundings that affect its capability to perform a function. The Opportunity Models look at the characteristics of the upslope watershed to determine whether the wetland will have the opportunity to perform a function. For example, for the Floodflow Alteration function the physical characteristics of the wetland determine its effectiveness at altering floodflow; characteristics of the downslope watershed (presence of a town, agricultural land, etc.) determine the Social Significance of the flood protection provided by the wetland; the ability of the upslope watershed to create flood conditions determines the opportunity of the wetland to perform the function.

Evaluation Areas

The delineation of the area to be assessed by the WET Models is very important to the model results. In general, WET Assessment Areas (AA's), are to be identified as areas having "a high degree of hydrologic interaction and interdependence (i.e., unconstricted movement and interchange of surface water)." An AA is easily delineated when the wetland is in a small, well-defined topographic depression. When the wetland is large, however, or is characterized by complex surface hydrology, a practical delineation is more difficult. The WET manual sets forth procedures for delineating AA's when the wetland is very large, or when it borders a lake or river. For very large wetlands with no discernible hydrologic discontinuity, somewhat arbitrary AA boundaries may be imposed to delineate an area that is practical for field review and functional assessment.

In the case where a small portion of a larger wetland is to be evaluated - for example, an enhancement or restoration site - an Impact Area (IA), is delineated and evaluated within the context of the larger wetland. Since delineation of an IA usually violates the WET delineation assumptions of hydrologic interaction, model results should be interpreted with caution.

Delineation of watersheds for most wetlands is straightforward. WET offers special guidelines for identifying watersheds of wetlands bordering large water bodies. In some cases, the watershed of the contiguous water body is included; in other cases it is not. The WET manual is not explicit in its rationale for these differences.

For most wetlands with a surface water outlet, WET evaluation calls for the identification of one or several Service Areas. A Service Area is the downstream area which might benefit from a particular wetland function. For example, the Service Area for the Sediment/Toxicant Retention Function may be a downstream dredged channel or fishery. A wetland without a surface water outlet is not assigned a Service Area. Since WET Model ratings for most of the Social Significance Function depend largely on charateristics of the Service Area, wetlands lacking an outlet are likely to receive Low ratings.

The WET authors recognize the limitations of the method and recommend careful interpretation of the results. Several cautions are offered here for the interpretation and use of WET Model results. (1) The Low, Moderate, and High ratings merely signify probabilities that a function is served at all by the wetland, not the degree to which it is served. (2) The identification and delineation of Assessment Areas and Service Areas is subject to some variation based on different but equally valid assumptions. Such differences can have large implications for the model results. (3) For many of the WET questions, more than one answer appears to be equally valid (depending on interpretation), yet the answer may be pivotal in the model's logic sequence.

Certain of the model results may thus be critically influenced by the evaluator's interpretation of and assumptions regarding a single question. (4) The WET manual offers few guidelines for the use of WET to compare wetlands, except to caution that WET does not produce a value judgement; that is, it cannot be concluded from WET results that one wetland is better than another.

The WET authors further caution that the models are not directly based on measured, statistically-tested data, but rather on intuitive interpretations of the technical literature available during the period when WET was compiled. The deficiencies in that literature base will be reflected in the WET results. Thus, the results are not intended to be used alone, but in conjunction with quantitative data, if available, and expert opinion. Statistical terms, such as probability and significance, are used throughout the WET document and throughout this report in a non-statistical sense.

Presented below is a brief outline of some of the assumptions and variables used by each of the WET Models, and the rationale for the weighting of the most pivotal variables.

Social Significance

The Social Significance Models are designed to assess the likelihood that social and economic benefits will accrue if a function is performed by a wetland. They look at special natural or cultural features within the wetland itself; adjacent and downstream features that might be aided or harmed by the wetlands presence; and general characteristics of the regional and local landscape. Several variables are considered by WET to be particularly important predictors of social value, and are pivotal in many or all of the Social Significance Models: (1) if the wetland is part of a wetland system that is uncommon in the region (e.g., lacustrine in a semi-arid region) its scarcity alone gives it some social value; (2) if the wetland is the closest wetland to the Service Area for a particular function, it is expected to have particular importance to that Service Area; (3) if the wetland is located in an urban area, it is expected to be socially valuable due to its accessibility, its high use potential, and its relative scarcity; (4) if the wetland is located in a State or region that is losing wetlands more rapidly than the nation as a whole, the social value of the remaining wetland is presumed to be magnified; or (5) if the wetland's acreage represents a significant proportion of the total wetland acreage in the Service Area's watershed (i.e., a proportion greater than the State's annual wetland loss rate) its importance to that Service Area is presumed to be enhanced. (A rationale for this latter calculation is not offered in the WET manual.)

For most of the Social Significance Functions, a wetland must possess at least one of the attributes described above to receive a High probability rating. Described below are other variables considered by each of the models.

The Groundwater Recharge Model looks for the presence of high-yield wells or important aquifers in the Service Area. The Groundwater Discharge Model considers the presence of wetland-dependent rare species in the Service Area, and the occurrence during dry years of low downstream flows that are critically limiting to fish and wildlife. The Floodflow Alteration Model confers a Low rating on any wetland containing or adjacent to pollution sources, or features of social or economic value for which flooding would pose a hazard. On the other hand, such features in the downstream floodplain will magnify the social value of any flood storage or desynchronization provided by the wetland. Similarly, the Sediment/Toxicant Retention Model looks for downstream features that might benefit from reduced sediment or toxicant outflow from the wetland. Some examples of such features are: channels or other water bodies that are regularly dredged; fish spawning areas or commercial shellfish beds; areas in violation of official water quality standards; or surface drinking water sources. The Nutrient Removal/Transformation Model considers these last two features as well as presence of high-nutrient waters or the use of downstream waters for swimming. The Sediment Stabilization Model looks for features of social or economic value for which the wetland might act as a buffer from erosion or wave action. The Wildlife Diversity/Abundance Model looks for the presence in the wetland of rare or important species or habitats, official recognition of the wetland's importance to waterfowl, or its ability to command user fees for consumptive or non-consumptive use of wildlife. The Aquatic Diversity/Abundance Model looks for the presence of rare fish species or rare habitats; fish species on the USFWS National Species of Special Emphasis List; official recognition of its fishery value; or the presence of a commercial fishery or shellfishery. The Uniqueness/Heritage Model confers a High rating on any wetland that supports rare species, habitats, or natural features; that is an important historical or archaeological site; that is managed for ecological conservation or low-intensity recreation; that is part of a pristine natural area; that is near and accessible to an educational facility for educational value; that has been the subject of substantial expenditures for ecological enhancement; or that is part of and essential to an ongoing environmental research or monitoring program. All of the mitigation wetlands in this study qualify for a High rating on the basis of one or both of the latter two criteria. The Recreation Model considers regular recreational use of the wetland, or the presence of an access point to a major recreational waterway.

Effectiveness

The Effectiveness Models are designed to assess the likelihood that a wetland is capable of performing each function. They look at hydrologic, topographic, geologic, chemical, and biological characteristics of the wetland in its local setting. WET provides for three levels of evaluation for Effectiveness. Levels 1 and 2 rely on maps, documents and field observations. Level 3 requires quantitative physical, chemical and biological data, in some cases involving long-term studies. Only levels 1 and 2 assessments were conducted for this study.

Described below are the most important variables considered by each of the Effectiveness Models.

WET recognizes that many wetlands serve both Recharge and Discharge Functions depending on seasonal and hydrologic factors, and even on substrate and surficial geologic factors in different areas within the same wetland. Without on-site, long-term hydrographic monitoring it is difficult to assess the actual nature of groundwater exchange. The Groundwater Recharge Model looks for conditions favoring net annual recharge to underlying groundwater; that is, where recharge exceeds discharge on a net annual basis. A High probability rating is possible only if a level 3 assessment is conducted. In the absence of such data, WET assumes a Low probability for recharge if (1) there is easily observable evidence of groundwater discharge, such as springs, or the presence of an outlet but no surface water inlet; (2) there are significant barriers to recharge, such as low permeability of underlying strata; or (3) there are other observable conditions unfavorable to recharge, such as a local topography suggesting a low elevation head or a low pressure head. Also, riverine tidal, estuarine, and marine wetlands are assumed to have a low recharge probability. Wetlands with none of the above attributes and for which level 3 data has not been collected will receive an Uncertain rating.

The Groundwater Discharge Model assesses the likelihood of net annual discharge of groundwater. Most permanently flooded, nontidal wetlands are assumed to have a High probability for discharge. It considers such variables as local topographic features that might influence groundwater exchange, the permanence of standing water, the relative size of the wetland's watershed, the stability of channel flow and areal extent of flooding, and the presence of upstream impoundments likely to influence the water table.

The Floodflow Alteration Model addresses only the probability that flood storage or desynchronization will occur at the site; it does not address storage capacity or the downstream effects of increased lag time. In regions having distinct seasonal variations, the model focuses on wet season conditions. The most important variables considered are presence and nature (e.g., constricted? artificially regulated?) of inlets and outlets; predominant hydroperiod; sinuosity of channels; soil infiltration rates; presence of woody vegetation; size; and areal extent of flooding. All riverine tidal, estuarine, and marine wetlands will receive Low ratings, as they are assumed to act as significant buffers only during mild storm surges at low tide.

The Sediment Stabilization Effectiveness Model combines both Opportunity and Effectiveness considerations. Only wetlands subject to significant erosive forces or conditions - such as high water velocities, long fetch, high waves or steep erosive banks - are eligible for a High probability rating. The model looks for vegetative and substrate conditions that will bind soil, create a depositional environment, and provide frictional resistance to erosive forces. It considers such variables as width and nature of the vegetated zone, instream water-vegetation interspersion, substrate, and areal extent of open water. Wetlands with no flowing water, little open water, and no inundated vegetation will receive Low ratings.

The Sediment/Toxicant Retention Model assesses the likelihood that a wetland will retain sediments and toxicants on a net annual basis. It looks for conditions creating a depositional environment, such as constricted or dammed outlets; slow velocities; broad zones of erect vegetation; long duration or expansive seasonal flooding; short fetch; great depth; brackish (flocculating) conditions with aquatic bed vegetation; or channels with good pool/riffle ratios or instream debris.

The Nutrient Removal/Transformation Model assesses the probability that a wetland will retain in the sediments or transform inorganic phosphorus or nitrogen into their organic forms, or transform nitrogen into its gaseous form (denitrification) on either a seasonal or net annual basis. The WET authors recognize that factors governing nutrient cycling between the substrate, vegetation, water column, and the atmosphere are complex and poorly understood. Consequently, this model takes a fairly broad approach to the question. It assumes that conditions conducive to sediment retention are also favorable to nutrient removal and transformation. It also looks for fine mineral substrates, high aluminum or iron concentrations (for phosphorus removal), vegetation class richness, and permanent flooding or saturation.

The Production Export Model assesses the probability that large amounts of plant material are exported from a wetland to downstream surface waters. Although this function is generally related to food chain support, WET does not attempt to determine whether such export will necessarily benefit either the downstream habitat or the wetland itself. Any wetland with a permanent outlet and with conditions favoring high primary productivity is assumed to have a High probability for production export. The model looks at such features as the breadth of the vegetated zone, the breadth of the inundated emergent zone, the erosion potential (rainfall erosivity), water velocities, substrate, water/vegetation interspersion, artificial water level manipulation; levels of suspended solids, and size of watershed. In regions having distinct seasonal variations, the model focuses on wet season conditions. Only wetlands lacking an outlet will receive a Low probability rating for this function.

All of the Wildlife Models address habitat conditions for wetland-dependent birds only. No other wildlife species are considered. The model assessing Wildlife Diversity/Abundance for Breeding looks for breeding season habitat favoring diversity and/or abundance of breeding birds. It considers such variables as surrounding land use and cover types, regional precipitation, toxin sources, wetland size, amount of open water and degree of interspersion and vegetation classes present.

The models assessing Wildlife Diversity/Abundance for Migration and for wintering consider similar combinations of variables to evaluate bird habitat during spring and fall migration seasons, and during the winter. Both models consider the wetland's juxtaposition with other wetland systems, water bodies, cover types and land uses; vegetation types, diversity, and interspersion; regional precipitation, size, substrate, presence of food species, and degree of human disturbance. Any non-evergreen wetland that remains frozen for more than 1 month during the winter will receive a Low probability rating for wintering habitat.

The Aquatic Diversity/Abundance Model assesses seasonal conditions affecting on-site diversity of fish and aquatic invertebrates. It considers such features as substrate, hydroperiod, toxin sources, water/vegetation and vegetation class interspersion, pH, and water level manipulation. In estuarine wetlands the model also considers regional storm intensity, and diversity of salinity conditions.

Opportunity

Only three functions are evaluated for their Opportunity potential: Floodflow Alteration, Sediment/Toxicant Retention, and Nutrient Removal/Transformation. The Opportunity Models focus primarily on characteristics of the upslope watershed to determine whether the wetland will have the opportunity to perform a function.

The Floodflow Alteration Model assesses a wetland's strategic location for intercepting floodflows. It considers such variables as size of watershed, character of watershed, land uses and soils, (e.g., urban? impervious surfaces? forested?), and the acreage of upstream wetlands. Marine, estuarine, and tidal riverine wetlands are given Low probability ratings because they are downstream of most floodable properties.

The Sediment/Toxicant Retention Model assesses the likelihood that a wetland will receive elevated levels of suspended solids or toxicants from point or non-point sources. It looks at the size and land cover of the upslope watershed, the acreage of upslope wetlands, observed on-site levels of suspended solids, and a suggested list of sediment or toxin sources, including: stormwater, industrial, or sewage outfalls; irrigation return waters; exposed soils; severely eroding banks; surface mines; landfills; pesticide-treated areas, and heavily traveled highways.

Similarly, the Nutrient Removal/Transformation Model looks for potential point or non-point sources of nutrients entering the wetland. It looks at similar general watershed characteristics as those listed above for the Sediment/Toxicant Model. Suggested nutrient sources are: sewage outfalls; agricultural tile drains; active feedlots or pastureland; fertilized soils; cleared land; septic fields; phosphate mines; or adjacent residential properties.

Hollands-Magee Models

The Hollands-Magee wetland assessment models are designed to evaluate the benefits contributed to the public interest by a given wetland.[(2)] The general categories for assessment are very similar to those evaluated by WET and include: biological production and support, hydrologic support, water quality improvement, and socio-economic functions.

The Hollands-Magee method is made up of 10 separate models. Two of the models, Economic Value and Aesthetic Value were not utilized in this study due to lack of compatibility with the functions evaluated by WET. Each model is designed to reflect the scientific literature and utilizes as inputs those biological and physical characteristics of a wetland (e.g., surface geology, vegetation type and interspersion, etc.) that give rise to a public benefit (e.g., flood storage, pollution control, etc.).

A computer program was developed to tally the raw scores for each model based on input parameters. During computer analysis of results, each parameter is weighted according to its significance based on the technical literature. A numerical score is thereby produced which is adjusted to range from 0 to 100. The score combines estimations of the wetland's potential public value and its present opportunity for providing that value. Scores are not indicative of absolute value, but are useful in making comparisons between wetlands. For example, model scores for New England wetlands are ranked relative to a data base of results from over 1,000 other New England wetlands which have been studied. However, no such data base exists for any other regions.

Therefore, for the purposes of this study, a comparison of raw scores is made only between the mitigation wetland and the impacted wetlands with which it is being compared. The Hollands-Magee models were applied to the same mitigation and control Assessment Areas identified for WET 2.0 assessment, except they cannot be utilized for evaluation of salt marsh systems. The eight models that apply to this study are described below.

The Biological Function Model assesses the role of the wetland in conservation and long term productivity of flora and fauna, determination of species composition, habitat diversity, and stability. The model parameters include those wetland features known to determine the kinds, numbers and relative abundance of animal species, wildlife production and use, and the short and long term importance of a wetland to the life cycles of aquatic and terrestrial species. This model has parallels to the WET Wildlife and Aquatic Diversity/Abundance Models.

The hydrologic utility of a wetland and its role in water supply is related to its capacity to discharge water downstream and maintain base flow during dry periods. The Hydrologic Support Function Model assesses those elements which control the quantity and quality of water discharged by a wetland to downstream water bodies, and includes such parameters as size, basin, shape, and surface hydrology.

The Groundwater Recharge Function Model assesses a wetland's ability to recharge underlying aquifers. Many wetlands seasonally alternate between recharge and discharge. Wetlands in a recharge condition pass accumulated surface water and direct precipitation from the wetland soil down to an aquifer. The model includes such parameters as surficial geology, soils characteristics, size, and surface hydrology.

The capacity of a wetland to play a role in preventing or reducing downstream flooding is assessed using the Flood Storage Function Model which is comparable to the WET Floodflow Alteration Model. Wetlands may contain many natural resource elements which intercept, retain and detain inflowing storm waters so that the outflow has a lower peak volume and occurs over a longer duration. Vegetative characteristics, basin shape, soils, surficial geology, and surface hydrology all influence water retention capability. The model was used to determine each wetland's capacity to store water and retard flows during periods of floodwater discharge.

The Shoreline Protection Function Model assesses a wetland's potential to protect upland areas from erosion due to flowing water and wave action at the edge of water bodies. Such elements as shoreline length, vegetation class and density, and open water fetch and depth are considered. This analysis is comparable to WET's Sediment Stabilization assessment.

The Water Quality Protection Function Model assesses those factors which govern a wetland's capacity to remove suspended and dissolved solids, nutrients and other chemical compounds from water passing through the wetland. Vegetation class and density, basin shape, surface hydrology and wetland size are considered. This essentially is a combination of the factors assessed by WET under the Sediment/Toxicant Retention and Nutrient Removal/Transformation Functions.

The Recreation Value Model assesses the potential of a wetland to be used by the public for fishing, hunting, or passive forms of outdoor recreation. The model includes general wildlife habitat values, amount of open water, size, and accessibility.

The Educational Value Model assesses a wetland's potential to provide educational opportunities to the general public. General habitat values, diversity and uniqueness are key model parameters.

METHODOLOGY

1. Initial Site Visit

An orientation and fact-finding visit was made to each of the primary sites and natural control sites selected during the site selection process. The Principal Investigator met with the State highway representative who had participated in project development if possible, as well as other State and Federal regulators who were involved in some aspect or other of the project.

Additional background data, photos, information, contacts and leads were assembled for the evaluation team. Most importantly, however, the primary and control sites were evaluated in person to see if they met the criteria being developed for the study. If there were questions, after consultation changes were made to the approach, the site, or both.

2. Field Study Methods

Primary Sites

Each of the 17 primary sites was visited by a team of at least two wetland biologists for a period of 2 to 4 days. The first tasks were to choose an appropriate control site and delineate Assessment Areas (AA) for the control and mitigation sites according to WET.[1] The goal in choosing a control was to identify a wetland representative of the type that initiated the mitigation process, as determined from the regulatory agencies, so that the effectiveness of the mitigation measures could be evaluated by comparing the functions of the impacted wetland with the compensatory wetland. All background documentation regarding the mitigation process was reviewed in order to obtain a clear view of the intended outcome. Whenever possible, the control chosen was the undisturbed portion of the wetland that was lost due to the highway construction. If such an area was not available, a nearby wetland similar to the impacted wetland was used as the control. Preconstruction documentation of the impacted resource and/or knowledgeable DOT or other agency officials were consulted to make this decision. If the mitigation package for a particular project involved several different mitigation sites, one or two representative AA's were chosen for functional analysis. Hollands-Magee and WET evaluations at a given site were directed at the same AA.

The watershed was delineated and WET Service Areas identified for each AA before proceeding to collect data for model inputs. Site documentation forms containing this and other pertinent information about each AA were completed (see volume II). All areas were estimated using a dot grid. In addition, the field crew familiarized itself with the site by thoroughly reviewing mitigation plans. DOT project personnel often provided additional information regarding undocumented plan modifications. The level 1 and 2 questions answered at each site for input to WET 2.0 appear in appendix B.

Most of the field observations made at each site can be grouped into categories including hydrological, biological, physical and environmental. Many of these data were utilized in the functional assessment models. Some of the information, such as slope and configuration, was also used to compare the outcome with the objectives of a given mitigation site.

Observations within the hydrological category included aspects such as number and type of surface water connections, water depth and velocity, extent of flooding and water level fluctuation, and presence and type of artificial control structures.

Biological observations covered plant and animal communities, both aquatic and terrestrial. At each AA, dominant plant species were listed (see volume II). Percent areal cover was estimated for each species for the entire AA as an indicator of abundance. Observed wildlife and wildlife sign were also recorded. Habitat aspects such as vegetative cover type diversity, degree of vegetation/water interspersion, cover type interspersion and special habitat features (e.g. resting logs, feeding mounds, structural diversity, standing snags) were noted. Extent of open water, vegetation density and availability of wildlife food plants were also observed and recorded.

Observations at each site concerning physical aspects included characteristics such as substrate type, slope, and overall basin configuration. A soil auger or probe was used to observe the depth of organic matter and aspects of soil development. Bank slopes were measured with a clinometer; underwater slopes were ascertained by measuring rise and run in relation to the water level.

Environmental features such as adjacent land uses, degree and frequency of human disturbance, direct and indirect recreational use were noted at each site. In addition, watersheds and Service Areas were either directly or remotely observed (depending on size) and their characteristics recorded.

In addition to the above qualitative observations, two water quality parameters, pH and specific conductance, were measured at each AA. A hand-held Nester Micromho Pen (Model 10) conductivity meter was calibrated to a standard solution 1000 micromhos prior to each use. An Orion (SA250) pH meter with an ATC probe was used to measure pH. The electrodes were calibrated to two standard solutions before each use. Photographs and videotapes (VHS format) were taken of each site.

Field observations and measurements, mitigation and construction project resource agency personnel, and published information sources (e.g. SCS soil surveys, National Wetland Inventory maps, USGS topographic maps, land use maps, etc.) were all utilized in answering model input datasets. Some inputs were ascertained by contacting sources after leaving the project area.

Secondary Sites

One half day or less was spent at each secondary mitigation site by one or more members of the field team. Three of the six secondary (CA, NY, WI) sites were visited in the company of DOT personnel who provided background that was often lacking in project documentation. Effort was concentrated on evaluating the physical results of the mitigative measures relative to the plans. Dominant vegetation was noted along with the extent and density of emergent growth. Photographs and a videotape were taken of each site. Observations focused on collecting enough information to describe the site and the progress toward stated goals.

3. Functional Analysis and Evaluation

Functional analysis using WET 2.0 consisted of levels 1 and 2 of the Social Significance and Effectiveness/Opportunity evaluations. Answer data-sets were analyzed using the computer software developed by the U.S. Army Engineer Waterways Experiment Station (WES) for that purpose.

The WHY Utility program, also developed by WES, was then used to aid in determining which predictors led to a particular probability rating (H, M, L) in each of the WET 2.0 functional keys for a given Assessment Area. WHY handles this interpretation for Effectiveness and Opportunity evaluations. The same type of interpretive review was conducted manually for Social Significance evaluations, as well as for the full set of model results for certain AA's. In addition to providing an analysis of results, this review provided a final check for the accuracy of answer data set inputs.

WET 2.0 analysis results in a qualitative estimate of the probability that a particular function is performed by a wetland rather than an indication of the actual level to which the function is performed. Therefore, the evaluation of model results focused on probability differences between mitigation and control sites rather than performance levels.

Inputs to the Hollands-Magee models were also made on and analyzed using a computer program. Volume II lists the model parameters and provides a partial legend. Two of the 10 Hollands-Magee models, Aesthetic and Economic Value, were not utilized in this study due to lack of parallel functions in WET 2.0. They were originally developed to address the wetland regulations of the State of Wisconsin and do not have wide applicability.

The numerical scores produced for the functions evaluated by Hollands-Magee are not indicative of absolute value, but are useful in making comparisons between wetlands. Differences in raw scores of 15 points or more between the mitigation and control wetlands were analyzed to determine which model inputs were pivotal in creating these differences.

SITE DESCRIPTIONS AND EVALUATIONS

This section contains a description and evaluation of each of the 17 primary mitigation and control evaluation study sites. The sites are grouped alphabetically according to the type of mitigation attempted, as follows:

- Enhancement of wetland values at six existing wetlands, one each in Florida, Iowa, Illinois (two sites), Maryland and Michigan.

- Enhancement of wetland values in combination with the Creation of new wetlands from uplands at a site in New York and another in Pennsylvania.

- Creation of persistent non-wetland areas into wetlands at six sites, one each in California, Minnesota, New Jersey, North Carolina and Oregon (two sites).

- Restoration of disturbed or altered sites to previous wetland conditions at three sites, one each in Maryland, Washington and Wisconsin.

Each primary mitigation site is evaluated by comparison with a natural control wetland. The area and each primary/control site is described in detail. Methods and conditions specific to a particular site are listed and a summary evaluation is provided.

Wetland evaluation model results are presented in tabular form and are included with with each site's functional analysis discussion in appendix A. In general, only those functions which have model results that differ between the mitigation and control sites are discussed in the functional analysis. This analysis is divided into the social significance, effectiveness, and opportunity categories of WET 2.0.

The Hollands-Magee models are designed to assess all three aspects of each wetland function, as appropriate. However, the focus is on effectiveness; therefore, most of the Hollands-Magee results are discussed under that heading.

WET 2.0 results are shown as a low, medium, or high probability, while Hollands-Magee results appear as point differences (positive or negative) between each mitigation site and its control.

Raw data and analysis output for each of the 17 pairs of study sites are contained in volume II. The information for one site is duplicated in appendix C of volume I for those readers who may not have volume II. The information includes: a listing of dominant plant species and their corresponding abundance; background information, answer datasets and evaluation output for all WET 2.0 analyses; and Hollands-Magee input data and raw scores for all mitigation and control sites.

Six secondary mitigation sites including enhancements, creations and restorations are described in the pages following the 17 primary sites. These are arranged alphabetically by State and include sites in California, Minnesota, New York, North Carolina, Washington and Wisconsin. Secondary mitigation sites area described briefly and evaluated in a general sense based on observations.

Enhancement Sites

1. Lake Hunter, Florida

Introduction

The north leg of the Lakeland North-South Route will be constructed on fill placed along 2,400 ft (732 m) of the western shoreline of Lake Hunter in order to avoid disturbances to a residential area. Although the road construction would not occur for several more years, 16,950 yds^3 (1,296.7 m^3) of fill were placed below ordinary high water line (OHW) during the spring of 1984 to take advantage of a pump-down being conducted by the City of Lakeland for lake restoration purposes. The fill covers 4 ac (1.6 ha) of the 100-ac (39.5 ha) lake. Approximately 1 ac (0.4 ha) will be required for road construction; the remaining 3 ac (1.2 ha) were graded and mulched to enhance Lake Hunter's emergent littoral zone.

Lake Hunter is one of several sinkhole lakes within the City of Lakeland, Polk County, located in central Florida. The lake is surrounded by residential development and is subject to elevated nutrient inputs in the form of runoff from lawns and streets. Lake Hunter's water elevation is controlled by a structure at the outflow on the south end. According to one account, the lakeshore prior to Florida Department of Transportation's (FDOT) enhancement activities, was characterized by a poorly developed emergent littoral zone consisting primarily of elephant ears (*Colocasia esculentum*) and cattails (*Typha* sp.).[12] Another account also lists arrowhead, pickerelweed and sedges.[13] The original width of this vegetated zone is not known. A discontinuous vegetated band ranging between 20 and 40 ft (6.1 and 12.2 m) is visible on aerial photos (10-13-80, 1 in = ± 2000 ft [1 cm ± 610 m]).

Utilization of 2:1 sideslopes minimized the total amount of wetland filling required for construction of the north leg of the Lakeland North-South Route from 8.2 ac to 7.3 ac (3.2 to 2.9 ha). This impact occurs at three locations adjacent to Lake Hunter. Fill amounting to 1.4 ac (0.6 ha) was required along the western shore of the lake as mentioned above. Portions of two wooded wetlands, located at the lake's inlet and outlet, will also be filled. This fill will directly impact 2.2 ac (0.9 ha) at the inlet and 3.7 ac (1.5 ha) at the outlet.

Mitigation Design

The compensatory mitigation plan was developed by FDOT with assistance from the Florida Game and Freshwater Fish Commission (FGFWFC) as specified by the Florida Department of Environmental Regulation (DER) permit. This was the only permit required as the work was covered by a U.S. Army Corps of

Engineers Nationwide Permit. Clean, sandy fill placed below the waterline was to be graded with a 10:1 slope. The initial revegetation plan called for plantings to occur in seven zones referenced to Ordinary High Water (OHW). However, high planting costs necessitated a change in plans. A revised plan (approved by FGFWFC) involved spreading "mulch" or wetland topsoil obtained from preapproved roadside donor sites. The donor sites were chosen based on the presence of the following target species: pickerelweed (*Pontederia lanceolata*), maidencane (*Panicum hemotomon*), arrowhead (*Sagittaria latifolia*) and spikerush (*Eleocharis baldwinii*). The goal was to expand the vegetated portion of the littoral zone with non-invasive native species that would provide cover for fish. Cattails, although native to Florida, are generally considered aes-thetically unpleasant by the local populace. They are quite hardy and their dense growth form tends to exclude other species, reducing plant diversity.

Lake Hunter was drawn down between November 1983 and May 1984 by the City to allow for consolidation and removal of nutrient-rich muck. Filling and grading for enhancement of the western shoreline took place between April and June 1984. The mulching operation was carried out in June and July 1984 and involved collecting and spreading 2,000 yds^3 (1,672 m^3) of wetland topsoil in a 4-in (10-cm) layer over the graded slope. The cost of the entire filling and grading project along the western shoreline was $19,000. Approximately 93,000 ft^2 (8,639.7 m^2) of additional littoral area was created.

Stormwater treatment measures are to be completed as part of the State permit conditions. In an effort to improve lake water quality, the conditions specify that two times the volume of stormwater generated by the new road must be treated prior to entering the lake. However, this element of the mitigation plan cannot be implemented until the roadway is constructed.

Site Descriptions

Mitigation

The assessment area (AA) in Lake Hunter was delineated as a 300 ft (91.4 m) strip around the entire lake according to the method suggested for fringe wetlands in WET 2.0.[1] The forested wetlands to the north and south were not included in this AA based on hydrologic discontinuity. An impact area (IA) was delineated to enable assessment of the segment of the AA encompassing the work. Conductivity and pH were measured at the lake's outlet.

Lake Hunter's watershed is approximately 575 ac (227 ha) and is urban in nature. Its service area has been designated as the channelized outlet stream to the downstream end of the trailer park located on Ariana Street.

When field work was conducted on May 16 through 18, 1989, the resculptured western shoreline of Lake Hunter was characterized by a 12 to 15 ft (3.7 to 4.6 m) band of persistent emergent vegetation. Dominant species included elephant ear, water pennywort (*Hydrocotyle umbellata*), alligator weed (*Alternanthera philoxeroides*), panic grass (*Panicum* sp.), water primrose (*Ludwigia octovalvis*) and southern cattail (*Typha domingensis*). A complete plant species list is attached in volume II.

The substrate was fine to medium sand with a thin, unconsolidated organic detritus layer blanketing the vegetated portion. Near shore the vegetated slopes within 12 to 18 ft (3.7 to 5.5 m) range from 5:1 to 9:1. The more gradual slopes were found at the northeast end of the project.

Lake Hunter is bordered on three sides by a heavily used walking trail set in a park-like landscape. Small trees dot the well-manicured lawn which is mown well into the saturated zone of the lake edge. A small boat ramp at the north end of the mitigation project has been fenced off, but recreational fishing occurs from the shore. Figure 1 shows the location and configuration of the evaluation areas.

Control

The basic goal of the mitigation work was to enhance the littoral zone rather than to replace the functions of the impacted forested wetlands. Therefore, the control AA was chosen to provide an estimate of the conditions and functions of the original shoreline of Lake Hunter. Based on a discussion with the FGFWFC, Lake Bonnet was chosen as the control AA. Lake Bonnet is located approximately 1 mi (1.61 km) northwest of Lake Hunter. It is a sinkhole lake with a controlled water level and has a fringe wetland dominated by cattail. The AA was delineated in the same manner as for Lake Hunter (figure 1). The fringe wetland around Lake Bonnet ranges from 10 to 50 ft (3.0 to 15.2 m) in width (mostly less than 20 ft). Underwater slope is approximately 4:1. Water quality was sampled at the lake's outlet.

The watershed of the control AA is approximately 660 ac (261 ha) and encompasses a large wooded swamp, sloping meadow, and heavy residential and commercial development. This AA's service area has been designated as the lake's outlet from the dam to Wabash Road. This portion of the stream (unnamed) is channelized and flows through a trailer park.

Field work for this study was conducted on May 16 through 18, 1989. All wetland units were visited and photo-documented, and general observations were made regarding dominant vegetation, vegetation density, and hydrology.

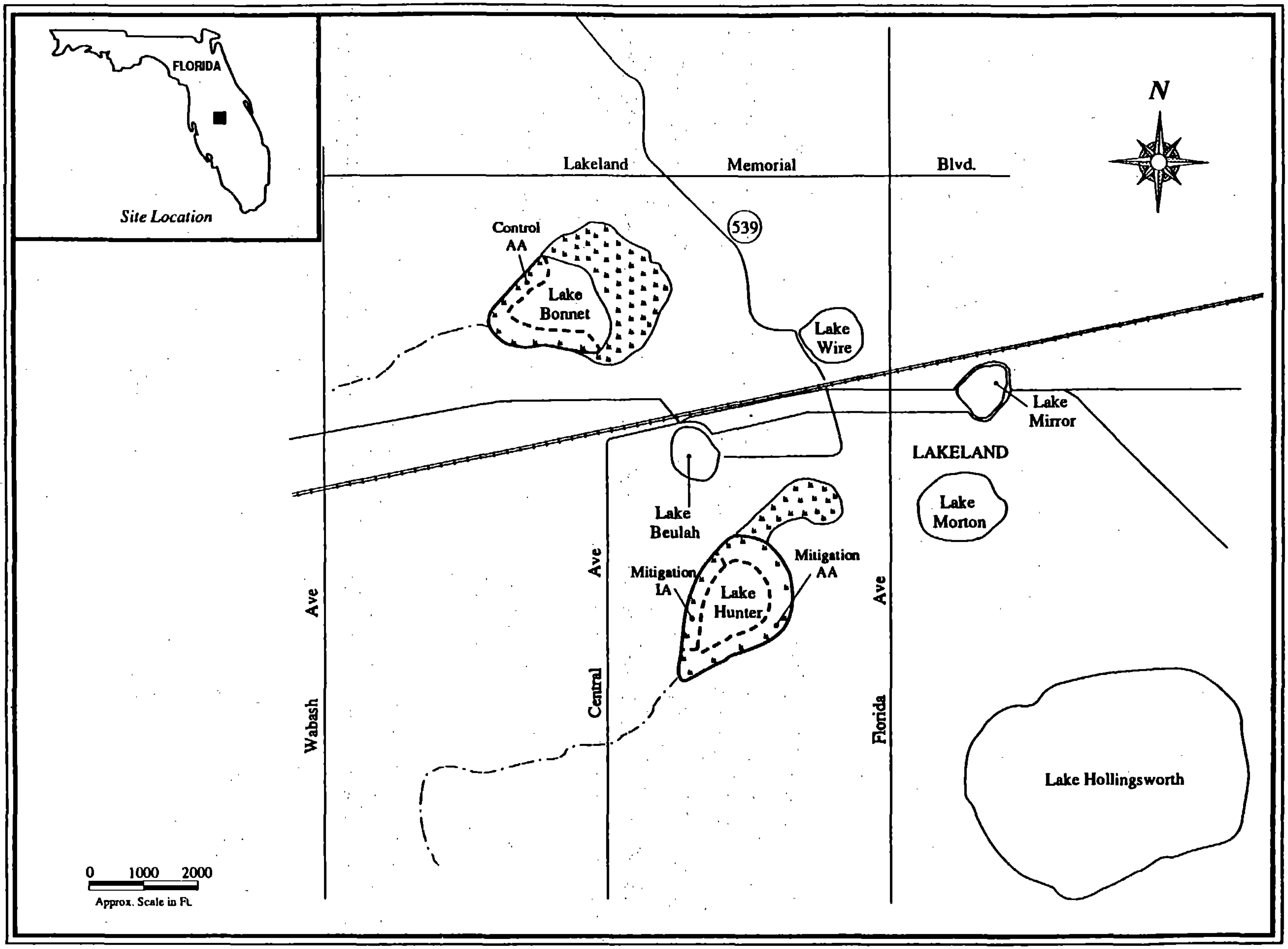

Figure 1. Mitigation and control wetlands, Lakeland, Florida.

Incidental observations of wildlife and wildlife sign were noted. Conductivity and pH were measured in the wetlands chosen for WET 2.0 and Hollands-Magee assessment.

On-site interviews were conducted with Florida DOT (FLDOT) staff. Contact was also made with the Florida Game and Fresh Water Fish Commission and Polk County Water Resources Department. Other resources included NWI maps, US Geological Survey (USGS) topographic maps, Soil Survey of Polk County, pre- and postconstruction aerial photographs, and many documents from FLDOT project files including agency correspondence and FLDOT drawdown contour maps.

Methods

Functional Analysis

WET 2.0 and Hollands-Magee results are included in appendix A.

Summary

The goal of the Lake Hunter mitigation project was to increase the extent of the vegetated littoral zone, thereby increasing its values. Secondary goals implied in the project literature included improvement of the lake's water quality, aesthetics and fishery habitat. Analysis of littoral zone (wetland) functions using WET 2.0 indicated no improvement in value of any of the functions. This conclusion is based on a comparison utilizing Lake Bonnet as a model of the pre-mitigation condition of Lake Hunter. Five years after the completion of work, it appeared that a littoral zone similar to that occurring along the original lakeshore was successfully re-established along the newly sculpted shoreline. However, no significant increase in the extent of the original littoral zone has been realized. Vegetation monitoring conducted at the mitigation site approximately 1 year after the mulching operation found a significant growth of pickerelweed and maidencane up to 39 ft (12 m) into the lake.[14] The same study noted, however, that whole plants were being found uprooted. Overgrazing by grass carp, stocked in August of 1984 to control Florida elodea (*Hydrilla*), was suspected as the cause of this damage and may also be the reason for the absence in 1989 of emergent vegetation from all but the shallowest waters of Lake Hunter.

The secondary goal of water quality improvement has not been reached; eutrophication continues. The present study did not include the analysis of those water quality parameters necessary for the determination of trophic status. The FGFWFC, however, found that Lake Hunter's Trophic State Index (TSI) actually increased slightly 1 year after the restoration work was completed. According to the Polk County Water Resources department the TSI has been increasing every year.[15] The increasing TSI index may reflect an increase in input to the lake. The treatment of stormwater runoff as specified in the DER permit may slow this trend. This mechanism will not be in place, however, until the roadway construction is completed.

Some improvement of aesthetics occurred as a result of the successful control of *Hydrilla* by the grass carp, but this achievement may have been at the expense of emergent vegetative growth. Dense cattail growth occurring after the 1984 drawdown was perceived as a negative aesthetic and fishery habitat element and consequently was controlled with herbicides. It is not known whether this activity has any relation to the current lack of emergents in Lake Hunter. Aquatic Diversity and Abundance ratings did not differ between the mitigation and control sites. This indicates that fishery habitat, another secondary goal, probably did not increase or improve in quality. The major reason is again the lack of persistence of the initially established emergent zone.

Several recommendations can be made which may increase the long-term effectiveness of the mitigation activities on Lake Hunter. Grass carp are seen by several local experts as being the reason for the lack of emergent vegetation in the littoral zone. Limited removal efforts have occurred with this species to date. An intensified carp removal effort coupled with minor lake level adjustments may provide the conditions necessary for vegetative re-establishment. Substrate grades, although not exactly as planned, are probably adequate. Further benefits may be realized from the curtailment of intensive lake-edge mowing practices and herbicide applications. The DER permit specifically prohibits these activities.

2. Wetland D, Iowa

Introduction

The U.S. Hwy. 18 bypass around the Town of McGregor, Iowa was routed down the valley formed by Bloody Run Creek in order to meet the existing bridge over the Mississippi River at Marquette, Iowa. This alignment required the filling of 5.5 ac (2.2 ha) of palustrine emergent, shrub and forested wetlands located in the valley bottom. The mitigation package consisted of "replacement" of the area filled by excavating a 6.5-ac (2.6-ha) pond (wetland D) in a nearby seasonally flooded shrub-meadow, and enhancement of the remaining, unfilled valley bottom wetlands through creation of open water and construction of water control structures (wetlands A, B, C). The configuration of the original wetland is shown in figure 2. The relative locations of wetlands A-D are shown in figure 3. In addition, a 27-ac (10.7-ha) upland

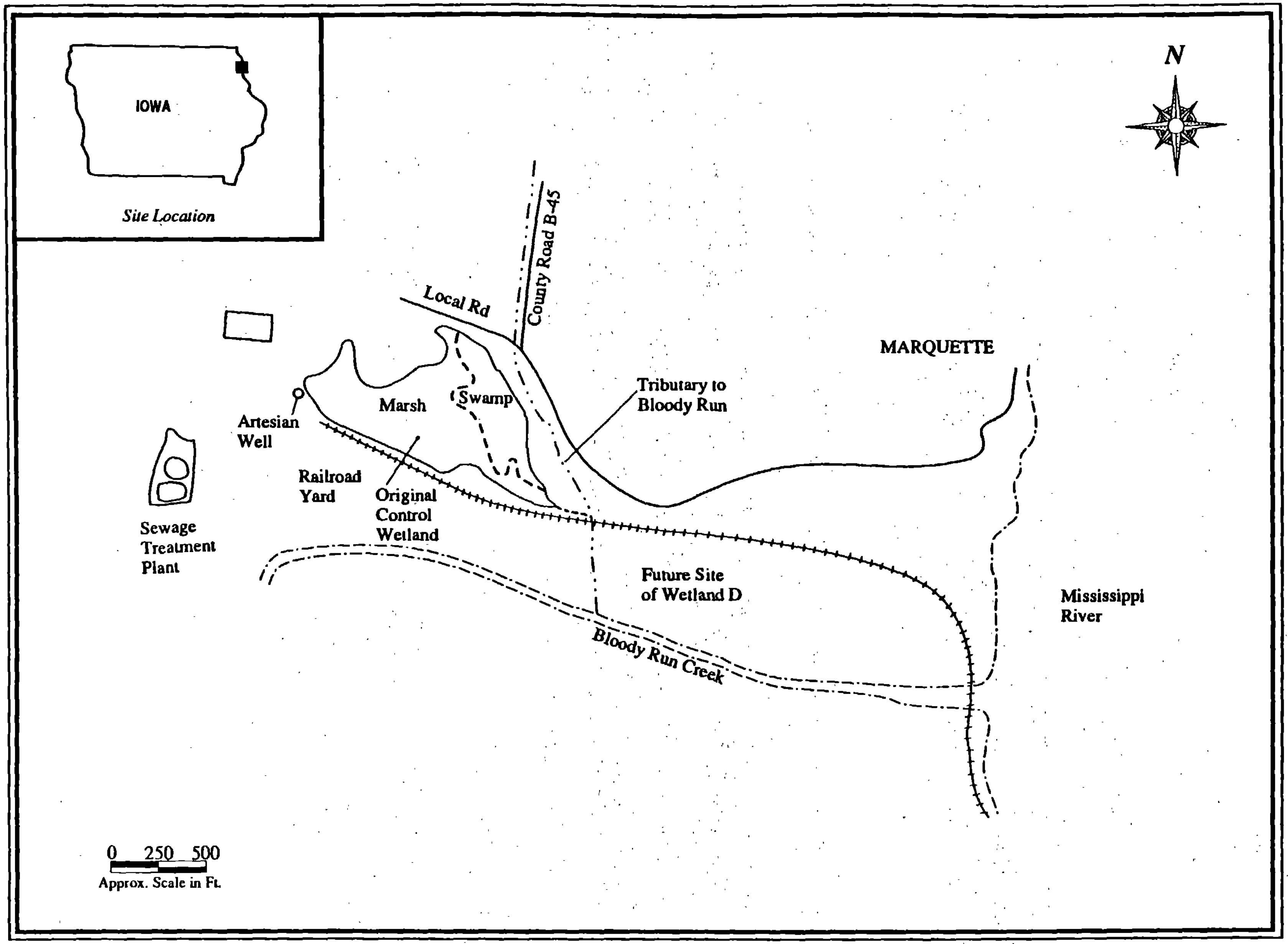

Figure 2. Location and original control wetland, Marquette, Iowa.

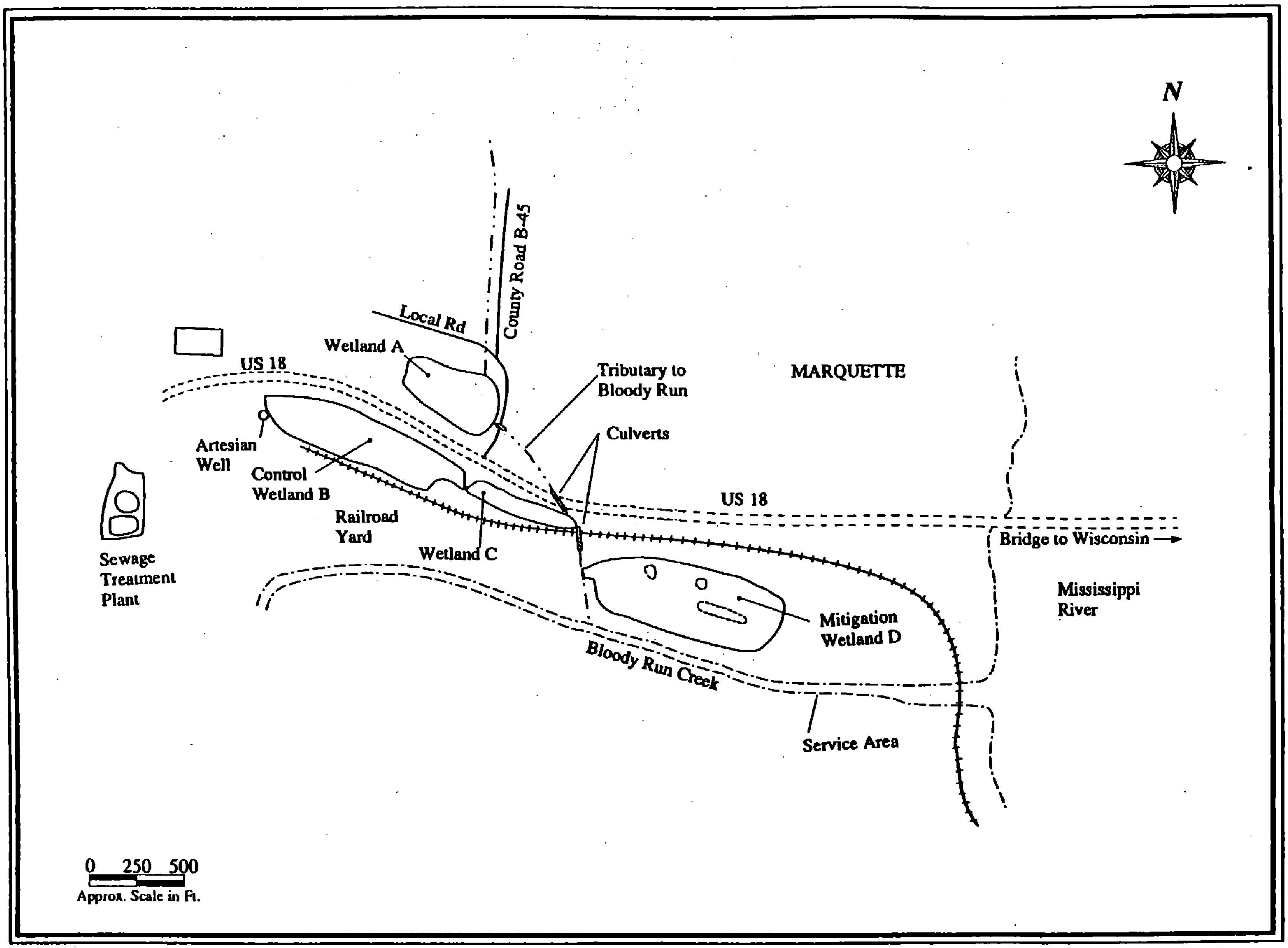

Figure 3. Mitigation and control wetlands, Marquette, Iowa.

area located off-site (mitigation site E) was acquired for threatened plant species protection as part of the project.

The project is located within the small town of Marquette, Clayton County, Iowa which is across the Mississippi from Prairie du Chien, Wisconsin. The mitigation sites are adjacent to Bloody Run Creek, a cold water tributary to the Mississippi River, typical of the deeply cut drainages common in this part of northeast Iowa. The high relief, bedrock-dominated physiography of this area is referred to by geologists as the Paleozoic Plateau. Limestone, sandstone and dolomite bedrock layers, deeply dissected by streams, are exposed on the steep valley walls which can reach 300 ft (91 m) in height near the Mississippi. Sinkholes, springs and cavern systems (karst topography) have developed in the carbonate bedrock layers. The valley slopes are typically wooded; the rolling plateaus once dominated by prairie are cultivated in corn or utilized for grazing livestock. Except for the Mississippi River's backwaters, wetlands are not plentiful in this region of entrenched streams and well-drained plateaus.

Mitigation Design

An extensive set of goals to be fulfilled by mitigation activities were proposed by the Iowa Department of Transportation (IADOT).[16] The primary goal was to ensure the continued existence of the remaining (non-impacted) wetland and to enhance its values. There was some concern that the flow from an uncapped artesian well located on adjacent private property would someday be utilized, jeopardizing the continued existence of the remaining wetland. It was mainly for this reason that enhancement activities involved excavating ponds. The intent was to provide a reliable source of water by intersecting the surface groundwater table.

Another goal was to maintain suitable habitat for rare or declining species occurring in the undisturbed wetland including: the spring peeper (*Hyla crucifer*) which was State-listed as a threatened species at the time of project permitting (has since been removed from the list due to population increase); the yellow warbler (*Dendroica petechia*) and the willow flycatcher (*Empidonax traillii*), listed by the Audubon Society as species of special concern; and the State-threatened grass pickerel (*Esox americanus*). As a general goal, the mitigation was intended to replace wildlife habitat lost to highway development by replacing the acreage of wetland filled. Wetland D, designated as the replacement wetland, was excavated during the fall and winter of 1987 at a cost of $218,460. The surface water connection was made in spring 1988. Costs were not available for the construction of wetlands A, B and C.

Site Descriptions

Control

The wetland impacted by U.S. 18 is situated on a broad alluvial plain near the mouth of Bloody Run's valley (figure 2). Here the stream's gradient levels off as it meets the Mississippi. The new two-lane alignment (still under construction in 1989) bisected an 8- to 10-ac (3.2 to 4.0 ha) emergent-shrub-forested wetland. This area, in its preconstruction condition, was chosen as the primary control wetland. Stereo aerial photographs taken in 1984 and preconstruction site documentation provided the data necessary to run the evaluation models.[16] Probably a seasonally-flooded shrub or wooded wetland initially, the wetland's permanently flooded condition prior to impact was maintained by a beaver dam blocking drainage from an uncapped artesian well. The well is located at the west end of this wetland in a railroad yard which shares the valley floor.

Surface water inputs were quite minimal as they were derived from a watershed of only 50 ac (19.8 ha) containing a railroad yard, a sewage treatment plant, a small landfill and some grassy meadows. The landfill was located on the northwest border of the original wetland apparently in an area of former wetlands. The tributary to Bloody Run, with its 550-ac (223 ha) watershed located north of the original wetland, was separated from the original wetland by a berm and did not contribute any flow.

Prior to 1961, however, Bloody Run flowed under the railroad yard, then meandered through the wetland, finally entering the Mississippi near the present bridge approach location. Soils in this part of the Bloody Run valley are mapped by the Soil Conservation Service (SCS) as Caneek silt loam, a somewhat poorly to poorly-drained substrate formed in calcareous, stratified alluvium. After a major flood in 1961, the railroad redirected the lower reach of Bloody Run away from the wetland. The new channel was located to the south and east of the yard where it continues to flow at present. The wetland is inundated by floodwaters of the Mississippi every second or third year despite the raised railroad grade.[16]

Vegetation in the original wetland was dominated by cattails in the predominating areas of shallow standing water. Willows and boxelder comprised the wooded northeast portion. Aerial photos indicated a high degree of variation in vegetation type interspersion as well as variable patterns of vegetation-water interspersion. Scattered clumps of shrubs were evident on the photos.

Assessment of the original control wetland relied on recorded information rather than field observations. Although this information (especially the preconstruction photography) is considered reliable, no detailed vegetation lists were available. A second wetland area, wetland B, was chosen as a backup control based on field observations (figure 3). Wetland B is a relatively unaltered portion of the original wetland, approximately 5 ac (2 ha) in size, located between the highway embankment and the railroad grade. Alterations to wetland B, other than isolation by highway fill, that occurred as a result of highway construction and mitigation activities area as follows: (1) the size of the watershed was increased to approximately 600 ac (243 ha) due to rerouting of the tributary to Bloody Run through wetland A to wetland B via an equalizer pipe under U.S. 18, (2) a water control structure was constructed at the outlet which appears (based on extent of open water on aerial photos) to be lower than the beaver dam that originally served the same purpose, (3) woody vegetation was cleared from the eastern end, reducing structural diversity. The uncapped artesian well continues to provide regular surface water flows to wetland B. Ownership of the well has been transferred from private to public. The mitigation plan called for the creation of "deep water ponds" within wetland B, but this work was not evident.(16)

Emergent vegetation in wetland B, a shallow marsh, was dominated by cattail (*Typha latifolia*), blue vervain (*Verbena hastata*), smartweeds (*Polygonum* spp.), and moss love-grass (*Eragrostis hypnoides*). Pondweed (*Potamogeton* sp.), duckweed (*Lemna minor*) and filamentous algae were the dominant species in scattered areas of deep marsh, and two parallel ditches running lengthwise (east-west) through the wetland. A full list of species and abundances can be found in volume II.

The watershed to the north of wetlands A and B is characterized by steep wooded slopes surrounding cultivated plateaus. Some residential development was present. Flow within the tributary to Bloody Run was intermittent.

The service area for both control wetlands was designated as the lower tributary to Bloody Run and the segment of Bloody Run between the tributary and the Mississippi River. Both waterways have been channelized (not as part of the project) and have silty substrates. Flow in the tributary was estimated at approximately 0.5 cfs. Lower Bloody Run is 30 to 40 ft (9 to 12 m) wide and 6 in to 2 ft (0.2 to 0.6 m) deep, with 8-ft (2.4 m) high banks and little fish cover. Discharge was estimated at 9 cfs. The gradient is almost level in this reach, although upstream Bloody Run supports a stocked trout fishery.(17)

Mitigation

Wetland D, intended as the replacement for construction-related wetland losses on U.S. 18, was the focus of the mitigation effectiveness study for Iowa. Wetlands A, B and C are described but were not assessed through functional modeling.

Wetland D (figure 3), a 6.5-ac (2.6 ha) pond with two islands, was excavated in a seasonally flooded wet meadow with a woody border. Preconstruction vegetation was dominated by reed canary grass (*Phalaris arundinacea*), willows (*Salix* spp.) and boxelder (*Acer negundo*).[16] Although the excavation of wetland D was initially termed a "creation" by IADOT, it actually constitutes an "enhancement" of an existing wetland.

Plans called for excavation of 4:1 slopes to the water table and 10:1 slopes below the water level to a depth of 3 to 5 ft (0.9-1.5 m). This material was utilized on the roadway embankments as top-dressing. No topsoil of any kind was spread in wetland D and no planting occurred. Upland banks were seeded with Sudangrass, pearl millet, buckwheat and vetch. Surface water was provided to the pond by the tributary to Bloody Run. The wetland's west end intersected the tributary, providing both inlet and outlet in close proximity. Original ground effectively acted as a berm segregating wetland D from the waterways that flow along its west and south sides.

The functional assessment area for wetland D did not include the surrounding seasonally flooded shrub/forest wetland. Wetland D was considered to be hydrologically distinct from its surroundings due to its permanently flooded character. Its watershed and service areas were the same as those described for control wetland B.

When field work was conducted in the summer of 1989, wetland D was found to consist of 90 percent open water with a narrow fringe of emergent vegetation and two islands with dense shrub growth. The emergent band was mostly three to 10 ft (0.9 to 3.0 m) wide, except in the southwest corner where it was up to 40 ft (12 m) wide. Underwater slopes were measured at 3:1 around most of the perimeter. Where the emergent zone was widest, the grade was 6:1. Maximum water depth was not measured, but is approximately 8 ft (2.4 m) according to the project engineer.[18]

Water net (*Hydrodictyon* sp.), duckweed and filamentous algae were predominant in the deepwater areas, although they did not form a solid cover. Emergents consisted of rice cut-grass (*Leersia oryzoides*), willow seedlings (*Salix interior*), cattail, water horehound (*Lycopus americanus*), beggarticks (*Bidens* sp.), ditch stonecrop (*Penthorum edoides*) and Dudley's rush (*Juncus dudleyi*). The pond's narrow wet meadow border consisted of a highly diverse mix of pioneer species such as smartweeds, mustards and nettles.

Abundant wildlife was observed in wetland D. Cattails were being uprooted by the Wetland's muskrat population. Muskrat burrows were abundant along the banks of wetland D although many had collapsed due to unsuitable soils. A functioning beaver dam with approximately 2 ft (0.6 m) of head was observed at the mitigation pond's outlet. Recent beaver activity was apparent in the wooded areas adjacent to the pond. According to the Iowa Department of

Natural Resources (IDNR), river otter are being reintroduced in Iowa.[19] A slide was observed on the berm between Bloody Run and wetland D, suggesting use of the area by otter.

Birds observed using wetland D included great blue heron, green heron, kingfisher, spotted sandpiper, goldfinch, song sparrow and yellow throat. The project engineer reported three pairs of Canada geese nesting on the banks in the spring of 1989.[18] Maintenance mowing of the seeded slopes was delayed until after nesting season.

Wetland D is used recreationally by local citizens. A wood duck box and a floating nest platform had been placed in the wetland. A raft used by local youths for fishing was moored on one of the islands. Bullhead and possibly carp may inhabit the pond.[17]

General

Two additional wetland components of the U.S. 18 mitigation package are wetlands A and C (figure 3). Costs and completion dates for these areas are not known. Wetland A located north of the highway embankment and fed by the tributary to Bloody Run and overflow from wetland B, was designed as a 2-ac (0.8-ha) pond with 10:1 slopes and a maximum depth of 6 ft (1.8 m). The intent was to excavate to a depth that would ensure some permanent open water at all times even if the artesian flow was to be terminated. The gradual side slopes were intended to eventually support emergent growth; however, no mulching or planting occurred. Wetland A was excavated in the northeastern portion of the original natural wetland. This portion supported woody vegetation, some of which was to be retained to provide structural diversity at the edge of wetland A.

During field work, very sparse emergent growth was observed. Underwater slopes had been graded on a 6:1 slope. According to the project engineer, wetland A was excavated further than the planned depth of six ft (1.8 m) in order to obtain more construction material.[18] Dominant species included barnyard grass (*Echinochloa crusgalli*), cattail, smartweeds, rushes (*Juncus*) and spikerushes (*Eleocharis*). Filamentous algae and some duckweed form a 3 to 5 ft (0.9 to 1.5 m) band. The area surrounding the pond had been filled, graded and seeded with the same mix used around wetland D. No woody cover remained. Mowing to control rye grass was occurring to the water's edge, leaving no wildlife cover. No wildlife except a turtle (species unknown) was observed, although local citizens report use by Canada geese in spring.[20]

Wetland A receives surface water inputs from Wetland B and the ephemeral stream draining the 550-ac (223 ha) watershed to the north (the tributary to Bloody Run) which was diverted through wetland A as part of the mitigation. IADOT anticipates periodic dredging to remove accumulated silt.[18]

Water level is maintained by a concrete dam with a 6-ft (1.8 m) head. No outflow was occurring during field work. Movement of aquatic life, between Bloody Run and wetlands A, B and C, precluded by this dam, was intended to be accommodated by the culvert connecting A and B and by a series of low head dams. Four such dams (including wetland B's outlet culvert) were constructed between wetland B and the tributary to Bloody Run and constitute wetland C (figure 3). According to an agreement between the Iowa DOT and DNR, three pools at least 3 ft (0.9 m) deep were to be created between the dams in order to provide habitat for grass pickerel. Aerial dimensions were not specified, but construction plans called for a 15 to 20 ft (4.6-6.1 m) wide channel with concrete dams set every 150 ft (45.7 m). Dam elevations were to be set at 1 ft (0.3 m) intervals.

Wetland C was constructed at the downstream (eastern) end of the natural wetland, in the vicinity of the original beaver dam below which the grass pickerel was observed in 1983. Downstream of the Wetland B outlet there are three V-notched concrete dams. Pools were not constructed with the specified depths or widths. The pool above the first dam was no greater than 6 ft (1.8 m) wide. No pool at all was excavated between the second and third dams. The negligible amount of flow leaving wetland B in August 1989 was creating its own narrow channel through this area. There was no evidence of greater flows at other times of the year.

A pipe at the lower end of wetland C emerges from the adjacent berm to discharge effluent from the municipal sewage treatment plant located upstream. According to Iowa DNR, pollutant levels in this discharge are typically within compliance standards. This discharge constituted the majority of the flow in the tributary to Bloody Run in August 1989.

Vegetation within wetland C consisted of duckweed and filamentous algae in the limited pool areas, and smartweeds, reed canary grass, barnyard grass and rice cutgrass along the edges. A mowed, gradually sloping wet meadow occurs along the north side of wetland C. A dense growth of willows lines the railroad berm on the south side. Muskrat, wood duck, green heron and goldfinch were observed using this 1/4-ac (0.1 ha) wetland.

According to the outlet elevations specified in the DOT/DNR agreement, water from wetlands A and B would flow out the east end of Wetland B (invert elevation = 620 ft [189.0 m]) through wetland C, except during wet periods when flow would also occur over the dam in wetland A (elevation = 620.5 ft [189.1 m]). During field work, only negligible flow was leaving wetland B despite a major input of an estimated 100 gallons per minute from the uncapped artesian well. Although this situation might be explained by the dryness of the season, wetland C showed no evidence of greater flows. When asked about this apparently unbalanced water budget, the DOT project engineer made reference to the possibility of a preexisting culvert running from wetland B under the railroad yard to Bloody Run. However, such a culvert could not be located on the plans or in the field.

Methods

Field work was conducted on August 1, 2 and 3, 1989 during a hot, dry period. Assistance and information was provided on-site by a botanist with IADOT, the IADOT project engineer for U.S. 18, District Wildlife Supervisor for the IDNR, and the IDNR area fish biologist. Other agencies contacted include the USGS and SCS. Water quality indicators were analyzed from samples taken at wetland B's outlet to wetland A, and along the north shore of wetland D.

Functional Analysis

Comparisons between the primary control (the original wetland) and wetland D (the mitigation AA) are included in appendix A. Model results for these assessment areas as well as for wetland B are presented there also.

Summary

Mitigation for impacts resulting from the construction of U.S. 18 in Marquette, Iowa has only been in place since 1988. Although this site did not quite meet the study criteria of at least two seasons of growth following construction, it was included in the study because of the complexity of the wetland mitigation. After one and one-half growing seasons, wetland D (the focus of the functional analysis) was showing many positive signs of developing into functioning wetland habitat, despite deviations from the plans. Management of all four wetland areas (A through D) will play a major role in their future development.

The desired insurance of continued existence, with or without artesian input, of the wetlands adjacent to the new highway, was guaranteed through creation of deep ponds. Certain functions such as waterfowl and amphibian habitat, were enhanced through this activity. However, this may have been at the expense of other wildlife values which are dependent on other wetland types, and water quality maintenance, which is largely dependent on vegetation density.

More careful adherence to mitigation plans, both conceptual and detailed, may have precluded some problems. Wetland slopes were intended to be more gradual and existing woody vegetation was to remain in Wetlands A and B. Curtailing mowing around the remaining wetland and open water can be expected to result in development of better cover with time.

Wetland impacts could have been reduced by steepening highway embankments which may be unnecessarily broad on this project. Further impact avoidance could have been realized by eliminating some of the extra filling that appears to have occurred around wetland A.

The project goal of maintaining habitat for rare or declining species has been partially met. The yellow warbler and the willow flycatcher nest in shrubbery along watercourses. The flycatcher favors willow-covered islands which occurred in wetland D. Preconstruction shrub growth on the islands and along the north shore of wetland D was retained and is spreading. Woody growth near the base of the railroad grade occurred adjacent to small areas of open water in wetlands B and C. Although no observations were made of these species, the habitat potential exists. This habitat can be expected to improve and expand with time, absent mowing.

The grass pickerel, if still present in the Bloody Run system, can be expected to gain access to wetland D during wet seasons. The beaver dam at its outlet was blocking access in August 1989. Unless deeper pools are excavated, wetland C probably constitutes a barrier to fish entering wetlands B and A except during the most severe floods.

The spring peeper's favored habitat was vegetated ephemeral pools in or adjacent to wooded areas. Some suitable habitat probably existed in and around the mitigation area, but retention of wooded zones and more gradual grades as originally intended would have provided better habitat.

Wetland D, intended as a replacement for wetland acreage filled, is more accurately an enhancement of a preexisting seasonally flooded wetland. Therefore, discounting the 27 ac (10.7 ha) of upland mitigation in site E, a net loss in wetland acreage resulted from construction of U.S. 18 and no replacement per se, actually occurred. Wetland D does not have the full capability to provide the functions that were apparently provided by the original valley bottom wetland complex. Certain functions will improve with time but the basin's configuration will be the limiting factor for many functions. The preexisting wetland, judging by its elevation, was probably very marginal in terms of hydrology. Excavation of the pond has diversified the habitat in the lower valley, as evidenced by the relatively abundant water-dependent wildlife observed in and around wetland D. Therefore, wetland D does constitute an enhancement of wetland values over those in the seasonally flooded area where it is located.

3. Galesburg, Illinois

Introduction

FA 404 is a 10.3-mi (16.6-km) supplemental freeway constructed around the City of Galesburg in the late 1970's and early 1980's. It connects at I-74 north of Galesburg with US 34 to the west. Planning for this project began in the 1960's when the Illinois Legislature and Illinois Division of Highways (now the Illinois Department of Transportation [IDOT]) embarked on the development of the Supplemental Freeway System. The system was designed to integrate with the existing Interstate system and to expand freeway service.

The Final Environmental Statement concluded that locating FA 404 within the Cedar Creek valley would minimize loss of farmland, provide a pleasant rolling topography for the traveling public and a welcome diversion from the monotonous flat freeways in this region.(21) The project involved several channel changes to Cedar Creek and the loss of wildlife habitat. According to the U.S. Fish and Wildlife Service (USFWS) cover type classification, the project impacted 14 ac (5.5 ha) of shrub, sedge and emergent wetland, 16 ac (6.3 ha) of wet meadow, 26.5 ac (10.5 ha) of forested wetland, 70 ac (28.4 ha) of upland forest and 9 ac (3.6 ha) of old field. The wetland cover types listed may or may not have been regulatory wetlands at the time of permit application. The Corps of Engineers (COE) required permitting only for the channel changes and issued a permit in 1976. Work was begun but halted because of lack of funds and the permit expired in 1979. Reapplication was made and a second COE permit was issued in 1983 for four channel changes and one crossing of Cedar Creek.

Mitigation Design

As part of the second permit, the COE and the USFWS required mitigation only for the 14 ac (5.5 ha) of shrub, sedge and emergent wetland. The goal of the mitigation was wetland enhancement for wildlife. Open water habitat was uncommon along this section of the Cedar Creek floodplain. Waterfowl ponds were excavated in existing seasonally flooded wetlands at four sites along the highway right-of-way and within the Cedar Creek floodplain. These sites are shown in figure 4. The 4 ponds, totalling 18.4 ac (7.3 ha) are divided as follows: location 1 is 2.5 ac (1.0 ha), location 2 is 7.8 ac (3.1 ha), location I is 4.3 ac (1.7 ha), and station 500 is 3.8 ac (1.5 ha). Surface water connections to Cedar Creek were constructed to function only during high water. During normal flow the ponds are not connected to the creek and water levels are maintained by rainfall and ground water seepage.

Pond banks were designed and constructed with 5:1 slopes. Several small islands were left in each area. No topsoil was spread on the banks.

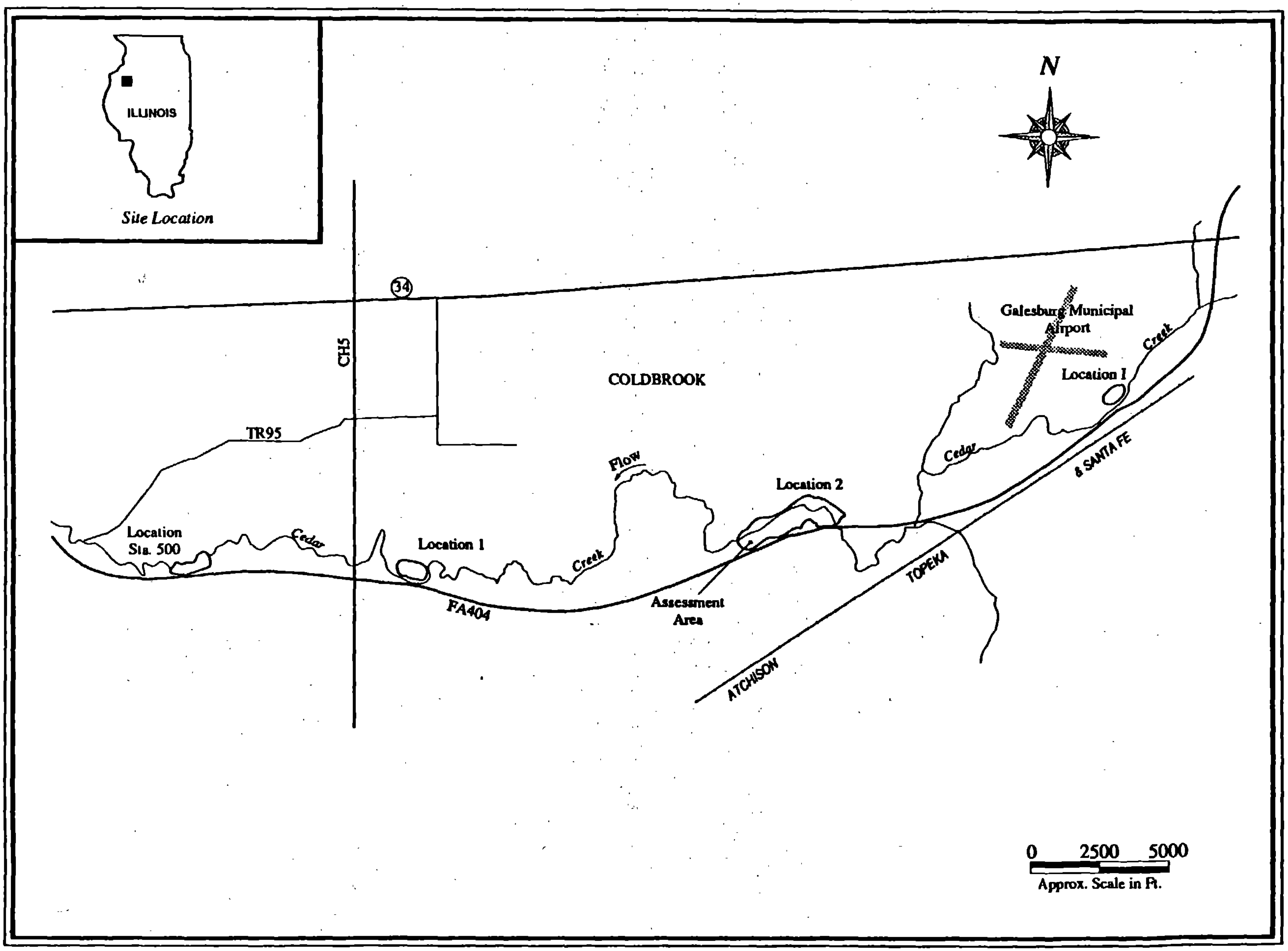

Figure 4. General location of the mitigation and control wetlands, Galesburg, Illinois.

According to the plans, seedlings were planted around the ponds and a native prairie (grasses and forbs) seed mix was applied. The seedlings included silver maple (*Acer saccharinum*), green ash (*Fraxinus pensylvanica*), sycamore (*Plantanus occidentalis*), red maple (*Acer rubrum*), river birch (*Betula nigra*), northern hackberry (*Celtis occidentalis*) and American linden (*Tilia americana*). Construction, planting and seeding were completed by the fall of 1986. Project cost was $520,000 or $28,000/ac ($69,160/ha) in 1986.

Site Description

General

Western Illinois topography is flat to rolling with entrenched stream channels. Rich, deep, silt loam (loess) soils and adequate rainfall make this one of the most productive farming areas of the world. Natural surface drainage is in a westerly direction toward the Mississippi River. The steep-sided stream valleys common to the project vicinity have broad, flat floodplains which contain meandering channels. Because of the intensive farming in this region these stream valleys and surrounding slopes are among the few natural forest and wetland areas remaining. Although much of the floodplain and rolling valley slopes are also in small fields and pasture, the wooded creek channels provide important travel corridors and food and cover habitat for wildlife. Correspondence from the USFWS indicated that while this project was not likely to impact any endangered or threatened species, creeks with large overhanging trees are good feeding and roosting areas for the Indiana Bat, an endangered species.

Cedar Creek is a typical dendritic stream system, originating in Galesburg and meandering west to the Mississippi River. The valley floor is 60 to 70 ft (18.3 to 21.3 m) below the surrounding prairie farmland. Much of the creek floodplain is forested wetland dominated by cottonwood (*Populus deltoides*), silver maple (*Acer saccharinum*), boxelder (*Acer negundo*), white ash (*Fraxinus americana*), honey locust (*Gleditsia triacanthos*), black walnut (*Juglans nigra*), hawthorn (*Crataegus mollis*), and willows (*Salix* spp.). Shrub, sedge meadow and emergent wetlands and oxbow ponds occur on the lower areas of the floodplain. Common shrub species include: black willow (*Salix nigra*), multiflora rose (*Rosa multiflora*), and red panicle dogwood (*Cornus racemosa*). Reed canary grass (*Phalaris arundinacea*), pink smartweed (*Polygonum pensylvanicum*) and ragweed (*Ambrosia* sp.) dominate wet meadows, old fields and wet pastures. Species commonly found in sedge meadows and emergent areas include: several species of sedge (*Carex* spp.), rice cut-grass (*Leersia oryzoides*), blunt spike sedge (*Eleocharis obtusa*), cattail (*Typha latifolia*) and dark green bullrush (*Scirpus atrovirens*). These areas provided habitat for several species of waterfowl, shorebirds, herons, muskrats, beaver, raccoon, squirrels and white-tailed deer.

At normal flow Cedar Creek in the vicinity of the project is 6 to 10 ft (1.8 to 3.0 m) wide and 1 to 2 ft (0.3 to 0.6 m) deep, slow flowing and meandering. During rainstorms Cedar Creek collects runoff rapidly from uplands comprised of slowly permeable silt loam. It quickly fills its banks and can overflow onto the floodplain. The Creek is not considered a fishery resource in the project area because of poor water quality caused by effluent entering the creek from the Galesburg sewage treatment facility. However, the water quality is expected to improve with future improvements at the sewage treatment facility.

Locating the freeway in the Cedar Creek valley while avoiding much of the impact to valuable farm land required several channel changes and considerable impact to wetland and upland wildlife habitat. Culverts or bridges large enough to accommodate high flow were prohibitively expensive. Therefore, culverts were sized for near normal flow and overflow channels were constructed on the north side of the highway.

Locations of the four wetland enhancement areas are shown in figure 4. The same general procedures were followed in the design and construction of each of these ponds. They were constructed in the floodplain adjacent to Cedar Creek with connections that permit overflow from the Creek to enter during high water. The intent was to create open water emergent vegetated edge and islands. However, most of the edge areas were too steep and had a narrow (<20 ft [6.1 m]) emergent zone. There was no attempt to line the ponds with topsoil or wetland muck. The narrow right-of-way and the topography of the highway fill embankment and natural levee of Cedar Creek for the most part mandated long narrow ponds with steep banks. The mitigation pond at location 1 was constructed near a natural oxbow pond on a wider area of the right-of-way. This pond is separated from the oxbow by berms. Part of the shoreline has good emergent zone vegetation. Other portions, especially along the northern bank, are eroding.

Mitigation

A representative wetland enhancement area (location 2) was chosen for functional analysis. This 7.8-ac (3.1-ha) wildlife pond is similar in design, construction, hydrology and vegetation to the other wetland enhancements along the highway project. It is located in a wet meadow that was partially filled for the highway. The mitigation assessment area (AA) was delineated to include the wetland enhancement pond and the surrounding hydrologically contiguous floodplain wetland and creek segment. The wet meadow appeared to be a field abandoned since the highway construction; it is dominated by dense ragweed (*Ambrosia* sp.), pond smartweed (*Polygonum pensylvanicum*) and reed canary grass (*Phalaris arundinacea*) with some areas reverting to shrub, willows (*Salix* sp.) and cottonwood (*Populus deltoides*). The assessment area also encompasses forested wetland on the north side of Cedar Creek and along the creek itself. The forest was dominated by large mature trees which included: silver maple, cottonwood, white ash and honey locust. These covertypes are representative of the wetland areas filled for the highway.

The mitigation pond at location 2 was primarily open water with duckweed (*Lemna* spp.) floating on the surface and pondweeds (*Potamogeton* spp.) as the submergent vegetation. The banks had 5:1 slopes and were incompletely vegetated. At the water edge a sparse, narrow (15 ft [4.6 m] wide) band of wet meadow/ emergent vegetation included the following species: blunt spikesedge (*Eleocharis obtusa*), umbrella sedge (*Cyperus strigosus*), cattail (*Typha latifolia*), arrowhead (*Sagittaria latifolia*) and water-plantain (*Alisma plantago aquatica*). A complete species list can be found in volume II.

Control

The control and mitigation AA's consisted of the same area. However, the control was assessed as it existed before the highway fill was placed and the wildlife enhancement pond was constructed. According to preconstruction aerial photos (June 1969), it consisted of the same wet meadow (5 ac [2 ha] larger before filling), forested floodplain wetland and Cedar Creek channel segment as the mitigation AA, but lacked the shallow marsh and open water created by the wildlife enhancement ponds.

The watershed of the mitigation and control AA was delineated in accordance with WET 2.0 guidelines. It consisted of the upstream watershed of Cedar Creek, an area of approximately 30 mi^2 (48.3 km^2) of primarily agricultural land and the community of Galesburg. The Galesburg Sewage Treatment Plant is the major pollution source discharging into the creek. Non-point sources of pollution are primarily from agricultural lands.

The service area of the control and mitigation AA was a section of Cedar Creek located approximately 8 mi (12.9 km) downstream of the project. In this segment the gradient levels out and the creek becomes larger and important for recreational fishing. The wetlands along Cedar Creek in the project area were important to improving downstream water quality given the pollution sources in the watershed.

Methods

Fieldwork was conducted from August 28 through 30, 1989. Rain during the night of August 28 afforded the opportunity of observing Cedar Creek at high flow, although not at bank overflow or flood stage. The waters quickly receded. Since this project had four separate but similar mitigation sites, detailed observations for functional analysis were made at one representative area (location 2). The same assessment area was evaluated in two different conditions: before and after excavation of the pond. Model results for these two conditions were compared to assess the degree of enhancement effectiveness. Conductivity and pH were measured in the location 2 mitigation pond and in adjacent Cedar Creek for the control.

On-site interviews were conducted with representatives of IDOT. Other information sources included IDOT Environmental Statement, Wetlands Report and agency correspondence.

Functional Analyses

WET 2.0 and Hollands-Magee evaluation results are shown in the appendix. The results are discussed by function under the major headings of social significance, effectiveness, and opportunity. Most of the Hollands-Magee results are discussed under the effectiveness heading. This discussion includes only those functions for which the mitigation and control wetlands received different ratings (for WET 2.0) or substantially different raw scores (>15 points for Hollands-Magee).

Summary

The location of the mitigation wetlands within the Mississippi flyway and the lack of other open-water areas along this section of Cedar Creek indicate that the goal of creating waterfowl habitat was an appropriate mitigation approach. Although the large amount of wetland habitat lost to the Supplemental Freeway (56 ac [22.1 ha]) was not effectively replaced by the construction of wildlife enhancement ponds (18.4 ac [7.3 ha]) in existing wetland within the highway right-of-way, this may not have been the goal. The project correspondence, for example, implies that activities in forested wetlands were not regulated by the local authorities at the time the project was permitted.

WET 2.0 model results indicate that enhancement of the original wetland condition in the assessment area was achieved. Wildlife and aquatic diversity indicators and cultural values were higher in the mitigation than the control. However, Hollands-Magee assessment indicates little difference between the two except in cultural values which are higher in the mitigation. The narrow, linear nature of the right-of-way presented basic difficulties for construction of the gently sloping shoreline required for establishment of a broad emergent vegetation zone. Coarse substrate and steep slopes in the excavated basin resulted in poor vegetative colonization, even above the water's edge.

4. Schaumburg, Illinois

Introduction

A commuter rail station and associated commuter parking lot was constructed in the Chicago suburb of Schaumburg in the fall of 1981 to spring 1982. The 1,400-car parking lot was built in a corn field adjacent to the existing rail lines and to a natural four ac emergent/forested wetland. The original stormwater management proposal called for excavation of this wetland to provide additional storage volume for parking lot runoff. Resource agency review of this plan concluded that this extent of impact was not necessary and could be avoided. The natural wetland was thought to have potential for habitat for endangered and threatened birds. Site constraints precluded the preferred option of constructing a retention basin between the parking lot and the wetland. Therefore, it was agreed that the runoff would be conveyed directly into the wetland. The originally proposed gross disturbance was thereby avoided.

Mitigation Design

The goal of the mitigation activities that took place on this project was avoidance of disturbance to a small natural kettle hole wetland, but the measured result was an enhancement of wetland values there. Destruction of a wetland ecosystem was avoided by leaving the wetland intact and routing runoff through it to a detention pond.

Catch basins with sediment, grease and oil traps route water from the parking lot into the wetland. From the wetland a culvert conducts outfall to the retention basin (3 ac [1.2 ha]) constructed at the same time as the parking lot to contain increased runoff. The outlet of the retention basin is designed to release water to adjacent wetlands and the West Branch of the DuPage River (see figure 5) at preconstruction flow rates.

Site Descriptions

General

The topography in the project vicinity is relatively flat with a slight slope to the southwest. The terrain is part of the Valparaiso morainic system formed by glacial deposits during the Wisconsin glaciation. Unconsolidated glacial till with an average thickness of 125 ft (38.1 m) overlies bedrock. Kettle hole wetlands are common features of the glacial landscape. The upland soils are silt and silty clay loams. These soils have slow permeabilities allowing surface runoff to accumulate in shallow wetland

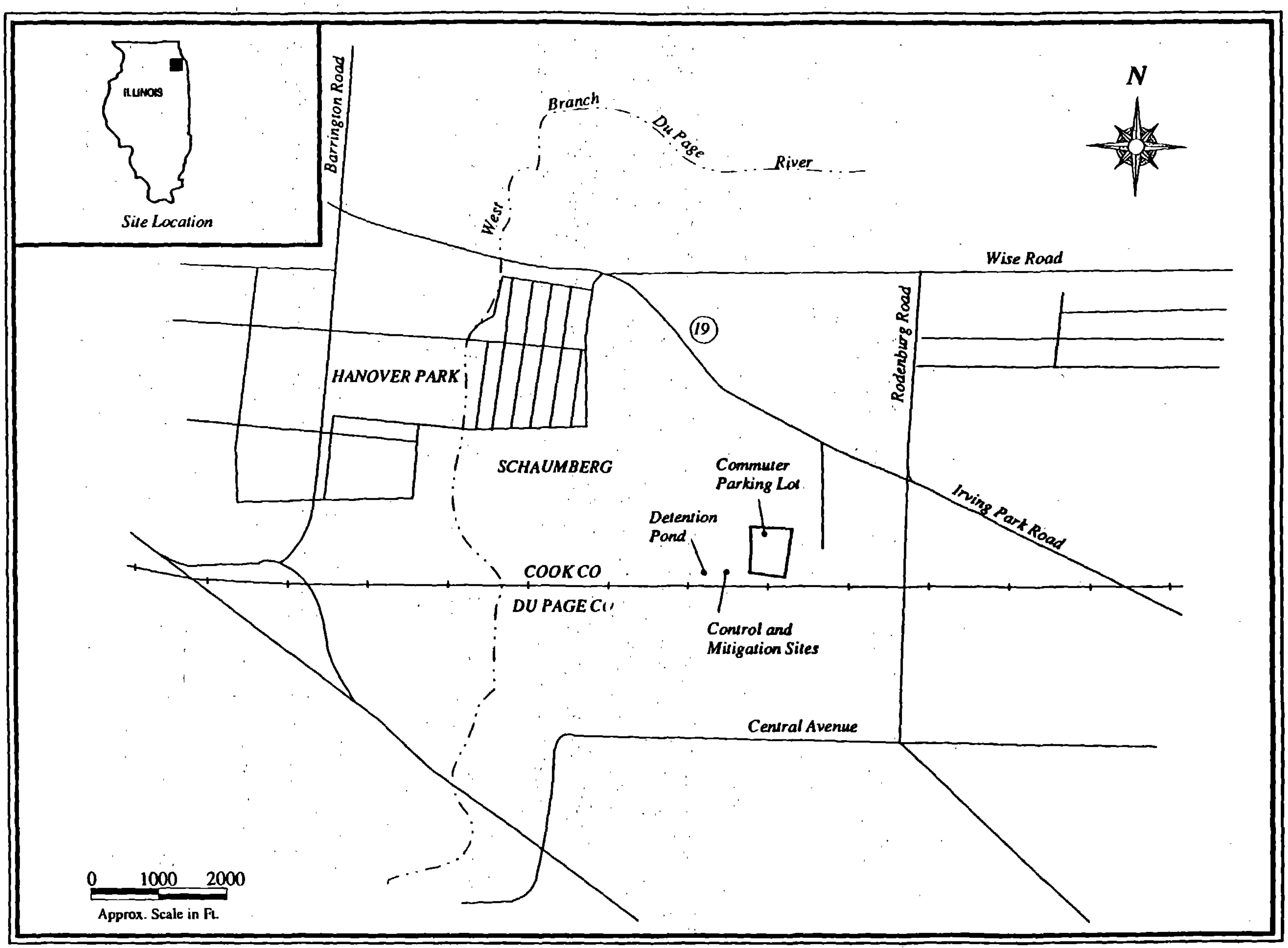

Figure 5. General location of mitigation and control wetland, Schaumberg, Illinois.

depressions. This area is not a significant ground water recharge site due to the slow permeability of the silty clay subsoils.[22] The land is intensively farmed or in residential or commercial development. The few remaining natural areas are the isolated kettle hole wetlands, narrow wetlands along drainages and streams, and land in some form of conservation or preservation.

The retention pond constructed to the west of the subject wetland is permanently flooded. There was no attempt to design the retention pond into the natural setting of the wetland. Its shoreline is rip-rapped. A native prairie seed mix was sown on the surrounding upland and the area was landscaped with trees. The site now belongs to the Village of Schaumburg and is kept neatly mowed. It provides a recreational resource that is frequently used by joggers and walkers, etc.

The retention pond and the wetland are not hydrologically connected (as defined by WET 2.0) except during storm events. Therefore, the retention pond is not considered part of the wetland and was not included in the evaluation study. It should be noted, however, that the two areas are hydrogeologically connected along subsurface sand seams.[23]

Mitigation/Control

The 4-ac (1.6-ha) wetland in its present condition was evaluated as the mitigation assessment area (AA). An evaluation of the same wetland in its preconstruction condition provided a control for assessing change created by the additional runoff. The preconstruction description and drawings of the wetland in IDOT's environmental assessment report and discussions with the Illinois DOT personnel familiar with the site were used to estimate the condition of the control AA. The control AA had 1.5 ft (0.5 m) less water depth and a dense tree canopy along its edge. It was also likely to dry out during drought periods. Dead trees are not mentioned in the environmental assessment. The trees all appeared to have died at the same time period, approximately 10 years ago. These trees are large cottonwoods (*Populus deltoides*) which now make excellent wildlife nesting sites.

As is common to kettle hole wetlands, the central open water pool is fringed by concentric wetland vegetation type zones of decreasing wetness: an emergent zone of cattail (*Typha latifolia*), bulrushes (*Scirpus atrovirens* and *Scirpus fluviatilus*), spikerush (*Eleocharis* spp.) and wetland grasses (*Phalaris arundianacea* and *Calamagrostis canadensis*) and several species of sedges (*Carex* spp.) and rushes (*Juncus* spp.); grades to a shrub zone of willow (*Salix* spp.), boxelder (*Acer negundo*) silver maple (*Acer saccharinum*) elderberry (*Sambucus candensis*) and dogwoods (*Cornus stolonifera* and *Cornus racemosa*); grades to forested wetland and upland of large silver maple, boxelder and cottonwood. Several floating and submergent plant species occur in the open water zone include duckweed (*Lemna* spp.) and pondweed (*Potamogeton* spp.). A complete species list can be found in volume II.

The lush density and diversity of the vegetation, rich soils and the presence of open water and large dead trees make this wetland, although small in size, a very productive wildlife habitat. Possibly due to the intensive surrounding land use in this urban and farming area, wildlife congregate in these small wetlands. The following wildlife were observed in the vicinity of the wetland: redheaded woodpecker, peregrine falcon, blue wing teal, pintail, black crowned night heron, green heron, kestrel, great egret, cow bird, starling, mallard, wood duck, kingfisher, turtles and evidence of muskrat and raccoon.

An Inventory of Endangered and Threatened Species was prepared for IDOT by the Illinois Natural History Survey. It noted that no rare plants were found. Since the wetland had received considerable sedimentation and nutrients from the surrounding farmland, it was unlikely that rare plants would occur there. The report noted a small area of high quality prairie between the railroad bed and the wetland that is one of the few remnants of prairie left in this part of Illinois.[24] Although this is a rare plant community, the report mentioned no threatened or endangered species. The report mentions the following endangered or threatened State birds that are likely to occur in the wetland: snowy egret (*Egretta thula*), black-crowned night heron (*Nycticorax nycticorax*), American bittern (*Botaurus lentiginosus*), northern harrier (marsh hawk) (*Circus cyaneus*), purple gallinule (*Porphyrula martinica*), Forster's tern (*Sterna forsteri*), black tern (*Childonias niger*), yellowheaded blackbird (*Xanthocephalus xanthocephalus*) and common gallinule (*Gallinula chloropus*) and Brewer's blackbird (*Euphagus cyanocephallus*).

The watershed of the mitigation/control wetland is 34 ac (13.4 ha) of primarily agricultural fields, railroad bed and paved surfaces. Water entered the control wetland by way of overland flow. The mitigation (post-construction) AA receives input from the drainage system of the parking lot. Water exits the wetland through a culvert to the detention pond only during high flow events. The invert of the culvert exiting the wetland is 2 ft (0.6 m) higher than the retention pond invert. The release of water from the retention pond is regulated by the size of the exit culvert. The impervious nature of the developed suburban watershed results in rapid fluctuations in water level. During the night between our visits to this wetland 2.5 in (6.4 cm) of rain fell. The water level had risen about 1.5 ft (0.5 m) higher than the previous day and was exiting to the retention pond.

The service area of the wetland is the West Branch of the DuPage River. This area as well as the retention pond are also the service areas of the mitigation AA. Because of the intensive farming, residential and industrial development in this watershed the wetland functions important to this service area are water quality, flood control and wildlife habitat.

Methods

Field work was conducted at the Schaumburg site on August 31 and September 1, 1989. The wetland evaluation techniques used in this study describe the probable functioning of the wetland in a general sense, and apply to the question: has the functioning of this wetland been changed by the development of the parking lot and detention pond?

Heavy rains (2.5 in [6.4 cm]) during the night of August 31 provided the opportunity for observation of the wetland and retention pond at high as well as average water level. Conductivity and pH were measured in the wetland and retention pond on both days (normal water levels and high flow).

On site interviews were conducted with representatives of the IDOT. Other information included IDOT file documents, the Environmental Assessment, the Illinois Natural History Survey report and correspondence of cooperating agencies.

Functional Analysis

WET 2.0 and Hollands-Magee results are shown in the appendix. The results are discussed by function under the major headings of social significance, effectiveness, and opportunity. Only those functions having different probabilities or significantly different (>15 points) raw scores for the mitigation and the control are discussed.

Summary

The goal of avoiding impact to wetland functions by placing the retention pond beyond the wetland was a significant achievement in cooperation among the various agencies and individuals involved given the pressure to excavate and enlarge this wetland for retention of additional water.

Only a few remnants of these diverse and productive biological wetland communities remain in this intensively developed area. The retention pond could have been designed differently to increase wildlife value. The pond has mowed banks, riprapped at the water edge. This is apparently the preference of the owner and manager, the Village of Schaumburg, to maintain a tidy landscape. However, this design has limited the wildlife value of the pond and prevented the development of the surrounding seeded prairie.

Vegetation changes have occurred in this wetland as a result of the increased runoff. The water level has been raised by approximately 1.5 ft (0.5 m) and resulted in a more stable water regime. Tree mortality apparent at the periphery of the wetland has likely resulted from the increased water level. Increasing the water level and opening of the wetland by tree mortality has allowed a lush emergent and shrub vegetation zone to develop with good water-cover interspersion and nesting cavities in old trees. This has increased the usefulness of this wetland for wildlife.

The evaluation models indicate that the same wetland functions occur in pre- and postconstruction conditions. Observations do not indicate a negative effect of the additional run off into the wetland. Flood protection, water quality and wildlife habitat appear to be compensated for in the location and design of inlet and outlet culverts and the retention pond.

5. Patuxent River, Maryland

Introduction

Widening of the Route 198 bridge over the Patuxent River in Laurel involved the filling of approximately 5 ac (2.0 ha) of bottomland hardwood swamp on the extensive Patuxent River floodplain. A 12-ac (4.9-ha) wetland was constructed off-site in Bowie to mitigate this loss. Several agencies cooperated and assisted in the wetland mitigation design, including the U. S. Fish and Wildlife Service (FWS), the Army Corps of Engineers (COE), the Environmental Protection Agency (EPA), and the Maryland Department of Natural Resources (MDNR). There was no attempt to recreate the type of wetland community lost to the bridge fill. The goal of the mitigation project was to provide for fishing, wetland wildlife habitat, public education, water quality protection and flood storage.[25]

Mitigation Design

As compensation the Maryland State Highway Administration (MSHA), in cooperation with the Maryland National Capital Parks and Planning Commission, designed a 12-ac (4.9-ha) wetland that was constructed at an old gravel pit site on the Green Branch tributary in Bowie. A large irregular basin was excavated with variable depths and several islands. A water control structure was installed at the outlet to the Green Branch. Plants and rhizomes of several emergent species were planted. Bald cypress were planted on the upland banks. Wood duck boxes were installed, and the pond was stocked with bass and bluegill. Work was completed in the spring of 1984 at a cost of approximately $190,000.

Site Descriptions

General

The Patuxent River is Maryland's longest river (110 mi [177.1 km]) and lies entirely within the State boundaries. With the spread of development in recent decades from Washington, D.C. and Baltimore, the broad, flat floodplain wetlands along the Patuxent are some of the few remaining large natural areas in the region. The upper portion of the River has relatively good water quality. North of Laurel, the Rocky Gorge Reservoir is used for drinking water. Water quality in the 15-mi (24.2-km) stretch of the Patuxent between the Route 198 bridge in Laurel and the Bowie mitigation site is poorer. This portion of the river transports waste effluent from several sewage treatment facilities.

The Patuxent River at the Laurel bridge is approximately 20 ft (6.1 m) wide, with 3-ft (1-m) banks. The forested floodplain wetland is 2000 ft (610 m) broad in this area. Water level fluctuation is very high. Ordinarily channel flow is 1 to 2 ft (0.3 to 0.6 m) deep, but during storm events it overtops the banks and covers the floodplain. The upstream dam at the Rocky Gorge Reservoir maintains river flow during dry summer periods. The floodplain topography is level, and the soils are primarily derived from alluvium.

The floodplain forest in the vicinity of the Bowie mitigation site (located approximately 15 mi (24.2 km) downstream) is at a higher elevation in relation to the dominant surface hydrology. The soils are sandier and better drained, and the topography is gently rolling. This forest includes many upland species, along with typical bottomland species. Most of this area would not be considered wetland. For many years, sand and gravel deposits intermixed with alluvial strata have been mined along this stretch of the Patuxent. The numerous abandoned gravel pits provide opportunities for wetland enhancement.

Mitigation

The mitigation assessment area (AA) consists of the excavated basin in Bowie including its islands and a small undisturbed (preexisting) shrub swamp on the site's southwest edge (figure 6). The AA's watershed is only 35 ac (13.8 ha) and consists of a wooded hillside below an open, grassy plateau which was used at one time to grow tobacco. Recently, the Washington Suburban Sanitary Commission and the Maryland Environmental Service conducted tests by applying sewage sludge onto corn fields in this area. The AA has one ephemeral inlet and flows permanently from the dammed outlet toward the Green Branch. Water is supplied by numerous springs within the excavated basin.

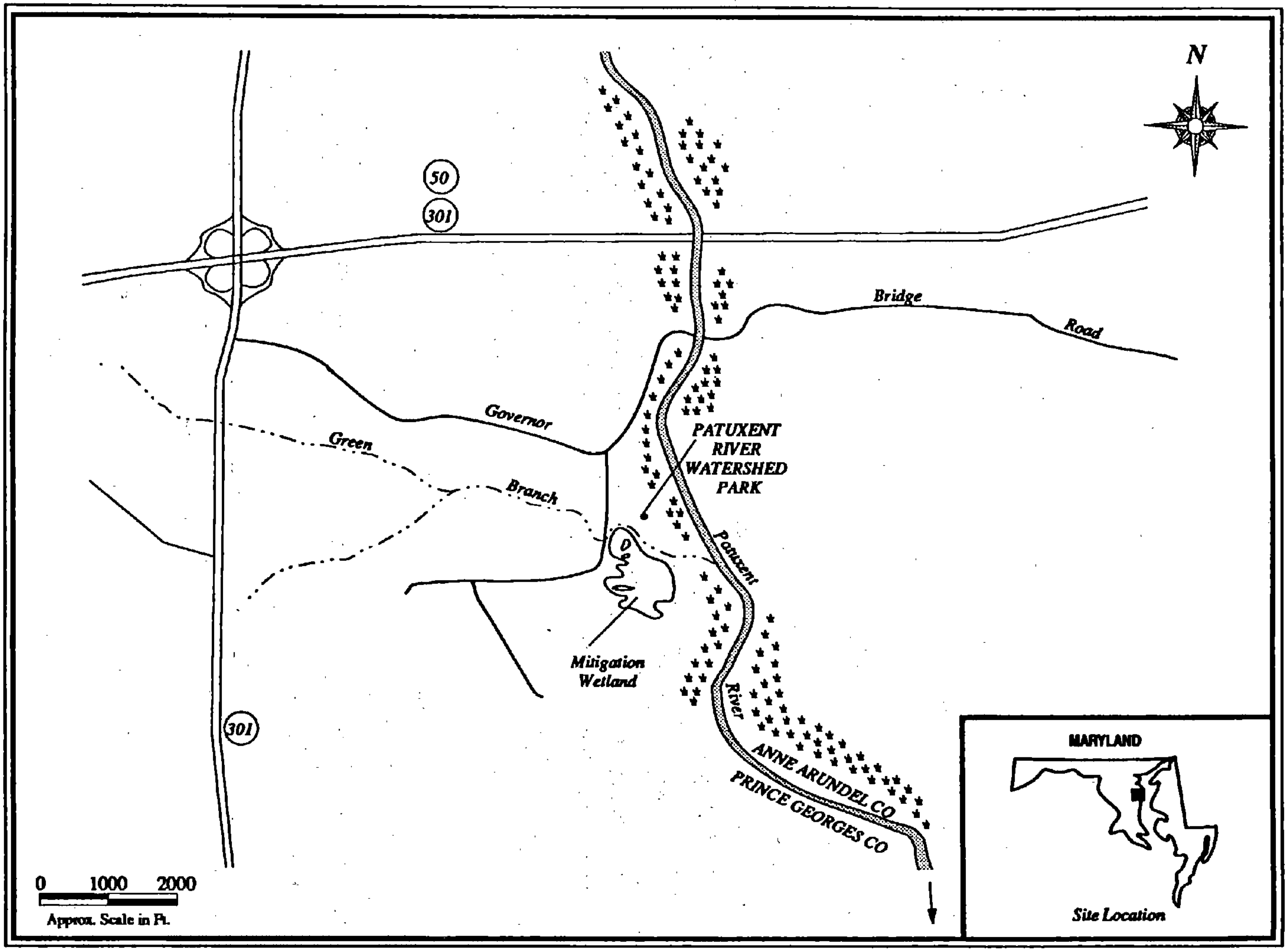

Figure 6. Patuxent River mitigation area, Bowie, Maryland.

The AA's service area is designated as the lower portion of the Green Branch, a tributary to the Patuxent River. This small, entrenched stream flows through wooded wetlands in the Patuxent valley.

Prior to construction, the gravel pits had been abandoned for 10 to 15 years and supported a cover of shrubs and saplings. The original basin was about 5 ft (1.5 m) deep with numerous spoil piles. Material excavated from the basin was used to build a water retention berm and five small islands.

The berm was covered with an impermeable barrier and a water control structure was constructed at the outlet to the Green Branch. The basin was configured with various lobes and coves, resulting in a highly irregular shape.

When regrading within the basin had been completed, a 3-in (7.6-cm) layer of clay was spread over the bottom to act as a sealant. Seven or eight springs were left uncovered to serve as the pond's water supply. They were protected during the grading process by geotextile filter fabric.

Two areas of shoreline located in lobes at opposite ends of the pond were then backfilled with 10 in (25.4 cm) of sand to provide bedding for proposed herbaceous wetland plantings. These areas were planted during a drawdown with arrow arum (*Peltandra virginica*), pickerel weed (*Pontederia cordata*) and arrowhead (*Sagittaria latifolia*). Buttonbush (*Cephalanthus occidentalis*), bald cypress (*Taxodium distichum*) and red maple (*Acer rubrum*) were planted at the water's edge. The islands and certain shoreline areas were seeded with a mixture of barnyard grass (*Echinochloa* sp.) and switchgrass (*Panicum virgatum*). Some additional species may have been planted as available.[25]

The deepest part of the pond is 10 ft (3.0 m). Bluegill and bass were stocked after construction. Recreational access was enhanced by a gravel road encircling the pond and construction of a canoe launch site where the bank is reinforced with railroad ties. The Isaak Walton League controls access to the area.

Observations made at the start of the sixth growing season after construction indicate that the wetland species that were planted have not become well-established. Emergent and floating-leaved vegetation are present, however. Spatterdock (*Nuphar advena*) is the predominant species, having established itself in most of the pond's protected coves. A sparse band of rushes (*Juncus* sp.) has colonized the pond's large and exposed east lobe where arrowhead was planted. No arrowhead was observed. Its tubers are especially palatable to waterfowl (hence, the alternate name: duck potato) and it is expected that the propagules were all destroyed by Canada geese.[26] Water depth, exposure and substrate may also have been factors in the failure of the arrowhead plantings to become established. Shoreline slopes are too steep and water depths too deep (>2 ft [0.6 m]) to support substantial emergent growth around most of the pond's perimeter. However, despite the large amount of open water, wildlife cover is available in the vegetated coves and among the islands. Evidence of nesting by Canada geese was observed (pair with six goslings). MSHA reports use by large numbers of visiting waterfowl during migration.[26]

Approximately one-quarter of the basin supports submergents consisting almost entirely of coontail (*Ceratophyllum demersum*). Water clarity is quite good. Large amounts of muskgrass (*Chara canescens*), an algae which favors clear, mineral rich water, has been reported to occur in large quantities later in the growing season.[27]

At least some of the tree and shrub plantings had survived although few of the 300+ buttonbush were observed. Detailed vegetation survival studies have not been conducted. A full list of species observed is in volume II.

Control

The existing floodplain wetland at Laurel was considered to be representative of the adjacent wetland impacted due to the bridge construction. A 650-ac (263-ha) segment of floodplain bounded by Brock Bridge Road on the south, and by the City of Laurel on the north was delineated as the control assessment area for purposes of WET 2.0 evaluation (figure 7).

The primary covertype in the control AA is forested deciduous wetland. Limited areas (8 percent) of shallow marsh and shrub swamp are also present. The forest canopy is dominated by mature individuals of the following species: silver maple (*Acer saccharinum*), box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*) and river birch (*Betula nigra*). Climbing vines of poison ivy (*Rhus radicans*) and virginia creeper (*Parthenocissus quinquefolia*) are in some areas common and large extending into the high forest canopy. Common shrubs include spice bush (*Lindera benzoin*) and young silver maple. The herbaceous cover is lush and consists primarily of jewelweed (*Impatiens capensis*), sensitive fern (*Onoclea sensibilis*), and gill-over-the-ground (*Glechoma hederacea*). A complete species listing can be found in volume II.

Wildlife and wildlife sign observed in the control included raccoon, deer, mallards and a woodpecker.

The control's watershed is approximately 19 mi^2 (30.6 km^2). It was delineated according to the method described in WET 2.0 and therefore only

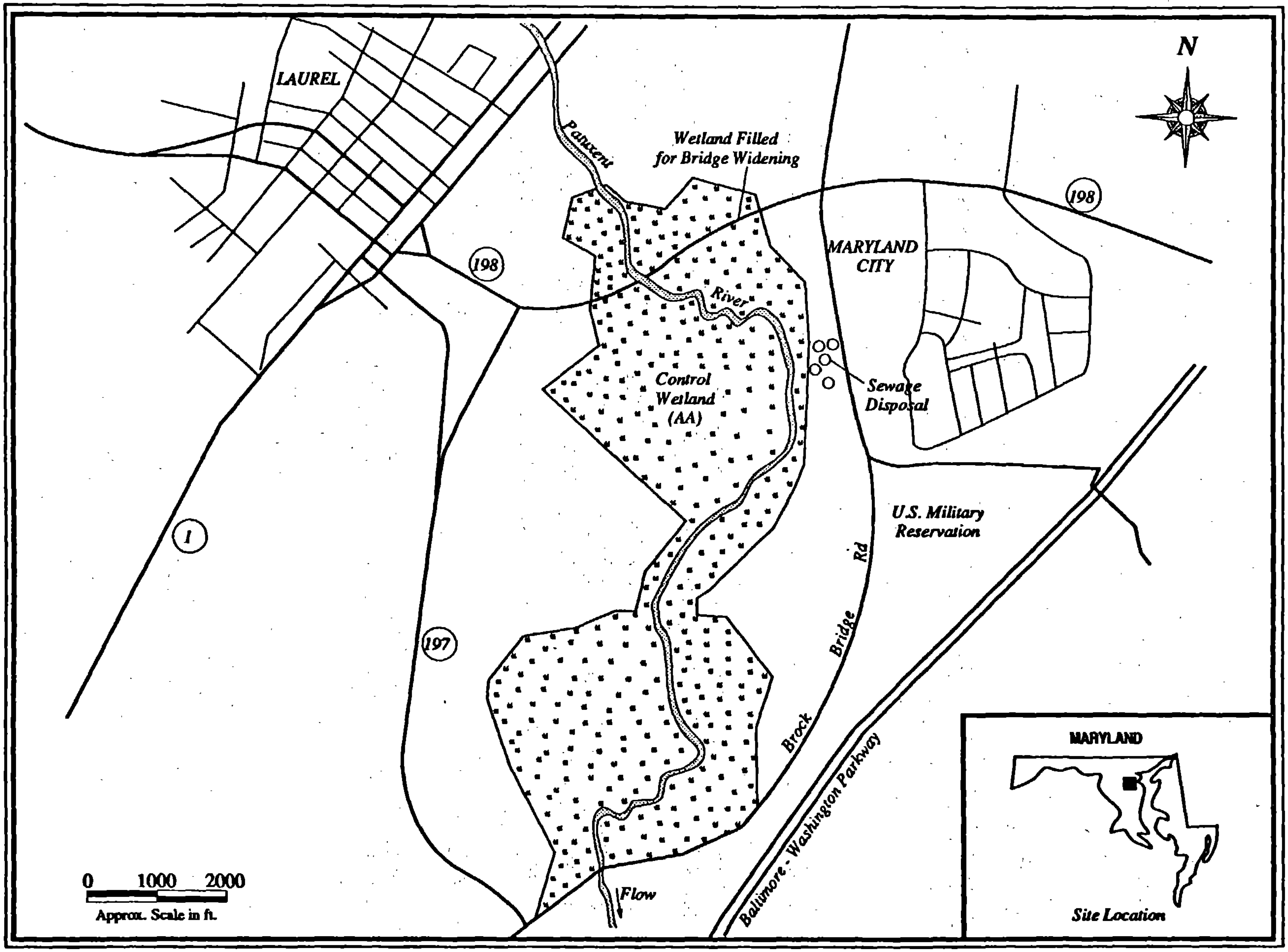

Figure 7. Patuxent River control wetland, Laurel, Maryland.

includes the drainage area below Rocky Gorge Dam. The dam is located approximately 2 mi (3.2 km) upstream of the control, on the northwest outskirts of Laurel. The area is undergoing rapid residential and commercial development. It includes the City of Laurel and several of its suburbs. Numerous perennial and intermittent inlets are tributary to the control AA and its segment of the Patuxent.

The service area for the control AA has been designated as the 5-mi (8.1-km) reach of the Patuxent River beginning immediately below the AA. Its watershed is much more rural in nature than the AA's watershed. The U.S. Department of Interior's Patuxent Wildlife Research Center is located along this segment of the floodplain.

Methods

Field work for this study was conducted during May 4 and 5, 1989. Wetland scientists met with and interviewed representatives of MSHA and the FHWA at the impact site and the mitigation site. MSHA grading and planting plans were reviewed and used to assess existing conditions. Information on project goals and intent were gathered from the above sources and from a brief MSHA report on the mitigation.[25] Other information sources that were consulted include the SCS, the DNR and the Prince Georges County Environmental Health Department. Conductivity and pH were measured in samples taken in the Patuxent River channel at Laurel, and at the outlet of the mitigation site.

Functional Analysis

The model results for the Patuxent River mitigation and control wetlands are presented in appendix A.

Summary

The mitigation area in Bowie was designed with much attention to detail and to project goals. The pond appears to have been constructed as planned. Although emergent plantings were not very successful, emergent zones have developed naturally with time.

Review of the plan suggests that emergent vegetation was not intended or desired to develop around the entire perimeter. The pond was designed for multiple uses including recreational fishing and wildlife habitat. The deep open water areas combined with the undulating shoreline's shallow, sheltered coves provide rather well for these two different goals. However, wildlife value could be easily enhanced by allowing the mowed area surrounding the pond to grow naturally to improve cover.

Water quality protection was one of the mitigation goals. According to WET 2.0, functions related to water quality protection (e.g. sediment/toxicant retention and nutrient removal/transformation) are very likely to be provided by the mitigation site. However, the analysis ignores important factors such as vegetation density, productivity and substrate characteristics. Hollands-Magee analysis indicates that characteristics of the mitigation area such as low vegetative density and productivity and lack of organic substrate are likely to provide little water quality improvement.

The mitigation site is not particularly well placed to provide significant flood control value. The pond's berm and its constricted outlet are not conducive to the entrance of floodwaters from the Green Branch. However, if stormwater finds it way in, storage volume is great.

The mitigation area was also designed with public education as a goal. The area is publicly owned and managed by a private conservation concern. The education function might be better served if access were unlimited. Presently, a locked gate limits access, although foot traffic is possible.

Mitigation goals were very specific on this project. No attempt was made to replicate the wetland impacted. However, in addition to goal attainment, the project must also be considered in regard to its effectiveness at replacing the functions that were lost to construction, since that is the purpose of this study. According to WET 2.0 analysis, the mitigation was quite effective in this regard, except where social significance is concerned. This exception is due primarily to aspects of the wetland's location and watershed charateristics.

The Hollands-Magee analysis rated most of the mitigation area's functions lower than those of the impacted site due mostly to their differing cover types. Assessment area size difference was also a major factor. However, it should be noted that the impact involved only 5 ac (2.0 ha). At least that much valuable emergent wetland was constructed as mitigation.

6. Stoll Road, Michigan

Introduction

Construction of a 20-mi (32.2-km) section of Interstate 69 on new location between Lansing and Morrice, Michigan will require filling of approximately 273 ac (110.6 ha) of wetland.[28] The most frequently impacted wetland type on the project is deciduous forest wetland (41 percent by area).

These areas are typically dominated by silver and red maples (*Acer saccharinum* and *A. rubrum*). Lowland conifer with associated hardwood species comprise 27 percent of the impacted wetlands. Shrub swamps and emergent wetlands make up 17 percent and 11 percent, respectively. The remaining 4 percent consists of other types.[29] Construction is still in progress and is proceeding in phases.

Mitigation Design

Part of the mitigation for the first phase of construction (wetland acreage undetermined) included enhancement of an existing borrow pit located south of Stoll Road in DeWitt Township near the project's western terminus (figure 8). The water-filled borrow pit was enlarged to approximately 6 ac (2.4 ha) and six small islands were constructed. The surrounding upland was seeded with a mixture of grass and wild flowers intended to improve aesthetics and provide cover for game birds. Wetland plantings were not included in the mitigation activities. Some references were made to placement of wetland topsoil in the pond's shallow west end, but a determination could not be made regarding actual occurrence of this activity. It was an option left up to the contractor.

The goals of the mitigation project at Stoll Road (according to Wetland Mitigation Site Data submitted by the Michigan Department of Transportation [MDOT] to the FHWA) were to provide fish spawning, nursery and cover habitat; and to provide nesting, feeding and rearing habitat for waterfowl. The site was completed late in 1986 at a cost of $71,835.

In addition to the Stoll Road site, the mitigation package for the first phase of I-69 construction included 15 ac (5.9 ha) of borrow pits near the intersection of Webster Road, and approximately 2 ac (0.8 ha) east of Grass Lake.[30] The Webster ponds were excavated from upland late in 1987 and have a maximum depth of 30 ft (9.12 m).[31] Very little information is available on the other areas. These ponds were intended to provide open water resources adjacent to Grass Lake that would enhance its wildlife value.

Site Descriptions

Mitigation

Stoll Road was chosen for analysis as a mitigation site because the intent was to establish a wetland rather than simply open water. Better documentation was available for Stoll Road and it had been completed earlier than any of the other components of the mitigation package for the first phase of construction.

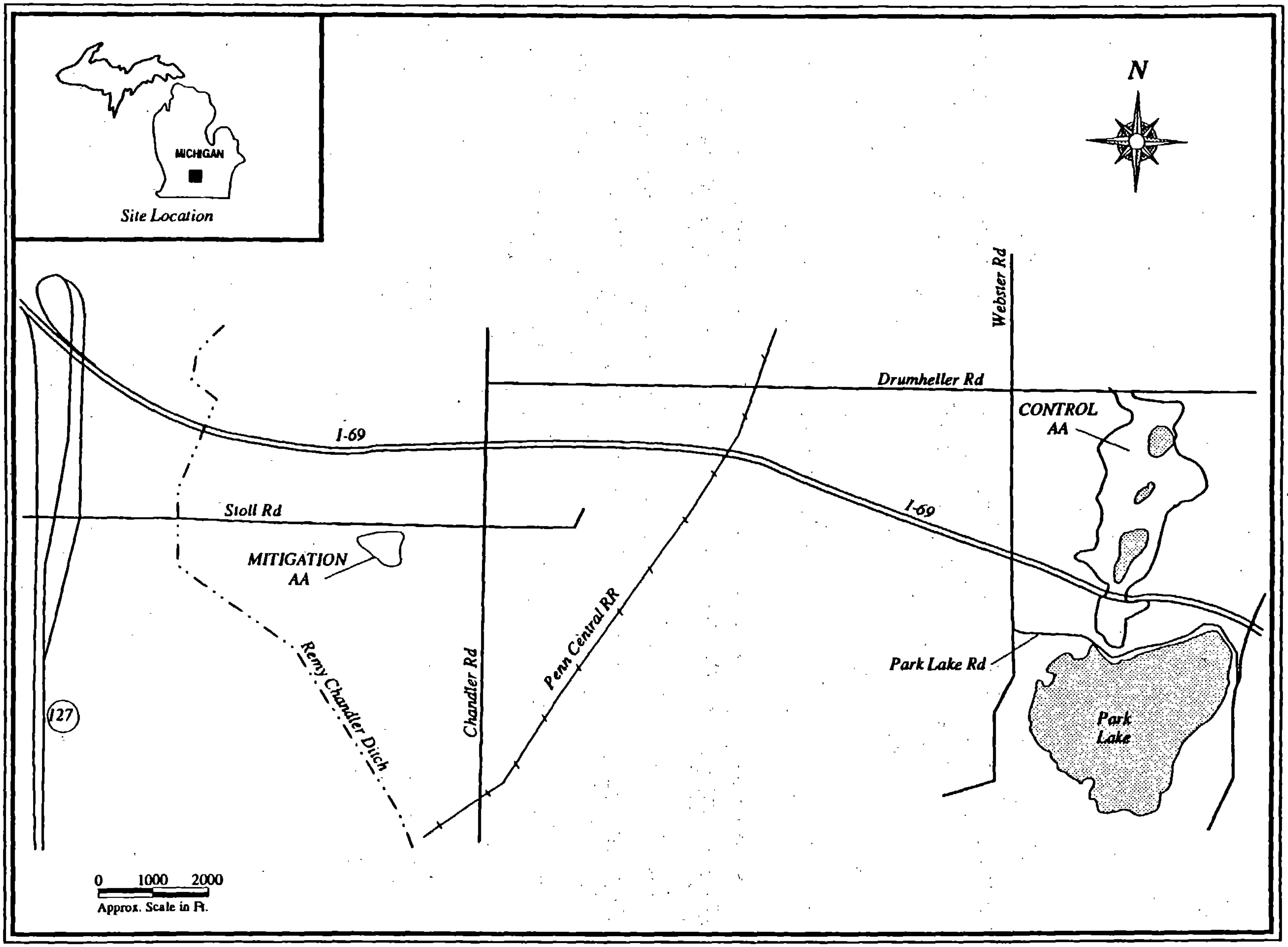

Figure 8. General Location of Stoll Road mitigation and control wetlands, Michigan.

The assessment area (figure 8) consisted of approximately 95 percent open water. A band of emergents approximately 2 ft (0.6 m) wide was observed along the shoreline of the pond's western end. This consisted primarily of rushes (*Juncus* spp.), reed canary grass (*Phalaris arundinacea*), cattail (*Typha latifolia*), boneset (*Eupatorium perfoliatum*) and water plantain (*Alisma triviale*). Uprooted cattails were observed, suggesting muskrat activity. No other muskrat sign were observed, however. Switchgrass (*Panicum virgatum*) and white sweetclover (*Melilotus alba*) were the most commonly occurring species on the pond's perimeter above the waterline.

A 5-ft (1.5-m) wide shrub zone, 4 to 6 ft (1.25 to 1.8 m) in height, had colonized the east end of the mitigation pond. Species included willows (*Salix interior* and *Salix* spp.) and trembling aspen (*Populus deltoides*). A dense growth of willow seedlings occurs along the south shore. Submergents, consisting of sago pondweed (*Potamogeton pectinatus*), knotty pondweed (*P. nodosus*), water milfoil (*Myriophyllum exalbescens*) and filamentous algae formed a nearly continuous growth in the shallow western end. A species list for Stoll Road is attached in volume II.

Stoll Road pond has no inlets or outlets, therefore there is no downstream service area. The pond's watershed is only slightly larger than the pond itself and consists of a grassy meadow. A planned spillway leading to the mitigation area from the wetland to the south was not constructed due to the concern that it might drain that wetland. The coarse, permeable substrate in the mitigation pond and the elevation of adjacent peatlands suggest that the water level in the pond is an expression of the local water table. The deepest portion of the pond (5 ft [1.5 m]) is located in the northeast portion.[30] The remainder is between 1 and 3 ft (0.3 and 0.9 m) deep.

Evidence of blue gill nesting was observed in the pond's east end. Wildlife and sign observed at the Stoll Road site included white-tailed deer, a mallard brood, a spotted sandpiper and abundant leopard frogs.

Control

Grass Lake is a 140-ac (55.3-ha) wetland complex consisting primarily of a bog mat dominated by bulrush (*Scirpus validus, S. acutus*) and sedges (*Carex* sp.). The substrate is Houghton Muck which is generally neutral in pH and explains the lack of "typical" acidic bog species. Small areas of open water/deep marsh are also part of the assessment area (AA). A species list indicating abundance can be found in volume II.

Grass Lake was used as the control wetland because its alteration was of major concern to regulatory review agencies and it was a focus of the mitigation negotiations. In addition, it contains many of the cover types impacted by the highway. It was evaluated in its preconstruction condition (based on aerial photography) to provide a more accurate assessment of the resource prior to impact.

The Grass Lake AA is bounded to the north by Drumheller Road and to the south by Park Lake Road. It is located east of the mitigation site. Most of its 400-ac (162-ha) watershed consists of wetland. Upland land uses include agriculture, abandoned pasture and gravel mining. No surface water inlets or outlets were evident. Based on topography, however, the Grass Lake system appears to discharge to Park Lake.(29) Park Lake is therefore the service area for the Control (Grass Lake) AA. Park Lake is a shallow basin (less than 6 ft [1.8 m]) ringed by residential development and wetlands that is an important resource for waterfowl. The lake has a public park and a beach, and is used for recreational hoating and fishing.

Interstate 69 has been constructed across the narrowest portion of the Grass Lake AA. Equalizer pipes were placed under the highway to prevent damming of groundwater flow. No obvious secondary impacts were observed as a result of the fill.

Methods

Field work was conducted on July 6, 7 and 8, 1989. On-site consultations were made with MDOT biologists. Other agencies contacted for information utilized in functional analysis included: the Soil Conservation Service, the Michigan Natural Features Inventory, the Michigan Department of Natural Resources and the Michigan Geological Survey.

Water quality samples were taken from standing water in Grass Lake wetland about 3000 ft (91.4 m) north of I-69, and from the north shore of Stoll Road pond.

Functional Analysis

Results of the Hollands-Magee and WET 2.0 models are discussed in appendix A.

Summary

Effectiveness of the efforts at the Stoll Road (mitigation) wetland in mitigating the losses caused by I-69 were assessed by comparing its functions with those of Grass Lake (control). Grass Lake was bisected by I-69 and is representative of the range of wetland impacts resulting from the construction.

Results of the two assessment methodologies do not agree in all cases. WET 2.0 analysis indicates that the majority of the functions are just as likely to be performed by the mitigation as the control. The results of the Hollands-Magee analysis indicates, however, that very few functions are performed as well by the mitigation as by the control. Both methods agree that aquatic and wildlife diversity/abundance functions at Stoll Road are not on par with Grass Lake.

Although observations made at the Stoll Road mitigation site during the third growing season after construction indicate that some use of the area by fish and waterfowl is occurring (see Mitigation section), improvements in habitat quality are necessary before project goals can be met. Based on the favorable water depth and the initial development of both emergent and shrub vegetation in the Stoll Road basin, such improvements can be expected with time. As the emergent zone expands and the shrub zones become better established, waterfowl and other wildlife habitat will improve. Wildlife will also benefit from the diversification of adjacent upland cover that will occur with time. The location of natural wetlands and farmland in close proximity to the mitigation area may encourage the utilization of the developing habitat by wildlife from those areas.

Enhancement/Creation Sites

7. Southern Tier Expressway, New York

Introduction

Construction of the Southern Tier Expressway (STE) in Cattaraugus County, NY involved the loss of 43 ac (17.4 ha) of wetlands. The STE was built on a new alignment which crossed forested, shrub and emergent wetlands in the Allegheny River valley between Salamanca and Olean, NY.

The Allegheny River valley is used extensively for agriculture; the mostly wooded hillsides are the site of oil wells and the foothills are often grazed. Gravel and sand pits are common along the edge of the valley. The majority of the wetlands impacted (51 percent) were floodplain forested swamps located at the base of steep hillsides. Other impacted wetlands consisted of wet meadows (19 percent), and shrub swamps (16 percent) located in areas once cleared for farmland. The remaining 14 percent of the wetlands impacted includes a mixture of types such as shallow and deep open marsh.

Mitigation Design

As mitigation for these losses, Federal permit conditions required the creation of 78 ac (30.8 ha) of replacement wetlands. This work was carried out in three separate areas. Eighteen experimental ponds totalling 4.5 ac (1.8 ha) were constructed in 1981 to provide data on substrate, water depth and planting treatments that could be utilized in the design and construction of the remaining 74 ac (29.2 ha) of replacement wetlands. Results of this demonstration project are detailed in reference 32 and will not be discussed further here.

By the end of the 1984 construction season, the next 47 ac (18.6 ha) of replacement wetlands had been constructed. This took place in two areas, referred to as the Reservation Road (9 ac [3.6 ha]) and Birch Run mitigation wetlands (38 ac [15 ha]). Birch Run is the focus of the current evaluation of mitigation effectiveness along the STE project in New York.

An additional 32.5 ac (12.8 ha) of ponds were constructed late in 1987, bringing the total mitigation acreage to 84; 6 ac (2.4 ha) more than initially planned. This most recent work is discussed only briefly.

The goal of the STE mitigation project was to create emergent wetlands with a variety of plant communities to compensate for the loss of wetland habitat.(33) This goal was supported by the purpose of the demonstration project which was:(32)

> "...to determine whether viable emergent wetlands could be constructed for mitigation...", to determine the types of environmental conditions necessary to meet mitigation objectives, and to utilize this information in designing and constructing the remaining mitigation wetlands.

Wetland habitat (non-specific) was the only function targeted for compensation through the proposed mitigation activities, according to project documentation.(33)

The cost of constructing this 84-ac (33.2-ha) mitigation project has not been determined. Expenses included the purchase of additional right-of-way for the wetland and the research costs. Costs were offset by the utilization of material excavated during pond construction as highway embankment fill. In the case of the Birch Run wetlands, work was completed within the normal highway right-of-way.

Site Descriptions

General

Construction of the Reservation Road pond (figure 9) located on the south side of the highway in the Town of Carrolltown was begun in April 1983. It was the first STE mitigation area to be constructed incorporating design recommendations from the demonstration project. A series of concentric shelves were designed to have water depths of 1, 2 and 3 ft (0.3, 0.6 and 0.9 m). The 1-ft (0.3-m) zone which was intended to support the highest density of emergent growth, was designed to be between 10 and 40 ft (3.0 and 12.2 m) wide. The 2-ft (0.6-m) shelf was expected to colonize over the long-term with different emergent species as well as floating leaved and submerged vegetation. Construction activities were monitored for New York State Department of Transportation (NYSDOT) by a firm which reported that contouring occurred according to plan.[33]

Influenced by weather conditions and borrow requirements, Reservation Road pond was constructed over a period of two years. Topsoil to be obtained from wetlands disturbed by STE construction was to be spread in a 6-in (15.2-cm) layer on the 1- and 2-ft (0.3- and 0.6-m) shelves. However, construction activities did not yield a sufficient quantity of wetland topsoil so a mixture of upland and wetland topsoil was spread in portions of the pond.

The pond had to be pumped down in order to conduct the earthwork. At the end of 1983 the pond was 90 percent complete and was allowed to fill. It was pumped down again in August of 1984 to complete earthwork and topsoil spreading in the "panhandle" portion of the pond which had been left undisturbed in order to allow access to an adjacent borrow pit. Surface water connection to an adjacent Allegheny River slough was finally made in October 1984.

Water level adjustments required for construction interrupted the development of emergent vegetation. Sparse growth was reported for the Reservation Road Pond at the end of 1984. In June, 1989 a 3- to 10-ft (0.9- to 3.0-m) band of emergents consisting predominantly of reed canary grass (*Phalaris arundinacea*), sedges (*Carex stipata*) and soft rush (*Juncus effusus*) rimmed the pond. NYSDOT indicated that growth could be expected to increase in extent by July and that there was enough growth in one summer for the construction of two muskrat houses.

The Birch Run wetlands are a series of 10 interconnected ponds totalling 38 ac (15.0 ha) excavated within a 1.4-mi (2.3-km) segment of right-of-way along the north side of the STE in the Town of Allegany (figure 10). All 10 ponds are connected, for at least some portion of the year, by flow from Birch Run and its unnamed tributary. Ponds 5, 6 and 7 are

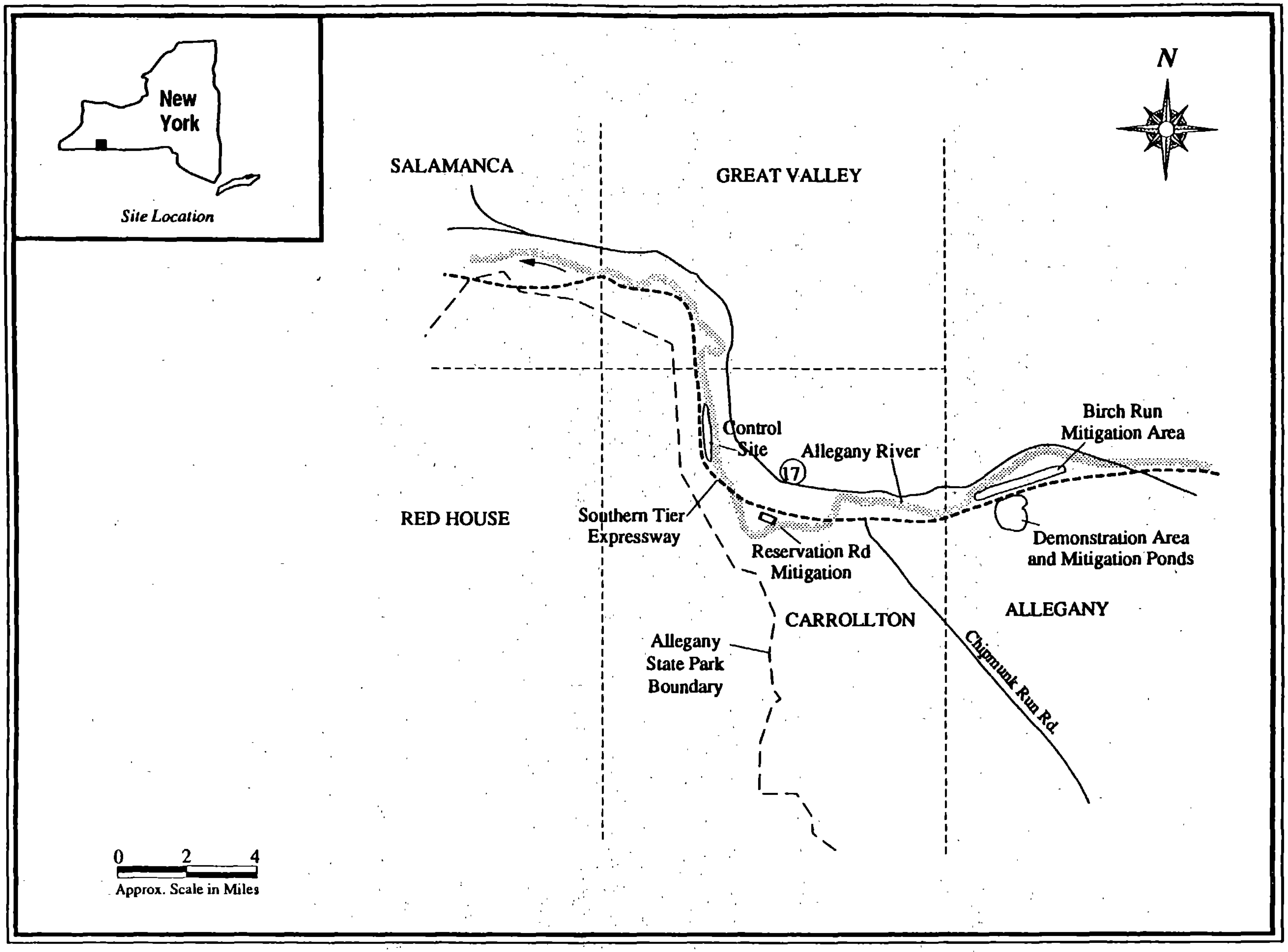

Figure 9. General Location of Southern Tier Expressway mitigation and control wetlands, New York.

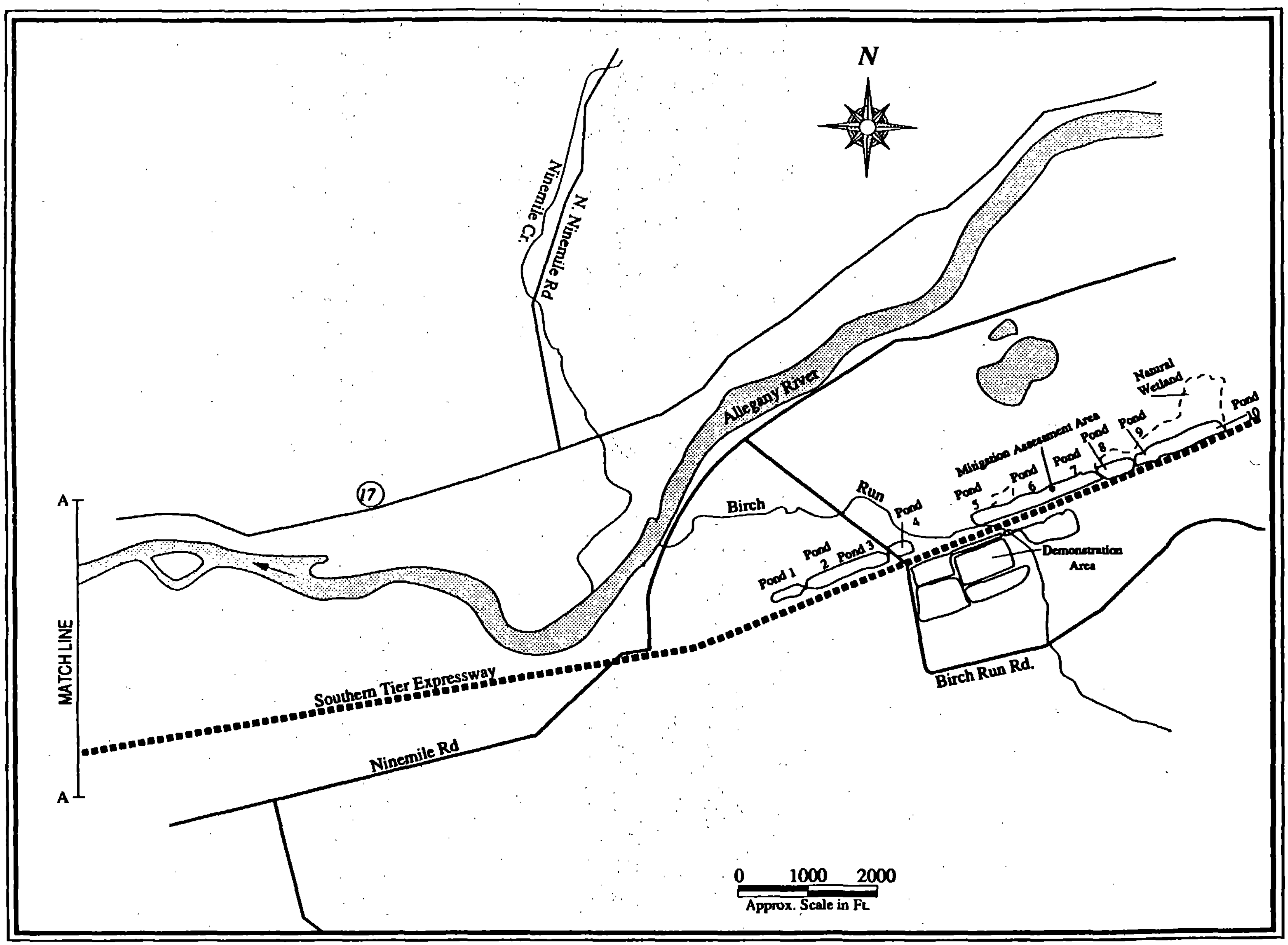

Figure 10. New York STE site, section A, to be matched to section B.

separated from adjacent upstream (ponds 8 through 10) and downstream (ponds 1 through 4 and two other borrow pits) mitigation areas by a berm and an undisturbed patch of wet woods, respectively. These are only partial barriers but fit the WET 2.0 criteria for hydrologic discontinuities that are sufficient for delineating an AA. A detailed description of the assessment area (ponds 5 through 7) can be found in the next section.

The Birch Run wetlands were all constructed between July and November 1983 based on designs similar to the Reservation Road Pond. Wetland topsoil was spread on the 1- and 2-ft (0.3- and 0.6-m) shelves after the latter part of September.(33) Many of the "divisions" between the 10 ponds (which were only numbered during construction to lend clarity to the monitoring reports) are shallow marsh areas while others are upland or transitional berms. In order to fit within the right-of-way, the Birch Run wetlands are narrow, generally ranging between 200 and 230 ft (61.0 and 70.1 m) wide. Several contain small islands, usually less than 1500 ft^2 (139.4 m^2).

Although not clearly documented, much of this area was wetland prior to excavation of the ponds. These wetlands consisted of wet agricultural fields and other wet meadows with scattered shrubs. These wetland types were apparently not recognized as such by regulatory agencies at the time. The wettest portion was at the east end of the Birch Run area in the vicinity of the unnamed tributary to Birch Run. This area was recognized during construction of the ponds and resulted in modification of the plans in order to retain some of the existing wetland for structural diversity and as a propagule source for vegetation establishment. Consequently, the STE mitigation project is a combination of wetland creation and enhancement of existing wetlands.

Other problems observed during construction and postconstruction monitoring led to remedial activities which improved the performance and stability of the Birch Run mitigation area. An inspection in June, 1984 found that high flow had eroded the outlet from pond 5 and the natural wetlands between ponds 9 and 10. The outlet was reinforced with medium stone and the channel between ponds 9 and 10 was reshaped to form meanders. In addition, to reduce the pressure on the pond 5 outlet (the only structure controlling water levels in the upper 6 ponds) and help maintain water levels, berms with rock spillways were constructed between ponds 7 and 8, and ponds 8 and 9. An outlet was created at the downstream (western) end of the Birch Run wetland in pond 1 to alleviate high water conditions in the lower four ponds. In June of 1987, ponds 2 and 3 were drawn down to promote better emergent growth. The effectiveness of this measure was evidenced by the 50- to 75-ft (15.2- to 22.9-m) wide emergent zone observed in these ponds compared to the very narrow fringe observed in pond 4.

The width of the emergent edge in June, 1989 varied widely within the Birch Run mitigation area. The shallow shelves between the numbered ponds usually supported the most extensive growth. The perimeters of some ponds such as #4 had as little as a 2- to 4-ft (0.6- to 1.2-m) border of emergents. Overall species diversity of the 38-ac (15.0-ha) area was quite good. The most commonly occurring species included: rice cutgrass (*Leersia oryzoides*), softrush, sedges (*Carex* spp.), woolgrass (*Scirpus cyperinus*) and manna grass (*Glyceria* spp.).

Submergents dominated the 2- and 3-ft (0.6- and 0.9-m) shelves and appeared to consist almost entirely of water milfoil (*Myriophyllum* sp.) Filamentous algae and other surface algal blooms were observed, suggesting high nutrient levels.

No additional mitigation areas were constructed on the project until 1987 when two borrow pits totalling 8.5 ac (3.4 ha) were excavated west of Birch Run. Very little documentation is available on these areas. It is not known whether they were constructed in the same manner as Birch Run and Reservation Road, or if topsoil was spread. No observations were made at these areas.

Four large ponds totalling approximately 24 ac (9.5 ha) were excavated in 1987 surrounding the demonstration ponds (located to the south of the STE opposite Birch Run wetland). Parts of this site appear to have been wetland prior to excavation based on characteristics of adjacent areas and several areas of undisturbed ground within the ponds. Maximum depths of these ponds may be 4 to 5 ft (1.2 to 1.5 m) according to NYSDOT.(34) Shallow shelves were not constructed; therefore very little emergent vegetation has developed. It is not known whether wetland topsoil was spread. Shrubs were planted around the perimeter of the eastern-most of these four ponds. Two rows each of willow (*Salix* sp.), red osier, and silky dogwood (*Cornus stolonifera amomum*) were planted within a 15-ft (4.6-m) band. Survival of the plantings, approximately 2 ft (0.6 m) tall in 1989, could not be evaluated as no records of the number planted were available. Few dead plants were observed, however.

The ponds are fed by groundwater discharge and water diverted from Birch Run. They are used frequently by anglers who report catches of northern pike, bass, suckers, bluegills and sunfish.

Mitigation

A representative 10-ac (4.0-ha) portion of the Birch Run mitigation wetland, ponds 5, 6 and 7, was chosen as the assessment area for functional analysis. This AA also includes a contiguous patch of wet meadow located in an adjacent agricultural field. Figure 10 shows the boundaries of the AA. Construction of this area was completed late in 1983.

Three vegetation cover types and open water comprise the AA. Deep fresh marsh (water depth > 6 in [15.2 cm]) covers 70 percent of the AA. The dominant vegetation here is water milfoil, a submergent. Filamentous algae is also abundant. Deep and shallow marsh (15 percent of the AA) emergents consist primarily of fowl meadow grass (*Glyceria striata*), soft rush, wool-grass, and rice cut-grass. The emergent fringe extends an average of 30 ft (9.1 m) out into standing water. More extensive stands occur in the shallows between the ponds and the upstream end of the AA. Wet meadow in the adjacent field and around the ponds' perimeter comprises 10 percent of the AA and is dominated by sedges (*Carex* spp.), soft rush, reed canary grass (*Phalaris arundinacea*), goldenrod (*Solidago* spp.) and fowl meadow grass. Scattered young willows (*Salix* spp.) can also be found in this area. The developing plant community in the AA is quite diverse. A species list is attached in volume II.

The mitigation AA has a permanent inlet and outlet, and three ephemeral inlets. The tributary to Birch Run flows intermittently into the AA across the berm between the AA and pond 8. Two other intermittent inlets carry stormwater into pond 7. Birch Run itself enters and exits the AA in pond 5, the downstream end of the AA. The AA's watershed is approximately 4.3 mi^2 (11.4 km^2) and extends 800 ft (243.8 m) up a steep, mostly wooded hillside (30 percent slope) to the south. The cleared portions are in pasture or gravel pits, except north of the AA where there are row crops. Many small oil wells are located in the upper reaches of the watershed.

The service area of the mitigation AA was designated as lower Birch Run and the segment of the Allegheny River extending 5 mi (8.1 ha) downstream from Birch Run to the vicinity of Riverside Junction near Tunungwant Creek.

Control

Palustrine deciduous forested wetland habitat sustained the highest losses from the highway construction. An assessment area encompassing this wetland type was therefore chosen for functional analysis and comparison with the mitigation area. The control is a 30-ac (11.9-ha) area of floodplain forest located adjacent to the Allegheny approximately 6.5 mi (10.5 km) down river from Birch Run (figure 11). A natural forested upland levee separates the AA from the river along most of its length. Floodwaters enter the AA by way of a meandering system of sloughs or over the levee in severe floods. No permanent surface water inlets or outlets are present.

Dominant vegetation in the control AA consists of an open canopy of sugar maple (*Acer saccharum*), green ash (*Fraxinus pennsylvanica*), red maple (*A. rubrum*), silver maple (*A. saccharinum*) and yellow birch (*Betula lutea*). The well-developed understory consists of ironwood (*Carpinus caroliniana*),

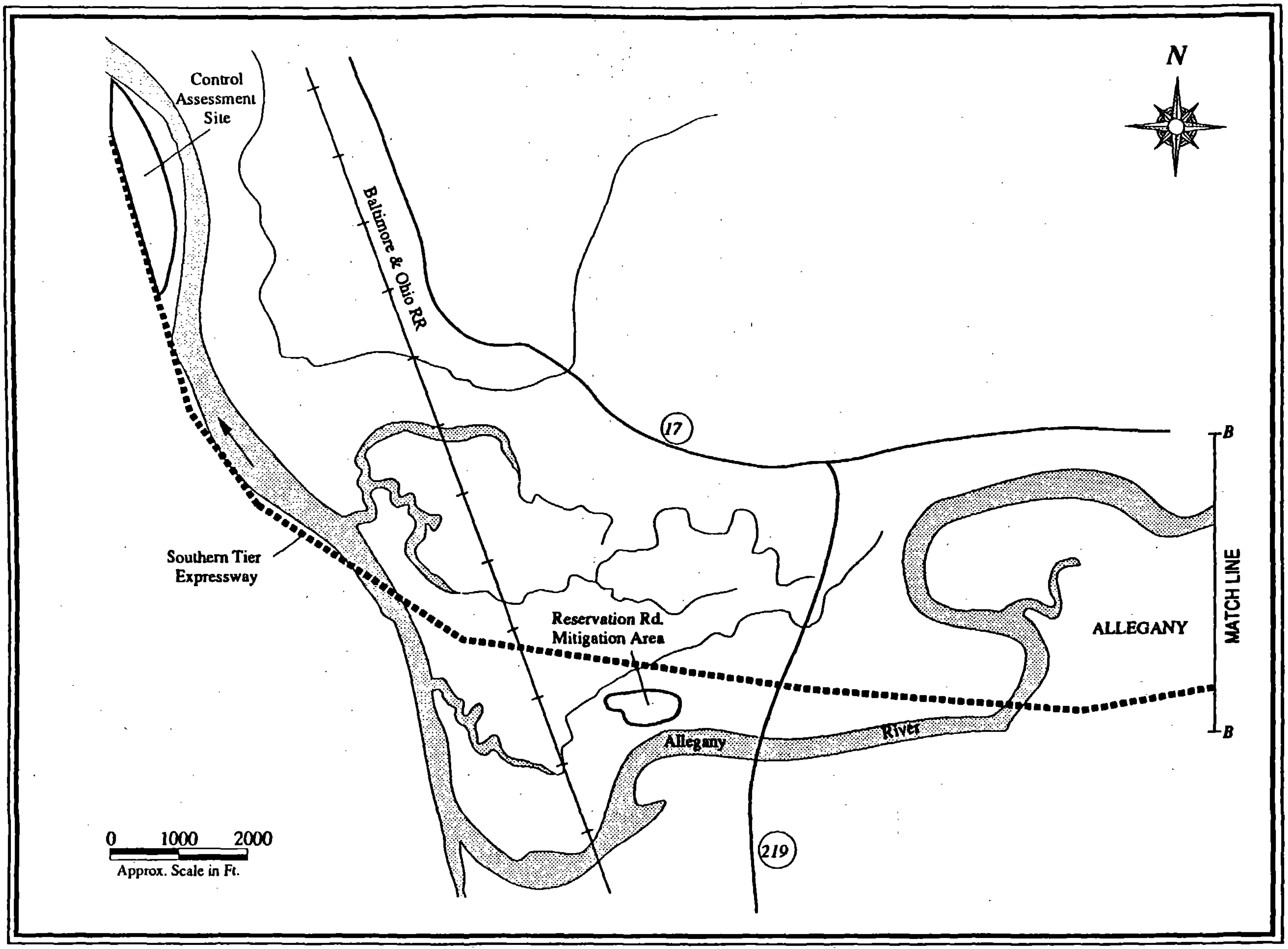

Figure 11. New York STE site, section B, to be matched to section A.

beech (*Fagus grandifolia*) and buttonbush (*Cephalanthus occidentalis*). Poison ivy (*Rhus radicans*) is abundant in vine form. The moderately dense layer of herbs is dominated by skunk cabbage (*Symplocarpus foetidus*), jewelweed (*Impatiens capensis*), white hellebore (*Veratrum viride*), smartweeds (*Polygonum* spp.), sensitive fern (*Onoclea sensibilis*) and cinnamon fern (*Osmunda cinnamomea*). A complete species list can be found in volume II.

The watershed of the control AA was delineated in accordance with WET 2.0 guidelines. It consists of the watershed of the Allegheny River upstream of the AA, an area encompassing around 1,200 mi^2 (1932.0 km^2) of forest, farmland and small to medium-sized communities in southwestern New York and Pennsylvania. Much of this area is steeply sloped. Industries discharging to the Allegheny or its tributaries include metal plating, fertilizer production and an oil refinery. Numerous municipal sewage treatment plants also discharge to the river. Non-point sources of water pollution include oil fields, dairy and agricultural lands.(35)

The service area of the control wetland is designated as the 5-mi (8.1-km) reach of the Allegheny River from Carrollton downstream to Salamanca, a floodplain town.

Methods

Field work was conducted along the STE from June 23 through June 26, 1989. Heavy rainfall on June 22 and 23 resulted in flooding of the Allegheny River and its tributaries, and inundation of the study sites. However, by June 25 water levels in the mitigation sites had receded to near normal. Floodwaters in the control, a section of Allegheny floodplain forest, had receded enough to allow entry and normal study activities by June 26.

All wetland units except two borrow pits were visited and photo-documented, and general observations made regarding dominant vegetation, vegetation density, morphology and hydrologic connection. Since this 84-ac (33.2-ha) mitigation project involved multiple wetland units, a subset of the total area having a high degree of hydrologic interaction was chosen for functional analysis and other detailed observations. Conductivity and pH were measured in a large slough in the control wetland. The same parameters were measured at the outlet of the mitigation assessment area.

On-site interviews were conducted with representatives of NYSDOT and the NYS Department of Environmental Conservation (NYSDEC) in Olean. Other information sources included NYSDOT file documents, and other NYSDEC and Soil Conservation Service (SCS) representatives and records.

Functional Analyses

WET 2.0 and Hollands-Magee evaluation results are shown in appendix A.

Summary

The primary goal of the STE mitigation was to create emergent wetlands with a variety of plant communities to compensate for the loss of wetland habitat. Observations made during the summer of 1989 indicate that this goal has been at least partially fulfilled for certain of the project's mitigation elements.

A segment of the Birch Run mitigation area was chosen to evaluate wetland functions representative of the entire 47 ac (18.6 ha) of mitigation constructed by 1984. The Birch Run mitigation area represents the successful creation of 38 ac (15.0 ha) of viable emergent wetlands. Surface and ground water sources appear to be adequate to maintain wetland hydrology. Two different plant communities, narrow-leaved emergent and submergent, covering up to 95 percent of each basin (pond), have already developed. Small patches of broad-leaved emergent species and the overall diversity of species in the Birch Run wetlands suggest that with time, the development of additional plant communities (greater structural diversity) can be expected.

The Reservation Road site, however, is less well-developed. Its extensive expanse of open water (approximately 900 ft [274.3 m]) in the direction of prevailing winds) may be a factor in the lack of establishment of emergent plant growth. The narrow, low-density band of vegetation observed around the pond's perimeter covers only 10 to 25 percent of the area that was planned to support emergent vegetation. Other factors affecting establishment may have been the use of some upland rather than all wetland topsoil as topdressing for the shallow shelves, and the possibility of incorrect assumptions regarding postconstruction water depth. As-built plans were not available for evaluating correspondence of final elevations to planned elevations. Any discrepancies in elevation would be suspected as a possible cause of sparse vegetation, given the great importance of water depth on growth.[32]

In the future, constructing wetlands with continuously sloping grades rather than with discrete shelves can be expected to reduce or avoid elevation problems. Vegetation establishing itself on a continuous, shallow slope has more ecological niches available to it than on a wide shelf of one elevation. A fluctuation in water level causes a much greater degree of change in conditions affecting a community inhabiting a shelf than for one inhabiting a continuous slope.

Cost effectiveness may also be an issue of importance in this regard. A continuous 40:1 slope requires excavation of only one-half the material that must be excavated to create a shelf 1 ft (0.3 m) deep and 40 ft (12.2 m) wide, making the continuous slope less costly. Accurate grading of a continuous slope can be assumed to require less time than a shelf, further reducing the cost of the former activity. Cost figures for the STE mitigation activities were not available, nor is it known whether the contractor considered the above factors in the bid.

Attainment of the goal of habitat replacement is difficult to assess because of its lack of specificity. Biological Function (Hollands-Magee) and the probability ratings of Wildlife Diversity/Abundance and Aquatic Diversity/Abundance are the most obvious predictors. Many other wetland functions are also important in considerations of wetland habitat value. These include functions relating to water quantity and quality as well as Sediment Stabilization and even Recreation. Values and probabilities for the Birch Run mitigation are equal to somewhat higher than those of the control site, according to the model results.

The habitat types of the created (mitigation) and impacted (control) wetlands are vastly different and support different wildlife assemblages. Without a specific species or set of species in mind, it is difficult to make a judgement of relative value of the two types of habitat. Certain general observations are useful, however. Woody edges provide important wildlife cover and structural diversity. The mitigation areas have yet to develop this covertype, a factor which somewhat impairs habitat quality.

Remedial efforts involving water level manipulation produced beneficial results in ponds 2 and 3. Emergent cover in the most recently constructed ponds surrounding the demonstration area might also benefit from adjustment of water level. Judging by the lack of records kept on these ponds, it appears that less attention was given to design elements that would lead to wetland development than for those units that were constructed in 1983. No shallow shelves were constructed even though the demonstration project report concluded that water depth was the factor having the greatest influence on growth of wetland vegetation.[32] There is some indication, however, that by the time these last ponds were constructed in 1987, mitigation goals had been modified through the interagency review process to focus on fisheries.[34, 36] The primary value of these steep sided ponds is for recreational fishing.

8. West Branch French Creek, Pennsylvania

Introduction

The Southern Tier Expressway (STE, Route 17) is part of the Appalachian Development Highway system whose purpose is to promote development in hitherto inaccessible areas between Binghamton, NY and Erie, PA. The Pennsylvania portion of the STE is 7.5 mi (12.1 km) long and passes through a sparsely settled agricultural region. Approximately one mi west of the PA/NY State line, the STE crosses the West Branch French Creek in Greenfield township, Erie County. Road construction involved filling 12.5 ac (4.9 ha) of emergent, shrub and forested wetland, 8 ac (3.2 ha) of which were adjacent to the Creek and an unnamed tributary. The mitigation plan was the result of collaboration between the Pennsylvania Deptartment of Transportation (PennDOT), Pennsylvania Fish Commission and Game Commission, Pennsylvania Department of Environmental Resources, the U.S. Fish and Wildlife Service, and Dalton-Dalton-Newport Consultants. The goals of the mitigation project were (1) one-to-one replacement of wetland acreage, and (2) enhancement of wetland wildlife habitat with particular emphasis on waterfowl.

Mitigation Design

At the West Branch crossing, three wetland basins totalling 12.5 ac (4.9 ha) were excavated in 1986 in land adjacent to the STE right-of-way, one north of the road and two to the south (figure 12). Two of these were constructed in existing wetlands, and the third was constructed in an upland corn field. At all sites, brush was cut, chopped, and disked into the topsoil, which was then stripped and stockpiled, and later spread in the excavated areas to a depth of 6 in (15.2 cm). In addition, a special construction detail for outer perimeter site grading was developed, the purpose of which was to incorporate existing wetland soils and plant material into the enhancement area to benefit revegetation. Nursery-stock shrubs, the species of which were selected for their wildlife food value, were planted in two of the mitigation areas, and five wood duck boxes were erected. The approximate cost of the mitigation project, including real estate was $277,000. The mitigation areas will remain under PennDOT ownership.

Site Descriptions

General

The project is located in a glaciated area of the Appalachian Plateau, underlain by sandstones, shales, and small amounts of limestone. The landscape is dotted with small oil and gas wells tapping deposits contained in

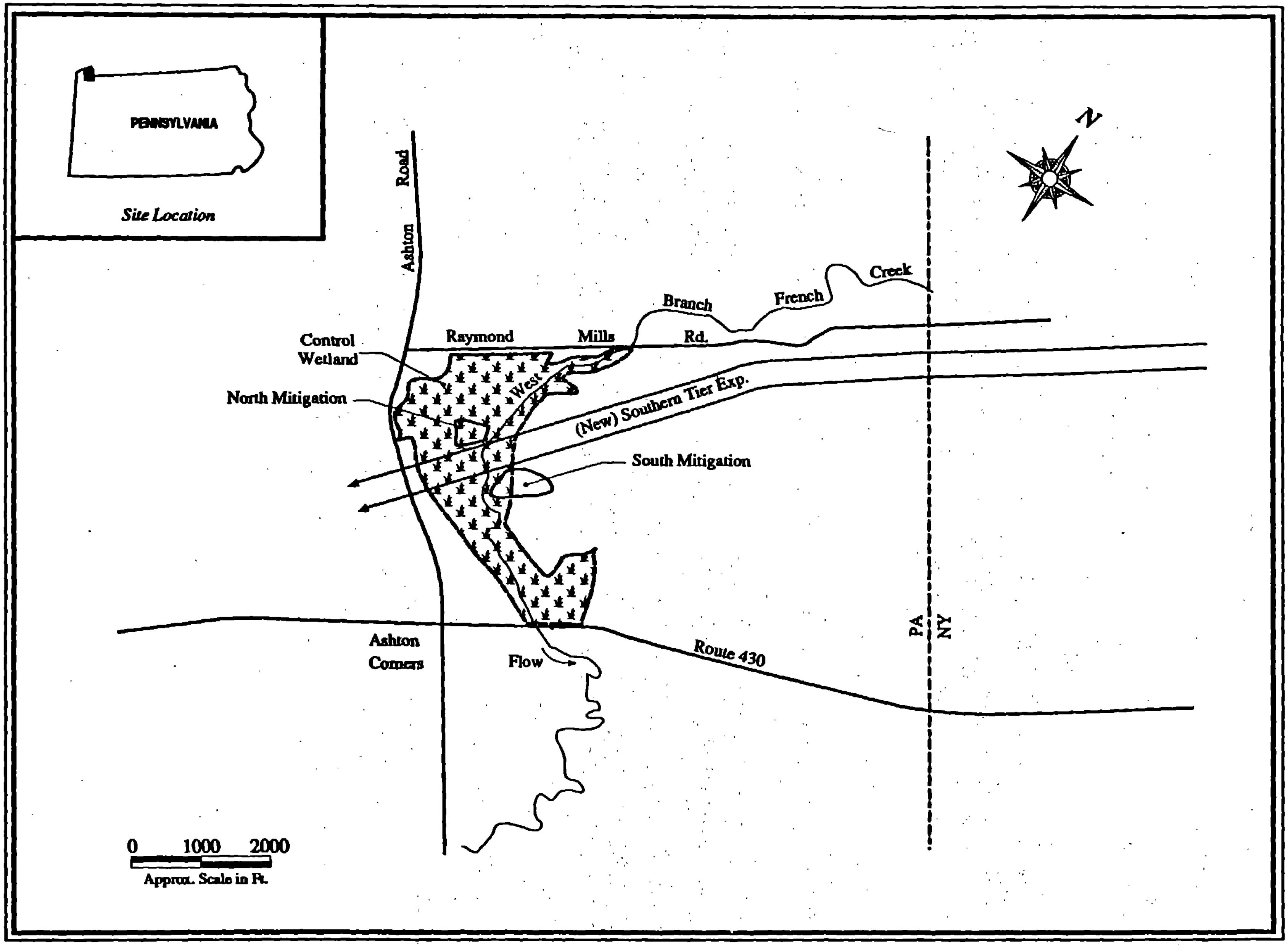

Figure 12. Location of mitigation and control wetlands at West Branch French Creek, Greenfield, Pennsylvania.

the underlying sedimentary rocks. The climate here receives none of the moderating influence exerted by Lake Erie. Winters are cold and snowy; summers are warm and humid. Average annual precipitation is 44 in (111.8 cm). Areas of glacial outwash hold abundant groundwater, but the shale underlying the region has little water storage capacity. Springs in the region tend to be high in sulfur and iron.[37] The landscape is characterized by low, rolling hills and slow, meandering streams. The major land uses are dairy pasture, hayfields, fallow fields, and deciduous forests. The dominant soils are silt loams derived from glacial till.

Mitigation

North Mitigation

The site of the north mitigation had been a wet meadow pasture dominated by reed canary grass (*Phalaris arundinacea*), with areas of alder/arrowwood (*Alnus rugosa/Viburnum dentatum*) shrub swamp along the West Branch and its tributary. According to the SCS Erie County Soil Survey, it is underlain by Wayland silt loam, a deep, somewhat poorly to poorly drained floodplain soil.[37] Construction began in late June 1986. Areas to remain undisturbed were surrounded with snow fence. Open water areas were excavated in the designed configuration (figure 13) to create three islands at elevations 3-ft (0.9-m) higher than the expected summer water level. The open water areas were designed to be approximately 2 ft (0.6 m) deep at midsummer. Islands were designed with irregular shapes and constructed with rough, variable steep slopes which were intended to provide for vegetative diversity and muskrat habitat.

The islands were fertilized and seeded with a seed mixture of birdsfoot trefoil (18 percent), tall fescue (72 percent), and redtop (10 percent). A similar mixture with creeping red fescue replacing birdsfoot trefoil was seeded at higher elelvations. These mixtures were intended to provide erosion control as well as wildlife food and cover. The following nursery-grown shrubs were planted: coralberry (*Symphoricarpos orbiculatus*), hawthorn (*Crataegus* sp.), American cranberry-bush viburnum (*Viburnum trilobum*), arrowwood (*Viburnum dentatum*), nannyberry (*Viburnum lentago*), silky dogwood (*cornus amomum*) and red-osier dogwood (*Cornus sericea*). Some of these species were dominant in the undisturbed portion of the natural wetland; others were chosen for their wildlife food value. Shrubs were also planted at two locations on the perimeter. Sixty to 75 shrubs of each species were planted in prepared beds and mulched to reduce competition from seeded grasses. The total number of shrubs planted in the north mitigation was 430.

The small tributary to the West Branch was rechanneled to pass through the mitigation basin and join the West Branch north of the new STE

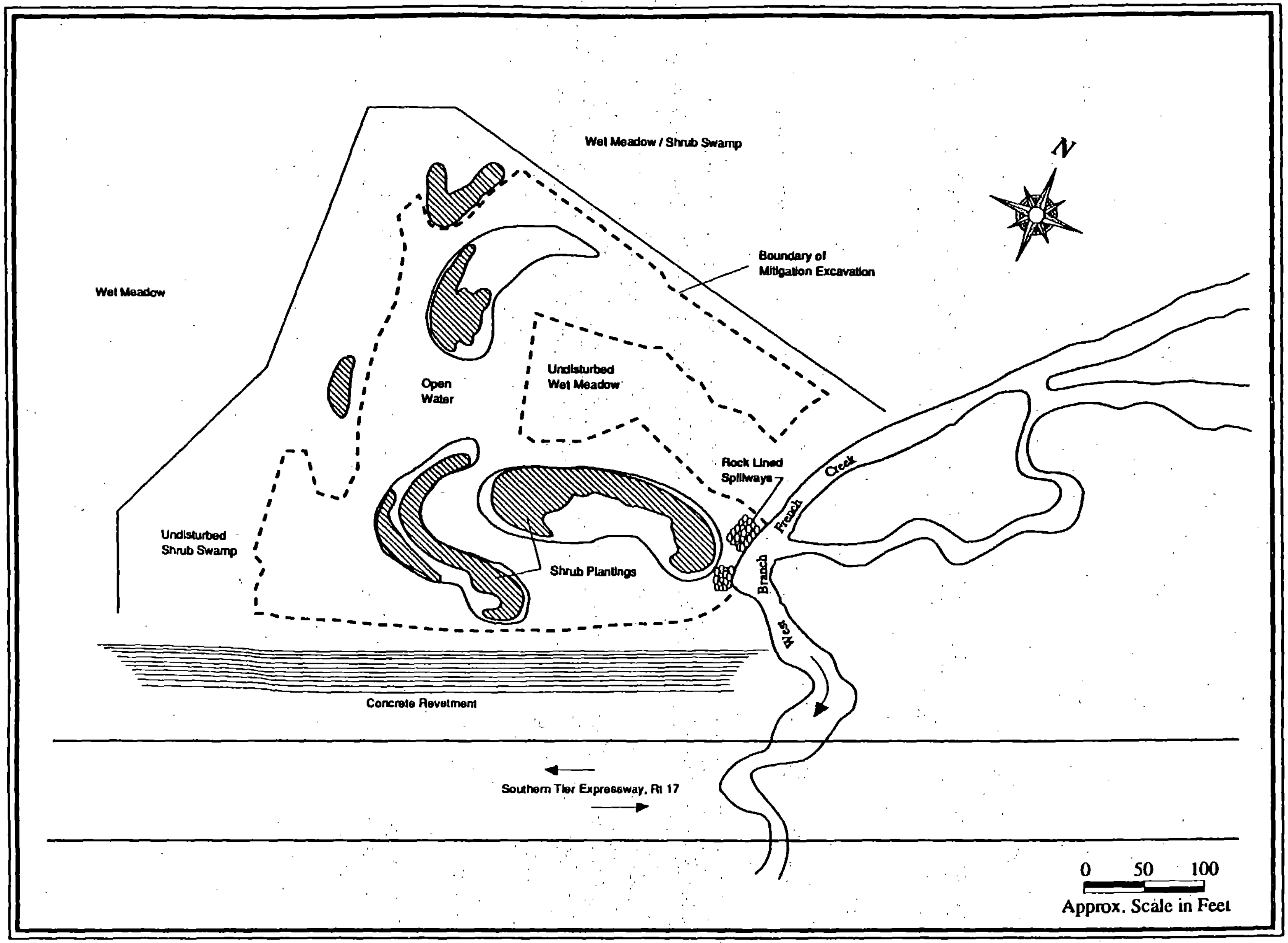

Figure 13. North mitigation wetland, West Branch French Creek, Greenfield, Pennsylvania.

bridge. Its outlet to the West Branch was lined with rip-rap. Stockpiled wetland topsoil was spread to a thickness of 6 in (15.2 cm). The site was surveyed by PennDOT upon completion of grading, and was found to have been constructed as designed. A second rock-lined spillway was constructed in the spring of 1987 to prevent bank erosion between the creek and the basin. Construction and planting of the north mitigation was completed in May 1987. A cement-filled canvas revetment, (Fabriform) was used to stabilize the road embankment adjacent to the mitigation area. The choice of slope treatment was not coordinated with the mitigation design.[38]

At the time of the site visit, reed canary grass was the overwhelming dominant at the basin's perimeter and on the islands. Other shoreline species included sensitive fern (*Onoclea sensibilis*), iris (*Iris* sp.), soft rush (*Juncus effusus*) and marsh fern (*Dryopteris thelypteris*). Small clumps of burreed (*Sparganium* sp.) growing in deeper areas appeared to have been uprooted by muskrats. Along the western edge of the basin, the undisturbed wetland supported cattail (*Typha latifolia*), sedges (*Carex* spp.), rushes (*Juncus* spp.), sweetflag (*Acorus calamus*), jewelweed (*Impatiens capensis*), skunk cabbage (*Symplocarpus foetidus*), willow (*Salix* spp.) and elder (*Sambucus* sp.). For a more complete species list, see volume II. The shrub plantings appeared to be doing well. PennDOT reported an 85 percent shrub survival rate throughout the mitigation project as of the summer of 1988. In addition to planted shrubs and reed canary grass, the islands supported goldenrod, thistle, redtop, milkweeds, bedstraw, brome grass and other grasses. The following wildlife were observed in the north mitigation during the site visit: snapping turtle, muskrat, bullfrog, leopard frog, killdeer, red-winged blackbird, willow flycatcher, yellow warbler.

For purposes of WET 2.0 analysis, the north mitigation site was chosen for evaluation. Since this area is contiguous with a large, natural wetland, it was treated as an impact area (IA) within a larger assessment area (AA). The impact area was delineated as an approximately 5-ac (2.0-ha) trapezium-shaped area. It encompasses the excavated basin, islands, and peninsulas, and it includes a 25-ft (7.6-m) band of undisturbed meadow and shrubby edge along the western and northeastern borders. This edge was included so that the mitigation area could be assessed in the contextual setting for which it was designed. The north mitigation wetland is described above.

South Mitigation - East Basin

The east basin of the south mitigation area was excavated in a cultivated cornfield. According to the SCS Erie County Soil Survey, the site is underlain by Lobdell silt loam, a deep moderately well-drained alluvial soil.[37] Open water areas were excavated to a maximum depth of 4 ft (1.2 m) and lined with stockpiled topsoil. The four islands (figure 14) remain at the original elevation of the cornfield, which is approximately 5 ft (1.5 m) higher than the expected summer water level. The islands were seeded with two seed mixtures, and their banks planted with the same shrub species planted in the north mitigation. Hawthorn was also planted here and there around the basin's perimeter. The total number of shrubs planted was 470. A rock-lined spillway was constructed in the berm along the western edge. There is no defined surface water input channel, but seepage from an adjacent wet meadow/ shrub swamp is evident along the northeast shore. Water levels are maintained by groundwater and overland flow.

In June 1989, the emergent zone in the east basin was narrow and sparsely vegetated. It was broadest, approximately 10 ft (3.0-m) wide, along the eastern shore, where it was composed predominantly of soft rush, reed canary grass, and sedges. Elsewhere, a narrow band (3 to 5 ft [0.9 to 1.5 m]) of soft rush at the toe-of-slope constitutes the emergent zone. The steep gradient of the excavated area may account for the narrowness of the vegetated zone. Filamentous algae, and submerged pondweed (*Potamogeton* spp.) and waterweed (*Elodea* spp.) are abundant in the open water areas. The islands and portions of the shoreline banks were purposely given a steep grade to provide suitable burrowing areas for muskrats. Such burrowing has led to some seepage and potential bank erosion along the western berm.

South Mitigation - West Basin

The west basin is within the annual floodplain of the West Branch, at an elevation several ft lower then the East Basin. According to the SCS Erie County Soil Survey, it is underlain by Wayland silt loam.[37] It was constructed in what was formerly wooded swamp, dominated by green ash (*Fraxinus pensylvanica*) and yellow birch (*Betula lutea*), remnants of which remain on the undisturbed island and the wooded area between the west and east basins. A basin of approximately 1 ac (0.4 ha) was excavated and spread with stockpiled topsoil. The island and adjacent wooded wetland were left undisturbed. No shrubs were planted. The west basin receives only ephemeral surface water input from the east basin, and occasional overbank flooding from the Creek. There is no surface water outlet channel.

The west basin is adjacent to and hydrologically continuous with a large floodplain wooded swamp to the south. A wet meadow and shrub swamp area lies to the west and northwest between the basin and the creek. In June 1989 a 5- to 15-ft (1.5- to 4.6-m) band of cattails constituted the emergent zone around much of the basin. Sensitive fern, soft rush, reed canary grass, and jewelweed were abundant along the saturated shoreline. *Elodea* and coontail (*Ceratophyllum demersum*) were common submergents; duckweed (*Lemna minor*) and filamentous algae are also abundant. A more complete species list is

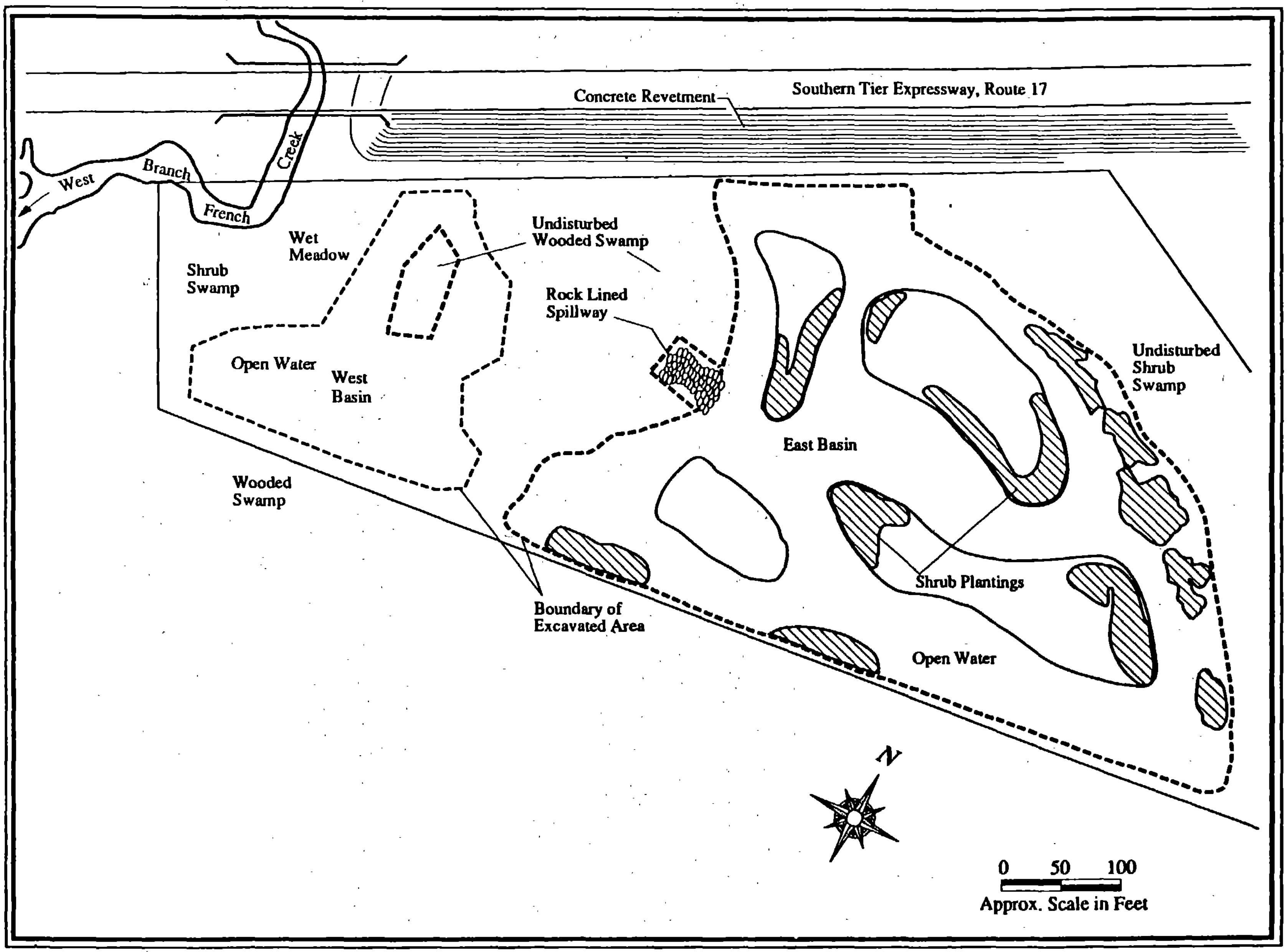

Figure 14. South mitigation wetland, West Branch French Creek, Greenfield, Pennsylvania.

presented in volume II. In water samples taken at the deepwater edge of the cattail zone, pH measured 9.5, and conductivity 133. The high pH may have been due simply to the high algal abundance in the water column, or it may suggest discharge from springs passing through underlying limestone deposits. The following wildlife were observed in the south mitigation during the site visit: white-tailed deer, swamp sparrow, song sparrow, meadowlark. PennDOT has reported observation and sign of the following species at the North and/or South wetlands: bullfrog, muskrat, beaver, raccoon, deer, Canada goose, great blue heron, American bittern, green heron, pied-billed grebe, spotted sandpiper, and belted kingfisher.

Control

The assessment area, or control, was delineated as the approximately 75-ac (29.6-ha) wetland within which the mitigation ponds were created. It is located between Raymond Mills Road on the north, Ashton Road on the west, and Route 430 on the south (figure 12) and is drained by the West Branch and its tributaries. It was assessed in its estimated original condition prior to construction of STE. These estimates were aided by preconstruction site descriptions, aerial photographs, USGS topographic maps and National Wetland Inventory (NWI) maps. This is a case where the WET 2.0 requirements for delineating Assessment Areas results in a large size difference between the mitigation and the control AA's. Such a difference can have a significant effect on the WET functional ratings. The control wetland lies within the 100-year floodplain of the West Branch. It includes large areas of wet meadow (50 percent), forested wetland (35 percent), and shrub swamp (15 percent). The wet meadow is grazed or fallow land dominated by reed canary grass. The shrub swamp areas occur mainly along stream edges and are dominated by alder and arrowwood, with large numbers of willows, silky dogwood (*Cornus amomum*), and hawthorn. Skunk cabbage, sensitive fern, and jewelweed are common in the understory. The wooded swamp portion is located south of the current STE alignment, and borders the West Branch and a southern tributary. Green ash, red maple (*Acer rubrum*) and black cherry (*Prunus serotina*) dominate the overstory; alder, ironwood (*Carpinus caroliniana*), arrowwood, and silky dogwood are common in the shrub layer; and skunk cabbage and sensitive fern grow profusely in the ground layer.

Most of the control is underlain by Wayland soils, described above. There are also significant areas of Wallington silt loam, a somewhat poorly to poorly drained soil formed in lacustrine deposits; and Birdsall silt loam, a poorly to very poorly drained lacustrine soil. The following wildlife were observed in the control wetland during the site visit: snapping turtle, white-tailed deer, three unidentified ducklings, killdeer, redwing blackbird, willow flycatcher, song sparrow, meadowlark.

The watersheds of the mitigation and control sites are the watersheds of the West Branch French Creek upstream of their outlets. Both are approximately 26 mi^2 (67.3 km^2). The West Branch watershed above these sites is largely rural agricultural and forested land. The dominant land uses are dairy cow pasture, hayfield, fallow land, and some cultivated feed crops. The watershed encompasses no large residential settlements and no industrial areas. It includes two large waterbodies on West Branch tributaries, Findley Lake and Howard Eaton Reservoir, each 250 to 300 ac (98.8 to 118.5 ha). Two large (350 to 450 ac each [138.3 to 177.8 ha]) wooded wetland systems border the West Branch and its tributaries in the upper half of the watershed. The dominant soil type in the watershed is Erie silt loam, a deep, somewhat poorly drained soil derived from glacial till. Erie is a slightly acid to neutral soil, with a fragipan at a depth of 12 to 18 in (30.5 to 45.7 cm), and lime at 40 in (101.6 cm).

The service area for both the mitigation and control sites was identified as the reach of the West Branch extending 5 mi (8 km) downstream from each site's outlet. This is a slow, meandering stretch of river with long pools and few riffles, traversing an undeveloped landscape. There are some agricultural lands within the floodplain, but no other developed features likely to be damaged by flooding. No recent water quality data were available at the time of this review. In water samples taken in 1978 by the Pennsylvania Fish Commission downstream of the service area, pH measured 7.4, conductivity measured 300 µmhos, and dissolved oxygen 7.2 mg/l. Fish collections in 1977 through 1978 included northern pike, large- and small-mouth bass, walleye, yellow perch, black crappie, creek chub, bluntnose minnow, yellow bullhead and white sucker. Walleye and muskellunge have been stocked here in the past. There are no drinking water sources or developed recreational areas within the service area.

Methods

The field work for this study was carried out between June 21 and June 23, 1989, immediately following a 10- to 50-year regional storm. Upon arrival, the study area was flooded, but floodwaters receded rapidly, and by June 23 water levels appeared to be at normal seasonal elevations. All wetland units were visited and photo-documented, and general observations were made regarding dominant vegetation, vegetation density, and hydrologic connections. Incidental observations of wildlife and sign were noted. Conductivity and pH were measured near the outlets, if present, in each of the mitigation ponds. General and notable features of the mitigation ponds and the adjacent natural wetlands were recorded on videotape and on 35-mm color slides.

At the PennDOT office in Franklin, the contractor met with the District Environmental Manager who had participated in the design, implementation, and monitoring of the mitigation project. For general regional information, the Erie County Soil Conservation District, the Pennsylvania Bureau of Topographic and Geologic Survey, the Pennsylvania Fish Commission, the Pennsylvania Department of Environmental Resources, and the U.S. Fish and Wildlife Service were contacted. Other resources included preconstruction aerial photographs, USGS topographic maps, Greenfield Township zoning maps, FEMA maps, NWI maps, SCS Erie County Soil Survey, 1976 Southern Tier Expressway FEIS and 1985 FEIS Reevaluation, and the PennDOT Mitigation Site Construction Plans showing preexisting and designed contours and planting plan.

Functional Analysis

A functional comparison of the wetland impacted by road construction (control) to the north mitigation wetland, using WET 2.0 and Hollands-Magee evaluation models is described in appendix A.

Summary

The goals of the mitigation project were (1) to replace the total wetland acreage, 12.5 ac (4.9 ha), lost to road construction, and (2) to enhance the wildlife habitat, with particular attention to waterfowl. Construction of the Pennsylvania length of the STE involved the filling of 12.5 ac (4.9 ha) of emergent, shrub, and forested wetland.

The north mitigation and the west basin of the south mitigation were excavated in existing wetlands that were mapped and identified in 1982 by the U. S. Fish and Wildlife Service (USFWS) as emergent marsh, shrub swamp and broad-leaved deciduous forested wetland. These wetlands were remnants of and adjacent to the very wetlands that were destroyed by the road fill. Only the east basin, comprising approximately 6.4 ac (2.5 ha), was constructed in upland. Thus, the highway construction resulted in a net loss of 6.1 ac (2.4 ha) of wetland.

The three mitigation sites were generally well designed and well constructed. The irregular shorelines and islands will act to limit sight distances, and provide topographic and vegetative cover for wildlife. The shrub plantings are doing well; they will eventually provide cover, resting sites, and food for wildlife. The wetlands' various locations in relation to the West Branch will provide a range of flooding regimes. The wetlands are surrounded by diverse, undeveloped habitats, so will be accessible to a large variety of wildlife species, and have themselves added to the local habitat diversity. The presence of standing water, islands, and wood duck boxes has probably improved the local waterfowl habitat.

There were shortcomings in the design and configuration of the mitigation wetlands. In some areas of the north and east basins, the steepness of the slopes may be inhibiting the establishment of emergent vegetation. At the time of the site visit there was little vegetative cover for swimming waterfowl. On islands and banks of the north mitigation, the aggressive habit of reed canary grass has greatly limited the diversity of herbaceous species. The concrete revetment on the road embankment will prevent the establishment of a vegetative screen from the road. The reduced organics in the substrate, and the reduced density of vegetation may have diminished the sediment/toxicant retention and nutrient removal/transformation capabilities of these areas, over those of the original wetland in which they were constructed. As of this writing, these properties are still in private ownership. PennDOT is involved in negotiations to acquire them, but until they are in public hands, their protection as conservation lands is not guaranteed.

The success of this mitigation project might have been enhanced by the following measures: (1) grading of more gradual slopes in areas of the north and east basins; (2) herbaceous plantings along shorelines and islands to preempt the reed canary grass and provide greater herbaceous diversity; and (3) use of road embankment stabilization materials that would support shrub or tree growth.

Creation Sites

9. Sweetwater River, California

Introduction

This project is located in the Jamacha Valley in southwestern California, east of San Diego and south of El Cajon. The replacement on a new alignment of the Route 94 bridge over the Sweetwater River involved the filling of 1.25 ac (0.5 ha) of riparian wetland and the impairment of an additional 0.5 ac (0.2 ha) due to disruption, fragmentation, and shading. The main environmental concern associated with this project was the loss and degradation of riparian habitat used by the Least Bell's Vireo (*Vireo bellii pusillus*), a California and Federal Endangered Species. The vireo's decline has been attributed to habitat loss and degradation, and to brood parasitism by the brownheaded cowbird (*Molothrus ater*).

Mitigation Design

The mitigation plan was designed by the U.S. Fish and Wildlife Service (USFWS) and the California Department of Transportation (CALTRANS), and was attached as a set of Special Conditions to the Army Corps of Engineers

(COE) 404 Permit. The purpose of the mitigation plan was "to avoid the net loss of vireo habitat values and the adverse modification and destruction of proposed critical habitat" and to maintain vireo productivity while new habitat is being created.[39] Since the plan was notable in its detail and its comprehensive monitoring and remediation requirements, its salient points are outlined here.

Mitigation design:

- Located 800 ft (243.8 m) downstream from the original bridge, and adjacent to the existing riparian wetland, a 2-ac (0.8-ha) mitigation site to be excavated from upland, and graded to 2.5 to 3 ft (0.8 to 0.9 m) above the non-water flowline.

- Final grading to be inspected by COE.

- Goal was to achieve a density of approximately 12,000 plants/ac (29,630 plants/ha), revegetation of the mitigation site and slopes with 125 potted trees including black willow (*Salix gooddingii*), cottonwood (*Populus fremontii*), and western sycamore (*Platanus racemosa*); 240 potted shrubs, including coast live oak (*Quercus agrifolia*), Mexican elderberry (*Sambucus mexicana*), laurel sumac (*Rhus laurina*), scrub oak (*Quercus dumosa*), lemonade-berry (*Rhus integrifolia*), and fuschia-flowered gooseberry (*Ribes speciosum*); 28,000 rooted cuttings, including sandbar willow (*Salix sessilifolia*), mulefat (*Baccharis glutinosa*), mugwort (*Artemisia douglasiana*), blackberry (*Rubus ursinus*), rose (*Rosa californica*); and seeding of shrub and herbaceous species on upland slopes.

- Sizes, placement, spacing and planting times were specified for potted plants and cuttings.

- A 2-year cowbird trapping and vireo nest-monitoring program was undertaken along a 3-mi (4.8-km) stretch of the Sweetwater River to boost vireo productivity during development of the created wetland.

Monitoring program:

- Plant survival to be monitored for 2 years after planting and mortality >10 percent of container stock, and >20 percent of cuttings to be replaced in kind, unless mortality caused by flooding or fire.

- For each of 5 years after completion, site to be inspected and evaluated by USFWS, COE, California Department of Fish and Game, and CALTRANS. Remedial measures recommended by majority to be carried out by CALTRANS within 1 year. Such measures may include but are not limited to replacement of failed vegetation, additional plantings, removal of non-native species, irrigation, or erosion control and repair.

- For each of 5 years after completion, a quantitative vegetation analysis to be undertaken by CALTRANS including tree height and density, shrub height and density, percent canopy cover, percent shrub cover, percent ground cover.

- Vireo nest-monitoring, removal of cowbird eggs and young, cowbird trapping program designed by USFWS to be implemented for 5 years on a 1.5-mi (2.4-ha) reach of the River, or for 2 years on a 3-mi (4.8-ha) reach.

- Breeding and wintering bird census to be conducted for 5 years.

- Site to be fenced to prevent access by horses and off road vehicles.

- For 5 years, annual reports to be submitted to COE & USFWS.

Excavation of the mitigation site was carried out during the summer of 1984. Due to wet conditions during construction, the graded elevation was established in the field at 2 to 5 ft (0.6 to 1.5 m) higher than the adjacent floodplain wetland. The mitigation terrace is expected to be inundated only during the more extreme storm events having an average frequency of 5 years or less.[40]

The site received no topsoil or other top dressing. Plantings were made between April and October of 1986. The planting plan outlined in the section 404 permit was generally followed. Himalayan blackberry (*Rubus himalaya*), an invasive species, was mistakenly planted instead of California blackberry (*Rubus ursinus*). Twenty-two mature trees from the impact site were transplanted at the south end of the site. An irrigation system was installed and operated for two years (deemed necessary in California wetland creation/-restoration projects due to the seasonal hydrologic changes).

Monitoring studies conducted in October 1986 showed an overall mortality of 92 percent for planted cuttings and 23 percent for potted plants. The cuttings, which should have been harvested during their winter dormancy period, were instead harvested and planted in April due to "construction constraints". Their high mortality was attributed to the poor timing of harvest. A reassessment by CALTRANS and USFWS of probable stems per plant to be provided by each cutting revealed that the original planting plan would produce stem densities 6 to 7 times higher than the ideal densities for Least Bell's Vireo. A revised replanting plan to achieve proper densities was agreed upon, and was carried out in May 1987. Transect studies conducted in July 1988 showed a 51 percent survivorship of cuttings. Only 41 percent of the woody plants encountered on the transects were planted cuttings, however. The remainder were root sprouts and volunteers. The total density was determined to be approximately 14,580 plants/ac (36,000 plants/ha). Therefore no further replantings were undertaken. If each plant eventually produces three stems, as expected, then the goal of 40,000 stems/ac (98,765 stems/ha) will have been achieved.

The total cost of the excavation, planting and replanting is not known. The transplanting cost for the large trees was $15,000. The cost of the cowbird trapping and vireo nest-monitoring programs was $84,000. The cost of the irrigation system was $20,000.

Site Descriptions

General

The project area is located in the Foothills physiographic province of southwestern California.[41] The average annual precipitation here is 13.5 in (33.8 cm), occurring mostly during the period November through March. It is an area of warm, dry summers and mild winters. The natural growing season is short, however, because the plants deplete the soil moisture early in the season. Soils tend to be low in organic carbon content because the organic matter is oxidized during the long dry summer.[42] The topography is hilly. Hillsides are characterized by rocky outcrops and chaparral and inland sage scrub plant communities. Streams and rivers fill broad floodplains after heavy rainstorms, but are nearly dry during most of the growing season. Soils in the region are predominantly sandy loams from decomposed granite or weathered sandstone. They are soft, easily eroded, and contain sand fragments that act as an abrasive in runoff. Gully and sheet erosion are common. Floodplains are dominated by sands or sandy loams from granitic alluvium.[42]

The Sweetwater River has perennial flow except during serious droughts. It is bordered by a broad floodplain supporting wooded and shrub wetlands. Two mi (3.2 km) downstream from the project site, it flows into the Sweetwater Reservoir which, together with imported water from the Colorado River, is the domestic water source for a population of 140,000.[41]

The riparian community along the Sweetwater River supports approximately 20 pairs of Least Bell's vireos, the third largest population in the United States. This migratory species was once common in California and Baja California, Mexico, but is now restricted to Santa Barbara County and south to northwestern Baja California. The population decline is attributed to the loss and degradation of over 95 percent of the suitable riparian habitat, and to brood parasitism by the brown-headed cowbird. The cowbird population in California has greatly increased during this century.[39]

The preferred vireo nesting habitat is dense willow woodland with a well-developed overstory of arroyo willow (*Salix lasiolepis*), black willow, cottonwood, sycamore, and sometimes coast live oak; and a dense willow thicket in the understory dominated by sandbar willow and mulefat. The project area on the Sweetwater River is located within an area of proposed critical Least Bell's vireo habitat.

Mitigation

For purposes of WET 2.0 evaluation, the mitigation site was treated as an impact area (IA) within the larger Sweetwater River floodplain wetland assessment area (AA).

The mitigation site is a long, narrow 2-ac (0.8-ha) area created from upland (figure 15). Wet conditions during construction made deeper excavation difficult, and there was some fear that young plantings would rot if their roots were exposed to prolonged inundation. Therefore, it was excavated at an elevation 2 to 5 ft (0.6 to 1.5 m) higher than the adjacent Sweetwater River floodplain wetland. At this elevation, it is expected to be flooded by the river during a 5-year storm event. During the normal wet season, the water table is estimated to be at 1.5 to 2 ft (0.45 to 0.61 m) below the soil surface at the mitigation site.[40]

At the time of the field visit, shrub and herbaceous cover was somewhat irregular. Shrub growth was dense in some areas and completely absent in others. There was much bare substrate within the herb layer dominated by everlasting (*Gnaphalium californicum*), spike-grass (*Distichlis spicata*), crabgrass (*Digitaria* sp.) and miscellaneous herbs. The dominant shrubs were sandbar willow, mulefat, and Goodding's willow. There was also a significant invasion of tamarisk (*Tamarix* sp.), an aggressive non-native. A more complete species list is presented in volume II. CALTRANS reports that most of the mulefat plants present are volunteers, but those from cuttings are taller and have broader canopies.

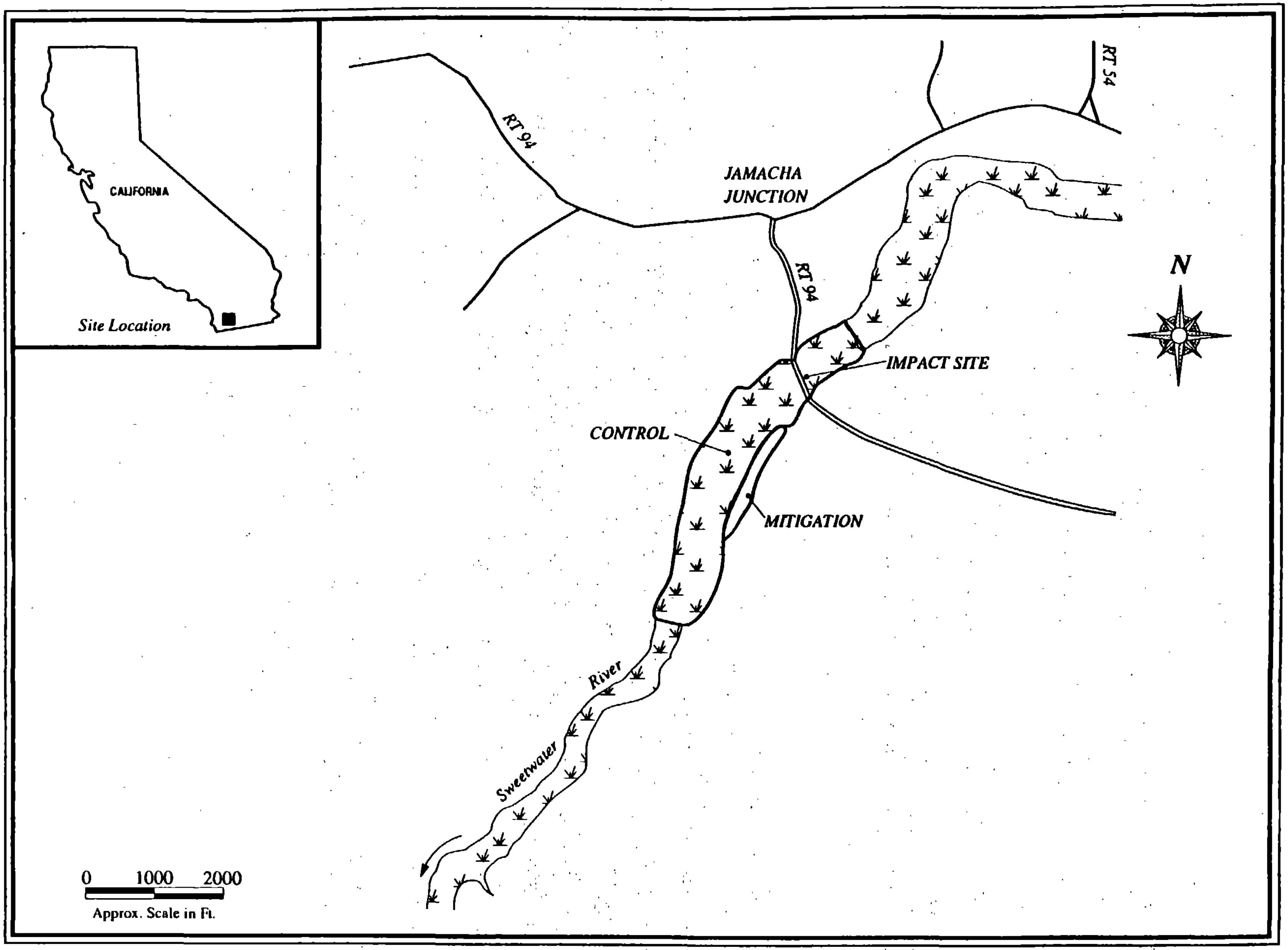

Figure 15. Location of the Sweetwater River mitigation and control wetlands, El Cajon, California.

There was no surface water on the site during the field visit. The soil surface was dry, even dusty, in most areas. Soils in slight depressions, however, were moist, and supported cattails.

Wildlife and sign observed on the mitigation site during the field visit included raccoon tracks, coyote scat, cottontail, mule deer, and California quail. CALTRANS has observed use of the site by Least Bell's Vireo for foraging.

Control

The control assessment area was identified as the 74-ac (30-ha) portion of the Sweetwater River riparian wetland located within one-half mi upstream and downstream of the mitigation site. It was delineated according to WET 2.0 instruction for large wetlands with no obvious point of hydrologic change. The downstream boundary is at a jeep trail crossing which may constitute a slight hydrologic constriction. This is a forested and shrub wetland on the seasonal floodplain of the Sweetwater River. Goodding's willow, Arroyo willow, cottonwood, and sycamore are common in the overstory and shrub layers. Mulefat is also abundant in the shrub layer. Willow and cottonwood snags are common. There are small openings in the forested and shrub areas. The ground cover is sparse; ragweed (*Ambrosia psilostachya*) and celery (*Apium graveolaus*) are the most common species. A more complete species list is presented in volume II.

There is little accumulation of organic material on the soil surface, and there is much bare substrate, varying from coarse sand to sandy silt. During the winter season, the floodplain is flooded to a depth of at least 1 ft (0.3 m). During the dry season, however, water is confined to the narrow river channel whose width along this reach varies from 5 to 20 ft (1.5 to 6.1 m). Dry braided channels meander throughout the floodplain.

Most of the Sweetwater's flow is urban runoff from El Cajon and Casa de Oro, with very high levels of minerals, coliform, oil and grease, and turbidity.(43) Above the old Route 94 bridge, a horse corral occupies a portion of the floodplain and constitutes a significant source of fecal pollution. Beneath the Sweetwater River is a shallow confined aquifer at a depth of approximately 100 ft (30.5 m) at the bridge site.(44) The aquifer surfaces approximately 3500 ft (1066.8 m) downstream where the bedrock is exposed. The control wetland is used for hunting and horseback riding. Wildlife and sign observed during the field visit included raccoon tracks, green heron, kingfisher, flicker, yellowthroat and hummingbird.

The watershed of the control and mitigation areas is approximately 170 mi^2 (273.7 km^2) of moderate to very steep hilly terrain. Chaparral and inland sage communities are the dominant vegetation. Although much of the watershed is rural and unsettled, it also contains the City of El Cajon and numerous smaller towns. Surface and groundwater in the region is of generally poor quality due to high concentrations of dissolved salts.[41] Wetlands are few and small, and are restricted to stream floodplains.

The service area of the control and mitigation wetlands was identified as the Sweetwater Reservoir for the purpose of WET 2.0 evaluation. This is a 1000-ac (395.0-ha) reservoir that is the domestic water source for an urban population of 140,000. Treated water from another source is carried in via aqueduct during off-peak periods, to augment the volume provided by the Sweetwater River and other small input streams. Urban runoff carried in by the Sweetwater and other small streams is the primary source of pollution to the reservoir. Reservoir waters are high in minerals, but low in nitrogen and phosphorus. There are plans to divert the Sweetwater River and other urban drainage streams around the Reservoir to improve the reservoir's water quality.

Methods

The field work for this study was carried out during October 19 to 22, 1989. At the mitigation site and in the natural riparian wetland, plant species lists and general descriptive notes were compiled, and field information necessary for WET 2.0 and Holland-Magee analysis was collected. Conductivity and pH were measured in the Sweetwater River channel. General and unstable features of the mitigation and natural wetlands were recorded on videotape and 35-mm slides.

The contractor met on the site with the CALTRANS biologist who was involved in the design, implementation and monitoring of the project. Among the agencies contacted for local and regional information were the San Diego county Department of Planing and Land Use, the Sweetwater Authority, the San Diego County Soil Conservation Service, the California Department of Fish and Game, and the U.S. Fish and Wildlife Service. Other resources included USGS topographic maps, NWI maps, the SCS San Diego Area Soil Survey, and the CALTRANS Geotechnical and Water Quality Control Report for the Sweetwater Bridge Replacement.

Functional Analysis

A functional comparison of the mitigation wetland was made to the natural control using WET 2.0 and Hollands-Magee evaluation models. Results are included in appendix A.

Summary

The goal of the mitigation project was to replace the Least Bell's Vireo habitat lost and degraded during bridge construction. It will be years before the overstory has developed to approximate ideal conditions for Vireo habitat as described by the USFWS although the species composition of the shrub layer and the eventual overstory is good. The current densities and growth rates indicate that the eventual densities will approach those in preferred vireo nesting habitats. In the meantime, the site serves as foraging grounds for vireos nesting in the adjacent natural wetland.

Design elevations, which were quite high to begin with, were modified based on field conditions during the excavation activities. This change may have been shortsighted in that it will probably reduce the benefits that could have been associated with this habitat creation project. Due to its high elevation in relation to the adjacent natural riparian wetland, the mitigation wetland will not routinely serve to a significant degree such functions as sediment/toxicant retention, nutrient removal, hydrologic support and production export. The bridge construction may therefore have resulted in net losses in these functions. The poor quality and limited quantities of the Sweetwater River and other surface waters in the region magnifies the importance of such losses. Wetland functions other than endangered species habitat were addressed the mitigation planning and design process. In addition, construction constriants should not be permitted to compromise mitigation design.

10. Lake George, Minnesota

Introduction

In the unincorporated town of Lake George in the pine-moraine region of north-central Minnesota, two mitigation projects were undertaken as part of the Minnesota Department of Transportation (MNDOT) wetland banking program. The mitigation projects were carried out in borrow areas used for the upgrading of a stretch of Trunk Highway (TH) 71 between Lake George and Itasca State Park, but they were not constructed as mitigation for that project.

Mitigation Design

In a 40-ac (15.8-ha) borrow area north of TH71, the primary site, 10 wetland basins (10 to 15, depending on how they are counted) totalling 10.8 ac (4.3 ha) were excavated. In a smaller borrow area 2 mi (2.3 km) east near the Schoolcraft River, a 1.7-ac (0.7-ha) wetland was constructed. These wetlands were created to mitigate for wetland losses on a number of yet unnamed future highway projects in the MNDOT Bemidji District. The goal at both sites was to create palustrine persistent emergent wetland, with particular emphasis on waterfowl habitat.

The contractor's equipment operator was given general instructions for enhancing the borrow areas for waterfowl habitat. These instructions included the following features: maximum water depths of 3 to 5 ft (0.9 to 1.5 m); uneven rolling bottoms with the goal of attaining approximately 50 percent open water and 50 percent emergent area (assuming that depths to 18 in [45.7 cm] will sustain emergents); long and narrow configurations, and/or irregular shorelines to maximize shoreline length; slopes of 10:1 to 20:1; islands created from muck or earth work; and topsoil spread in excavated areas. The operator was given a free hand to design the wetlands to include these features.

The sites were excavated in what was formerly jack pine (*Pinus banksiana*) forest. Topsoil was stripped and stockpiled. Borrow material for road construction was taken down as close as possible to the underlying clay layer. Basins were graded to incorporate the above elements, and stockpiled topsoil was spread to a depth of 4 in (10.2 cm) wherever possible. Standing water prevented topsoil placement in the deepest areas. No planting or seeding was done in the wetlands or on their banks. Red pine seedlings were planted by Hubbard County in upland areas on County land. Final grading was completed in the spring of 1986. MNDOT reports that the costs for the projects were negligible. Borrow material was used for road construction; costs for grading and spreading of topsoil were absorbed as routine site-reclamation costs.

The accounting system for MNDOT's banking program is based on Habitat Units (HUs) determined by Habitat Evaluation Procedures evaluation (HEP).[45] A HEP study, performed by a team of MNDOT and USFWS personnel in August 1986, arrived at a HEP value of 925 wetland wildlife HUs for the primary mitigation site. This evaluation was based on the assumptions that the wetland basins would eventually be surrounded by a fringe of grassy vegetation, and that the wetlands would eventually provide shallow marsh habitat. Twenty ac (7.9 ha) of this 40-ac (15.8-ha) site is still owned by a commercial timber company. Consequently, the wetland bank will be credited for the full 925 HUs only as long as the wetlands remain unfilled and unaltered.

Site Descriptions

General

The project area is Hubbard County in a rural, heavily forested region of north central Minnesota. It is located at the interface between a hilly glacial moraine area to the south and a sandy outwash plain to the north. Fires and timber harvesting have destroyed most of the original conifer forest communities of white pine (*Pinus strobus*), Jack pine (*Pinus banksiana*), and red pine (*Pinus resinosa*). Jack pine forests now predominate, with aspen (*Populus sp.*) growing on finer textured soils. Low lying areas support black spruce (*Picea mariana*), tamarack (*Larix laricina*) and white cedar (*Chamaecyparis thyoides*) over muck or peat layers 2 to 20 ft (0.6 to 6.1 m) thick. The region contains many extensive wooded and shrub wetlands and many shallow, sandy-bottomed lakes. The moraine area is pockmarked with small ponds and wet depressions. Many of the ponds and lakes in the region have high filamentous and single-celled algal populations. It has been postulated that nutrient-laden dust blown in from agricultural areas to the west may be a cause of these high algal concentrations.(46) The average annual precipitation is 25 in (63.5 cm), most of which falls during the spring and summer. The winters are long, snowy and cold; the summers are warm. Timbering, recreation, and tourism constitute the regional economic base. The many lakes, streams, and extensive forests attract fishermen and hunters. The Itasca State Park, several mi to the west, encompasses the basin at the source of the Mississippi River, and draws large numbers of tourists.

Mitigation

Primary Borrow Area

The primary mitigation site was in a borrow area north of TH71, half of which is owned by a commercial timber company, and the other half by Hubbard County (figure 16). This was formerly an upland jackpine forest on sandy soils. A mixed wooded swamp occupies a depression in the southern-central portion of the site, and was left undisturbed by gravel operations. Most of the basins were constructed as isolated depressions with no surface water connection to other basins, but some subsurface seepage between basins is expected. The average depth of most basins is 2 to 3 ft (0.6 to 0.9 m), with maximum depths of 3 to 4 ft (0.9 to 1.2 m). Pond 1 has a maximum depth of 7 ft (2.1 m); Ponds 6 and 7 have maximum depths of 1 and 2 ft (0.3 and 0.6 m) respectively. The basin substrates are primarily sand or clay. The dressing of topsoil is not evident in most areas. All basins were graded to have very broad shallow zones conducive to emergent growth, and variable depths to promote diversity of plant species and aquatic habitats. No seeding or plantings were done on banks or in basins. Irregular shorelines were

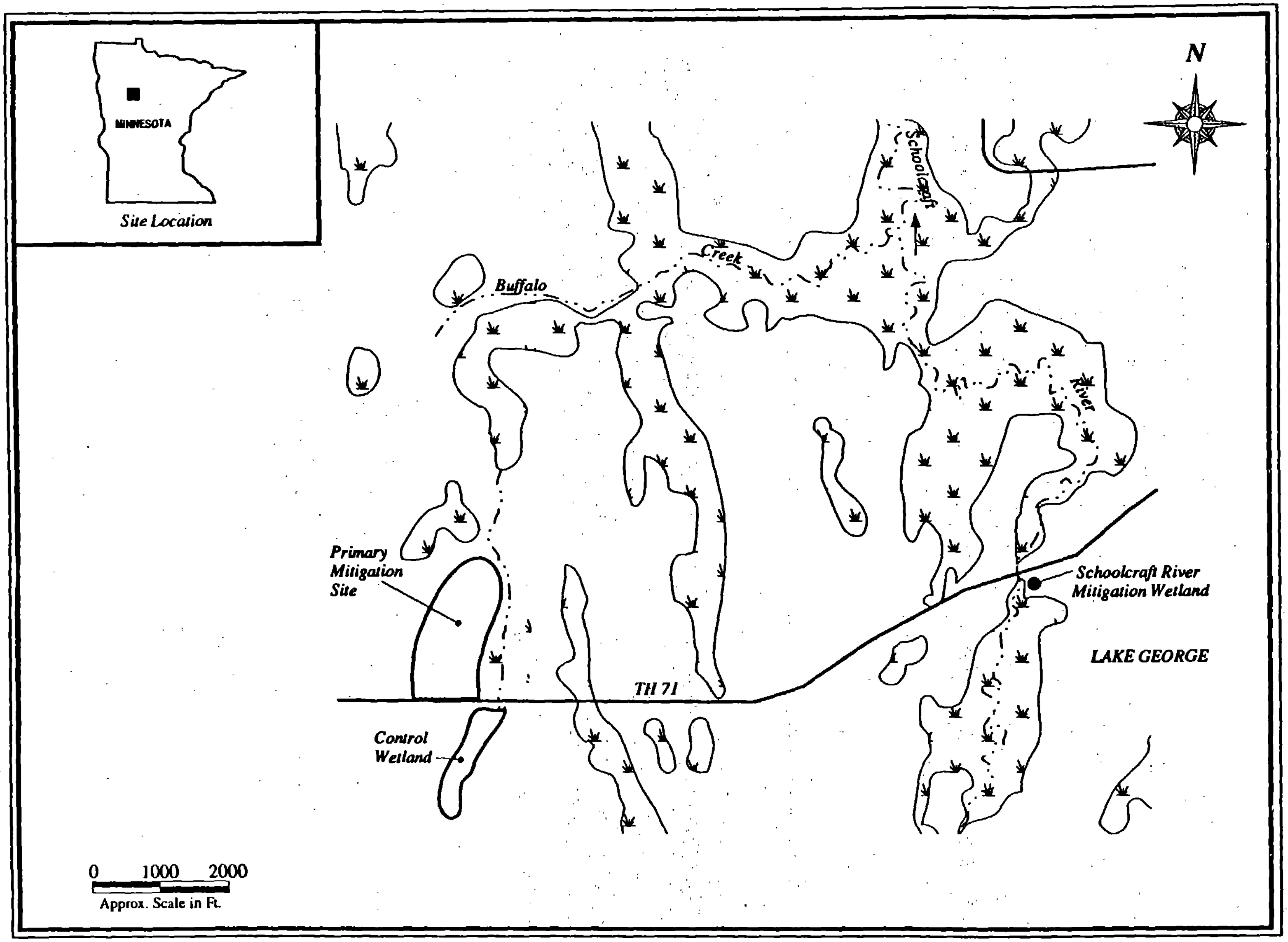

Figure 16. General Location of mitigation and control wetlands, Lake George, Minnesota.

constructed with peninsulas and coves to provide protected areas and to limit sight distances for wildlife. Due in part to a reluctance to introduce non-native plant species to the mitigation area, no stabilization seeding was done on the surrounding upland areas.

Emergent and submergent vegetation were quite well established in most of the basins at the time of this study. Common species included cattail (*Typha latifolia* and *T. angustifolia*), woolgrass (*Scirpus cyperinus*), sedges (*Carex* spp.), rushes (*Juncus* spp, *Glyceria* spp.), spikerush (*Eleocharis* spp.), pondweed (*Potamogeton* spp.), and duckweed (*Lemna* sp.) Young willows (*Salix* spp.) grew here and there along the banks. Some bank erosion had occurred, forming small gullies and washing silt into the wetlands. This had inhibited emergent and upland herbaceous growth in those areas. According to agency correspondence, lack of topsoil and lack of stabilization seeding were the likely causes of slow vegetation development in the first 2 years after construction. The aquatic environment varies greatly from basin to basin. Some basins were nearly dry during the time of the site visit. Others had shallow pools with algal mats and abundant submerged pondweeds (*Potamogeton* spp.). Pond 1 had large areas of deep water with little aquatic bed vegetation. Abundant aquatic organisms were evident in some ponds: copepods, fish larvae, water boatmen, water striders, and bed mites. Wildlife and signs observed at the site included several species of ducks, green heron, great blue heron, spotted sandpiper, killdeer, Virginia rail, song sparrow, pocket gopher, and tracks of white-tailed deer. MNDOT has reported seeing ducks, snipe, horned grebe and otter on the site.

Schoolcraft River Site

A shallow 1.7-ac (0.7-ha) basin was excavated in what was formerly pine uplands near the Schoolcraft River. It is a closed basin located about 150 ft (45.7 m) east of the River channel. MNDOT reports that springtime high waters in the River sometimes overtop the intervening berm and flood the basin. Ordinarily, water levels are controlled by the local water table. Stockpiled topsoil was spread but no plantings were done. The final grading produced very uneven bottom contours with many ridges, peninsulas and seasonal islands.

At the time of the site visit (July 20, 1989) the water depth was 2 ft (0.6 m) at its deepest, but much shallower elsewhere, with broad zones of nearly saturated soils on much of the perimeter. Cattails (*Typha latifolia* and *angustifolia*) were the dominant emergents. Dense stands of cattails occupied the shallow water and saturated shoreline zones and extended into the pond on irregular ridges. Woolgrass, rushes, sedges and other herbaceous emergents occupied drier clearings on the perimeter. The open water/vegetation interspersion is excellent. Pondweed (*Potamegeton pusillus*) and filamen-

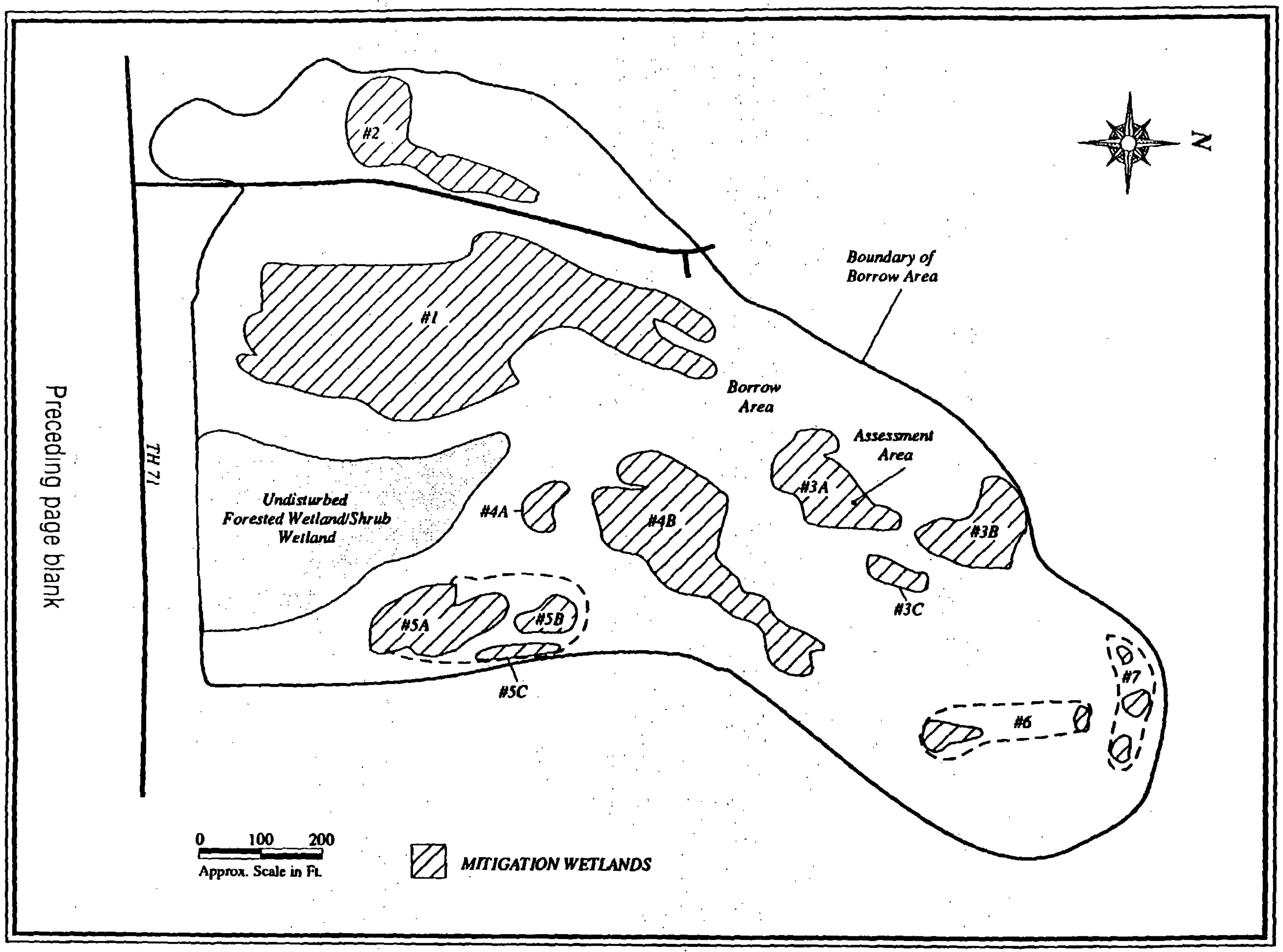

Figure 17. Mitigation basins at primary mitigation site, Lake George, Minnesota.

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Control

The mitigation project was not undertaken in response to a specific road construction project, but instead was part of a mitigation banking program. There was therefore no "impacted wetland" to use as a natural control for functional comparison. Since the created wetlands are to be used as mitigation for future unspecified projects in the region, a control wetland representative of local natural wetlands was sought. With the aid of NWI maps, it was ascertained that shrub swamps are the dominant and most ubiquitous wetland type. The wetland chosen as the control for WET 2.0 and Hollands-Magee evaluations was a 23-ac (9.1-ha) shrub swamp located south of TH71 (figure 16), occupying a valley running south to north between two low hills. It drains to the north via an intermittent outlet under TH71. The stream flows eventually into Buffalo Creek, a tributary to the Schoolcraft River. This is a densely vegetated shrub swamp dominated by speckled alder (*Alnus rugosa*) and willows (*Salix* spp.) with dense herbaceous cover of sedges (*Carex lacustris, C. hystricina, C. pseudocyperimus* and others), cattail (*Typha latifolia*), jewelweed (*Impatiens capensis*), sensitive fern (*Onoclea sensibilis*), and many other species. The terrain is hummocky, with standing water between the hummocks at the time of the site visit, but no sizeable open water areas. An organic soil layer 30 in (76.2 cm) deep overlies an unidentified compacted layer. Narrow areas of wooded swamp flank the east and west edges. Willows, black ash (*Fraxinus nigra*), tamarack (*Larix laricina*) and elm (*Ulmus americana*) are the dominant species. A more complete species list is presented in volume II. There were many fresh beaver signs in and around the wetland at the time of the field work. Other wildlife and signs noted were deer track, yellowthroat, cuckoo, chickadee, woodpecker, phoebe, and Philadelphia vireo.

The watershed of the control is a 280-ac (110.6-ha) forested area of low hills and wet depressions over glacial till. Approximately 30 percent of the watershed area is wetland, including a 15-ac (5.9-ha) conifer bog. The upland areas are predominantly jack and red pine communities. The service area of the control was identified as Buffalo Creek to its confluence with the Schoolcraft River. Buffalo Creek and its environs are described above.

Methods

Field work for this study was conducted during July 19 through 21, 1989. All wetland units were visited and photo-documented, and general observations were made regarding dominant vegetation, vegetation density, and hydrology. Incidental observations of wildlife and sign were noted. Conductivity and pH were measured in the wetlands chosen for WET 2.0 and Hollands-Magee assessment.

On-site interviews were conducted with the MNDOT wildlife biologist and project engineer. Among the agencies contacted for general regional information were the Minnesota Geological Survey, the Hubbard County Soil Conservation Service, the MN State Planning Agency, and the University of Minnesota Forestry Biological Station at Itasca State Park. Other resources included NWI maps, USGS topographic maps, the Soil Survey of Hubbard County postconstruction aerial photographs, and many documents from MNDOT project files including HEP results, agency correspondence, and postconstruction contour maps.

Functional Analysis

A functional comparison of the mitigation wetlands with the natural control, using WET 2.0 and Hollands-Magee evaluation models is discussed in appendix A. Only two of the mitigation wetlands were selected for model evaluations: pond 3A and the Schoolcraft River wetland. The model results for the pond 3A and Schoolcraft River mitigation wetlands, and the control wetland are presented in appendix A.

Summary

As part of a mitigation banking program, approximately 12.5 ac (4.9 ha) of emergent marsh wetlands were created in borrow areas used for road construction. Great attention was paid to construction of irregular shorelines and very gentle variable gradients (10:1 to 20:1). Some upland topsoil was spread, but no plantings were done, nor were disturbed upland areas seeded. The wetlands have developed broad and irregular zones of emergent vegetation. Submergent *Potamogeton* is abundant in some basins, willow seedlings of several species have become established along shorelines. Due to natural water level fluctuations of 1 ft (0.3 m) or more, some of the basins dry up completely by mid-summer, but elsewhere average water depths of 1 to 3 ft (0.3 to 0.9 m) or deeper are maintained throughout the growing season. Some of the upland areas and wetland banks have been slow to revegetate, and minor erosion has occurred here and there. There is evidence of significant wildlife use of the area, primarily deer and waterfowl.

The goal of the mitigation project was to create persistent emergent wetlands, with particular emphasis on waterfowl habitat. That goal appears to have been achieved. The configuration of these wetlands is well suited for waterfowl use, and they can already provide adequate cover and plant foods. Cover and structural diversity are expected to improve as the wetlands mature.

Other functional losses resulting from future road construction were not addressed in the mitigation plan. There is a general tendency among planners to overlook the broad habitat values provided by mature natural wetlands, along with the other non-biological wetland functions, in favor of the wetland wildlife functions enjoying the greatest public recognition and appeal (e.g., Illinois, Iowa, Michigan, etc.). In regions experiencing growth in road traffic, tourism, and general development, where wetlands and other natural areas will be subject to increasing disturbance, the importance of the broad range of wetland functions relating to water quality and quantity will become increasingly apparent. These mitigation wetlands are substantially isolated from other water bodies and wetlands, except through possible groundwater connections. Their contribution to water quality maintenance and downstream food chain support will thus be limited.

These wetlands were well-designed and constructed to achieve the stated goals. Spreading of topsoil on upland areas, and spreading of wetland muck in the excavated basins, would probably have hastened revegetation and reduced the erosion of disturbed soils. The organic soil horizon in natural wetlands takes years to develop, and is virtually impossible to recreate in a new wetland within a reasonable length of time. Spreading of wetland muck (removed from natural wetlands during road construction) introduces anaerobic soil microbes and wetland plant propagules, and thus hastens the development of wetland vegetation. When designing future contributions to the regional mitigation bank, some attention should be given to wetland functions other than waterfowl habitat.

11. Rancocas Creek, New Jersey

Introduction

The 1986 replacement and widening of the Route 130 bridge over Rancocas Creek in Delran, Delanco and Willingboro townships, Burlington County, New Jersey necessitated the filling of 2.3 ac (0.9 ha) of freshwater tidal wetlands dominated by wild rice (*Zizania aquatica*), arrowhead (*Sagittaria* latifolia), smartweeds (*Polygonum* spp.) and arrow arum (*Peltandra* virginica). Mitigation involved the creation of 4.45 ac (1.8 ha) of freshwater tidal wetlands. Two upland old field areas adjacent to the impacted wetland were excavated and graded to provide for tidal inundation of between 1.0 and 2.2 ft (0.3 and 0.7 m) at high tide by way of man-made tidal channels. These areas are known as sites 1 and 3. (Site 2 is a forested buffer.) Site 3 (1.4 ac [0.6 ha]), located several hundred feet west of Route 130, was completed in the spring of 1984. Site 1 (3.1 ac [1.2 ha]) is located adjacent to the new road and was not completed until 1986. The cost of this work was approximately $300,000 including planting, earthwork and land acquisition.(47)

Route 130 is approximately 3 mi (4.8 km) upstream of Rancocas Creek's confluence with the Delaware River at Philadelphia, PA. The salt/

fresh water interface occurs on the Delaware River downstream of this junction. A variety of bridge and roadway alternatives were considered prior to receiving the U.S. Army Corps of Engineers (COE) and New Jersey Department of Environmental Protection (NJDEP) permits in 1981. Of the alternatives that were considered impractical, only the complete spanning of the wetland would have significantly reduced wetland fill. However, the bridge would have been only four feet above the marsh. Shading caused by the bridge is likely to have eliminated the vegetation, resulting in a barren mud flat in the area under the bridge. The additional cost would have been approximately $2.4 million.

Mitigation Design

Studies described construction, planting, hydrology and two seasons of sedimentation and vegetation data for sites 1 and 3.[48, 49] The mitigation wetlands were compared with the adjacent natural marsh.

Prior to construction, sites 1 and 3 consisted of sandy soils supporting old field vegetation. A substantial amount of old bottles, tin cans, wood and other debris were scattered about. Elevations ranged from 2 to 9 ft (0.6 to 2.7 m) above the adjacent tidal wetlands. The operations undertaken to establish wetlands on these sites were: (1) excavation to a suitable elevation for tidal inundation, (2) construction of a system of channels designed to convey tidal flow from natural channels in the adjacent marsh, (3) planting of appropriate wetland species to establish vegetative cover.

From the elevations of mean high and low water a grading plan was developed that would produce a water depth of 1.0 to 2.2 ft (0.3 to 0.7 m) over the marsh surface at high tide. The sites were contoured to discourage the formation of stagnant pools at low tide. The tidal channels were constructed with a bottom width of 2 ft (0.6 m), a side slope of 4:1, a top width of 15 ft (4.6 m) and a water depth of 4 ft (1.2 m) at high tide. These channels were excavated in the existing soil. Since the natural erosion and deposition of tidal action is desirable in these areas, no vegetation planting or other methods to prevent erosion of the banks of the channel were undertaken. Excavation was accomplished by heavy backhoes, bulldozers and dump trucks in essentially the "dry" condition by leaving the high ground near the natural marsh as the last section to be removed. The excavated material was used in the bridge approach fill.

On both sites grading was done in March and planting in May (of 1984 on site 3 and 1986 on site 1). The two sites are connected by a tidal channel and are flooded twice daily. Site 1 is surrounded by a tidal channel and drains from the center. These ditches connect to tidal channels in the adjacent natural marsh. Prior to planting, tidal action had smoothed the surface and deposited a fine layer of silt. A surficial layer of algae had also formed by the time of planting. Also, annual volunteer species, particularly smartweeds and wild rice had begun to cover the new wetland.

On site 3 bare root, actively growing plants of arrow arum and arrowhead were planted alternately every 2 ft (0.6 m) in rows spaced 2 ft (0.6 m) apart for a total of 12,742 plants on the 1.35 ac (0.55 ha) site. Thirty grams of Osmocote was applied to each plant. The arrow arum failed to survive the first season. This was attributed to a severe freeze that occurred while the plants were stored before planting. The arrowhead established well as did the volunteer smartweed and wild rice. At the end of the second growing season the most common species in both the created and natural marsh were arrowhead, wild rice and smartweed.[48]

On site 1, 7,732 arrowhead, 6,732 arrow arum and 100 pickerelweed were planted. Canada geese ate the new arrowhead seedlings before this species could become established. The arrow arum survived well as did the volunteer smartweed and wild rice. At the end of the second growing season smartweed (*Polygonum hydropiper*), arrow arum and water purslane (*Ludwigia palustris*) were the most common species on the created marsh.[49]

Site Description

General

The Rancocas Creek has a watershed of approximately 360 mi^2 (932.4 km^2), used intensively for farming, industry and suburban residences in Burlington, Ocean and Camden Counties. The tidal mainstem flows 7.5 mi (12.1 km) from the confluence of the north and south branches of the Rancocas to the Delaware River. This stretch of the Rancocas has a mean width of 400 to 800 ft (121.9 to 243.8 m), a mean depth of 13 ft (4.0 m) and average discharge of 150 ft^3 per sec. Lush stands of freshwater marsh vegetation on tidal mudflats form bands along either side of the main channel and occasional islands within the channel. The marsh varies in width from completely absent in bulkhead areas to over 1000 ft (304.8 m) (figure 18).[50]

Rancocas Creek has been designated as Tidal Water 1 (TW-1) by NJDEP, Division of Water Resources. By definition these waters shall be suitable for: public potable water supply (after such treatment required by law or regulation); shellfish harvesting where permitted; the maintenance, migration and propagation of natural and established biota; primary contact recreation; industrial and agricultural water supply and other reasonable uses. Suitable water quality for each of these uses is not always maintained. Nutrient enrichment and pollution from various sewage treatment plants, landfills, septic tanks urban runoff, agricultural runoff and industrial waste lagoons

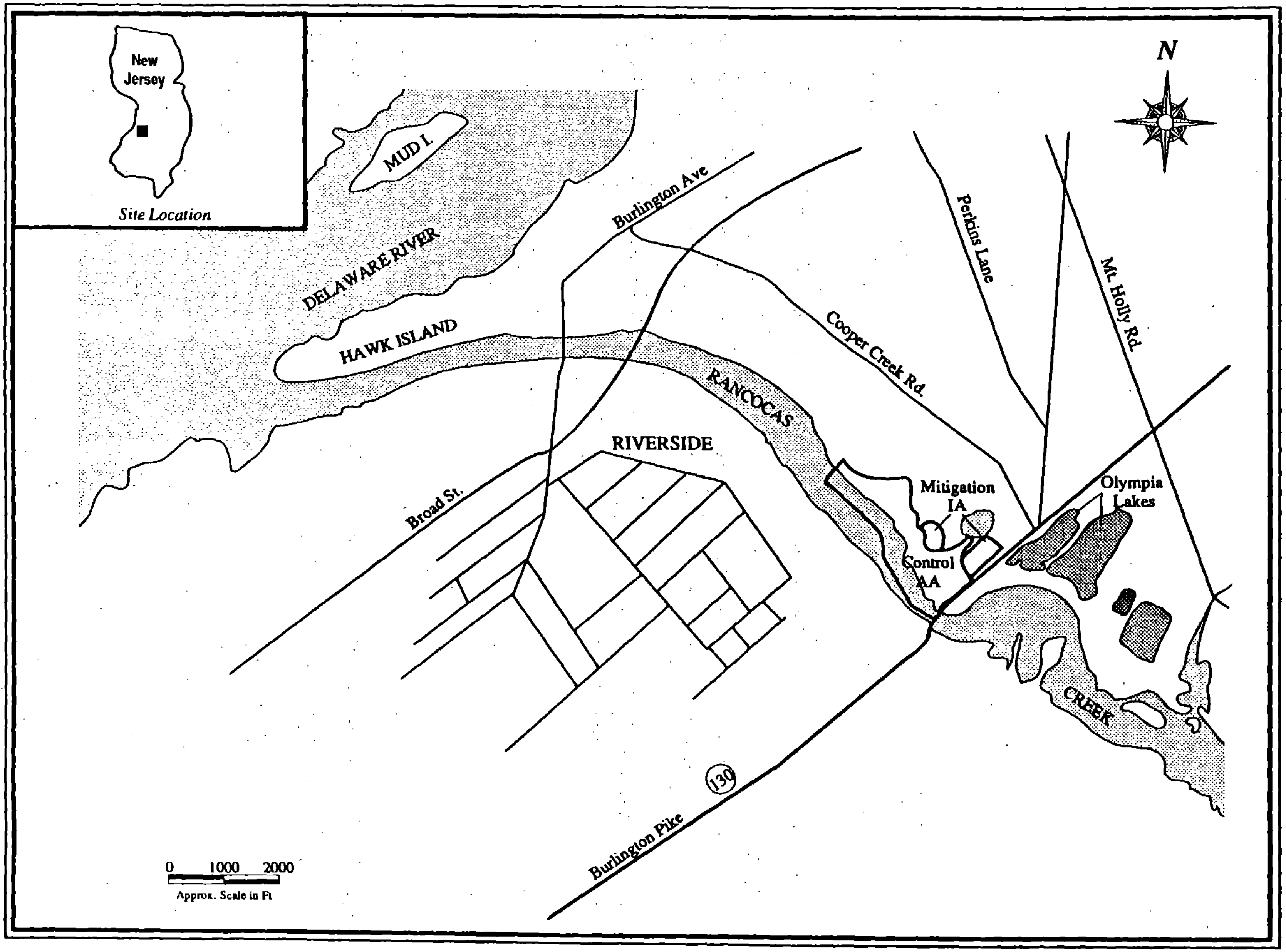


Figure 18. Location of Rancocas Creek mitigation and control wetlands, New Jersey.

threaten water quality and cause aquatic weed and low dissolved oxygen problems.[50]

These freshwater tidal marshes have been mapped by the NJDEP and are under the jurisdiction of the New Jersey Wetlands Act of 1970. It is recognized that through daily tidal flushing these wetlands are integral to complex natural systems. These systems provide vital functions which improve water quality, maintain aquatic and wildlife resources (especially migratory waterfowl) and protect uplands from erosion and flooding.

Control

The adjacent undisturbed portion of the original freshwater tidal wetland bordering Rancocas Creek is representative of the wetland filled for the bridge and was evaluated as the control assessment area (AA). The hydrologically contiguous wetland area delineated as the AA is approximately 96 ac (39 ha) and includes open water (Rancocas Creek), fresh water tidal marsh, shrub and forested floodplain wetlands. Vegetation in the natural marsh is dominated by arrow arum, wild rice, smartweed, jewelweed (*Impatiens capensis*) and bur marigold (*Bidens laevis*). Several vegetation bands grade into each other from the creek inland. These are: yellow waterlily (*Nuphar advena*) near the creek channel; then a larger area of wild rice, bur marigold, arrowhead arrow arum; nearer to the upland are cattails (*Typha angustifolia*) and shrub and forested floodplain wetlands dominated by red maple (*Acer rubrum*), green ash (*Fraxinus pensylvanica*) and tulip-tree (*Liriodendron tulipifera*). A complete species list can be found in volume II.

The watershed of the control AA was delineated in accordance with WET 2.0 guidelines. It includes only the area immediately upslope of the AA rather than the entire upstream watershed of Rancocas Creek. This area is approximately 245 ac (96.8 ha). Land use is primarily agricultural and residential. The service area of the control and mitigation wetlands is designated as the municipality of Riverside, located less than a mile downstream.

Mitigation

Sites 1 and 3 are hydrologically connected and were evaluated together as the mitigation impact area or IA (figure 19). Site 1 (3.1 ac [1.2 ha]) was planted in 1986 but still had a man-made appearance early in 1989 due to the symmetrical spacing of the planted arrow arum. Some experimental blocks were left unplanted in site 1. These areas became vegetated with smartweed (*Polygonum hydropyrer*), water-purslane and wild rice. Purple loosestrife (*Lythrum salicaria*), an agressive non-native had become estab-

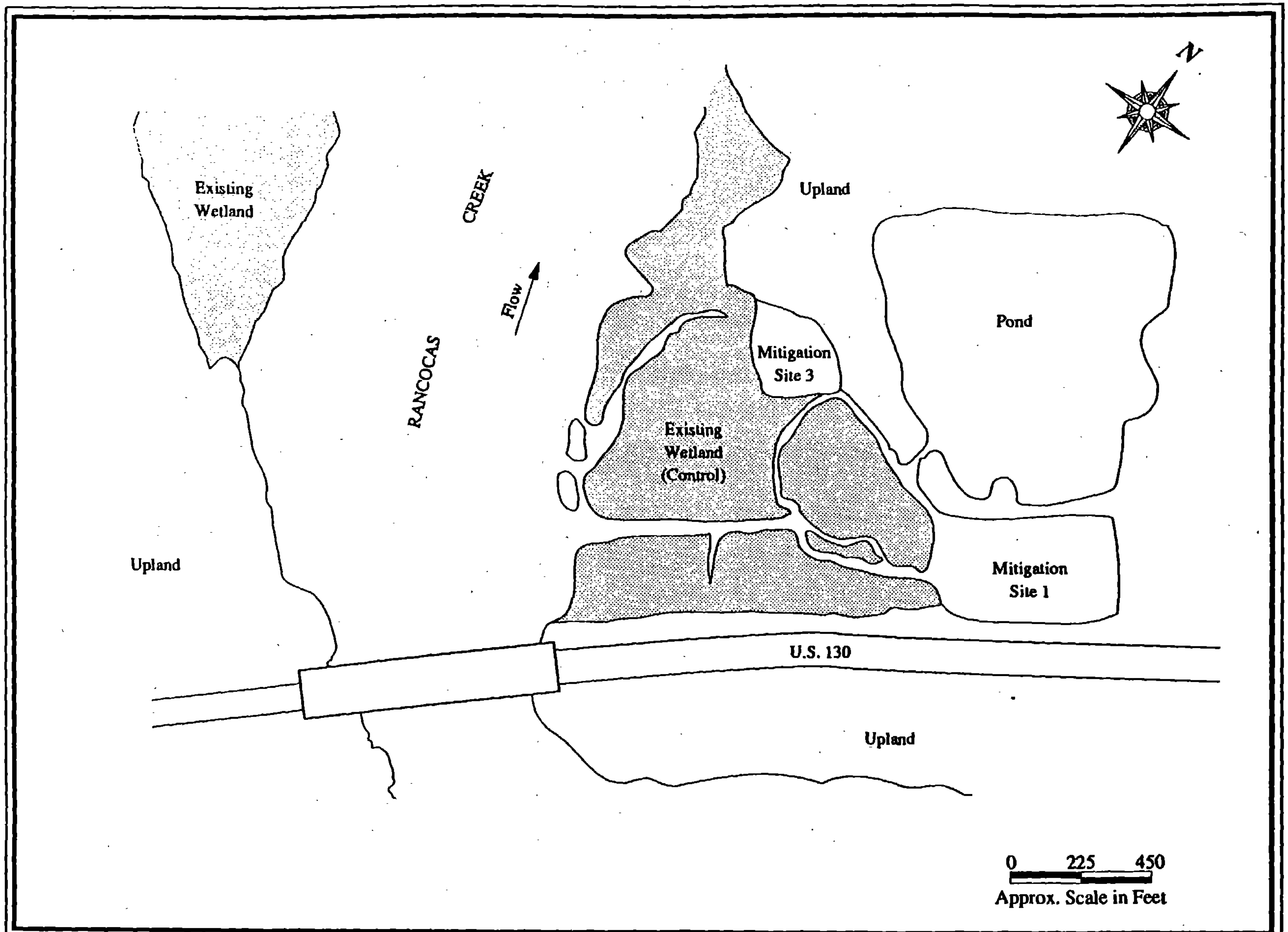


Figure 19. Study area showing mitigation sites 1 and 3, Rancocas Creek, New Jersey.

lished in limited areas. The overall density of vegetation appeared somewhat lower in site 1 than in site 3 although the field visit was in spring before the full season's growth had developed. Site 3, planted in 1984, looked much more like the natural marsh in both the arrangement and density of the vegetation and the irregular nature of the tidal channels. A complete plant species list can be found in volume II.

Silt deposits have begun to accumulate over the sand substrate and secondary tidal drainage channels are developing in both mitigation sites. Site 3, the older of the two, has 3 to 5 in (7.6 to 12.7 cm) over most of the area, and 9 in (22.9 cm) along the north tidal creek. Site 1 has 1 to 3 in (2.5 to 7.6 cm) of silt accumulated over most of the area. However, 4 to 5 in (10.2 to 12.7 cm) of silt occur near the south creek with a maximum of 6 in (15.2 cm) in the protected southeast corner. The northern corner of Site 1 has less than one inch of silt accumulation. Filamentous algae growth over small unvegetated portions of both sites appears to promote and retain silt accumulation. These sediment deposition rates appear to be in the range expected for natural tidal marsh systems.(49)

Methods

Field work was conducted at the site on June 6 through 10, 1989. The impact area (IA) option was utilized for the WET 2.0 evaluation because the control and mitigation sites are hydrologically contiguous. Water samples from Rancocas Creek and the tidal channels within the Mitigation areas were analyzed for pH and conductivity. On-site interviews were conducted with representatives of NJDOT. Other information sources included NJDOT file records publications, and agency correspondence.

Functional Analyses

WET 2.0 and Hollands-Magee evaluation results are discussed in appendix A.

Summary

The primary goal of the mitigation was to replace the natural tidal marsh lost to the bridge approach by creating a functioning marsh from the adjacent upland. The created wetland is similar to the adjacent natural freshwater tidal marsh in hydrology and dominant vegetation. The two wetland areas have similar functions except for those relating to water quality protection. This difference is due to the lower vegetation density in the mitigation areas. This high degree of effectiveness may be attributed to the location of the project and the careful attention given to final elevation.

12. Wilmington, North Carolina

Introduction

Construction of an interchange at the junction of Interstate 40 with State highway 132 (NC 132) on the outskirts of Wilmington required the relocation of 2,900 ft (884.5 m) of Smith Creek and placement of fill in 18.8 ac (7.6 ha) of wetlands. The impacted wetlands consisted of palustrine deciduous forestland located along the Smith Creek floodplain (figure 20). As required by federal and State permitting authorities, impacts were minimized through use of 2:1 embankment slopes, and by retaining wetlands within the interchange loops in their natural condition and maintaining hydrologic connections with culverts. These changes reduced the originally proposed fill by 9.1 ac (3.7 ha).(51)

In addition, the U.S. Army Corps of Engineers and North Carolina Department of Transportation (NCDOT) agreed that a borrow area providing fill for interchange construction be left in a condition such that it could develop into wildlife habitat. The resulting 50 ac (20.25 ha) pond, now owned by the University of North Carolina at Wilmington (UNC-W) for research purposes, is the subject of this study. Work in the borrow pit was completed in June 1985.

Mitigation Design

Mitigation goals, other than minimization of filling, were vague for this project. The NCDOT's Environmental Assessment refers to proposed design elements such as gradual slopes and varied water depths.(51) These conceptual plans were developed in cooperation with the UNC-W Biology Department and were intended to be conducive to the natural development of fish and wildlife habitat over time. Section 404 permit conditions simply stated that the borrow area would be "partial mitigation for wetlands lost" and should be constructed as shown on a specified plan (Permit Number SAWC081-N-065-0056). The specified plan is neither in NCDOT's nor the Corps' files and was not available for inspection.(52) Although it was mutually agreed that the borrow pit would offset wetland losses, it was not specifically designed as a wetland, but rather as a pond in which to observe natural succession processes.(53)

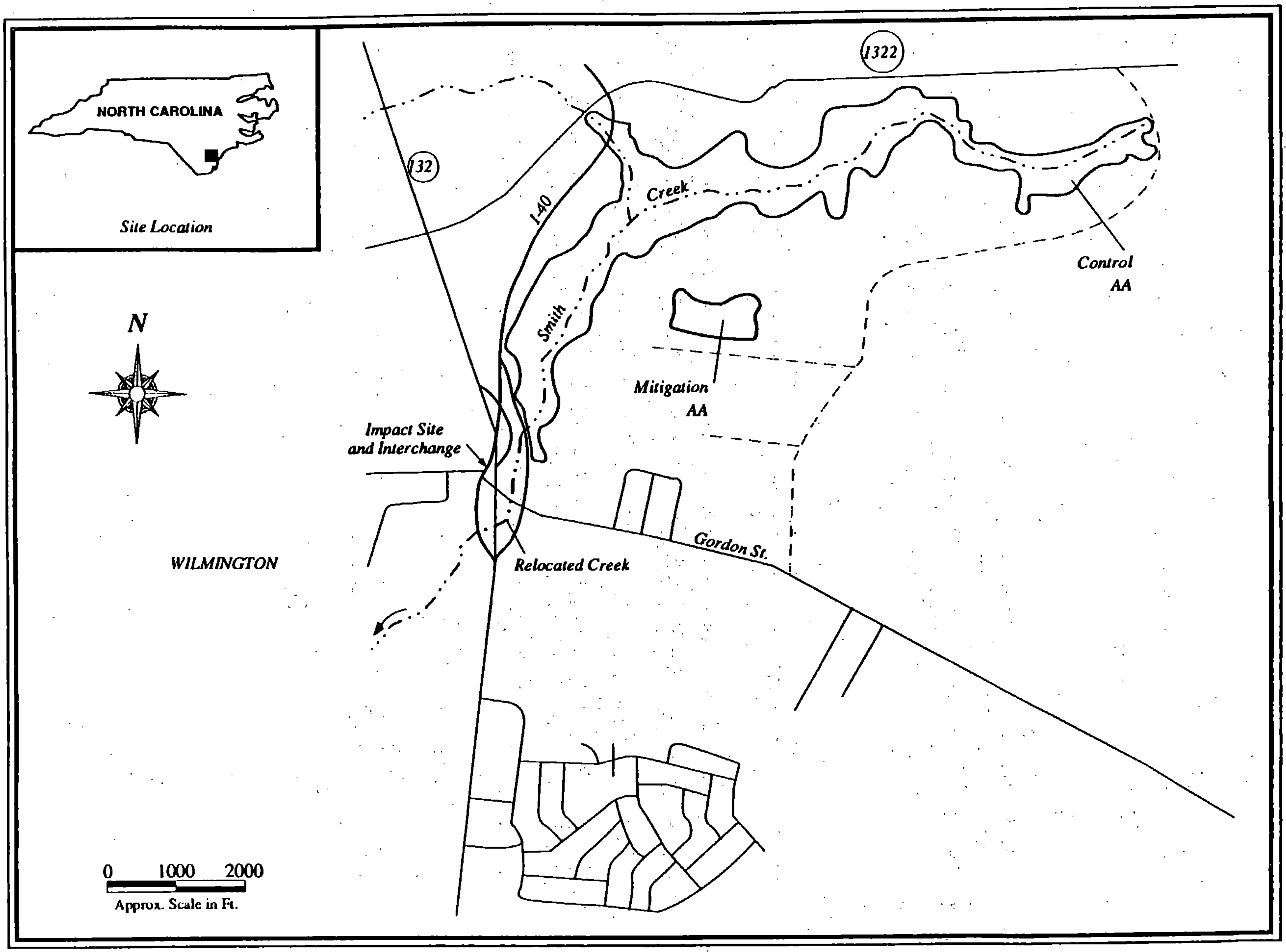


Figure 20. Location of mitigation and control wetlands, Wilmington, North Carolina.

Site Descriptions

Mitigation

Prior to excavation of the borrow pit, the mitigation site supported a pine woodland dominated by longleaf (*Pinus palustris*) and loblolly pine (*Pinus taeda*).[51] County soil maps and observations of hydrophytes in the adjacent undisturbed woods indicate that portions of the site may have supported marginal wetlands.

The mitigation borrow pit (figure 20) was excavated 7 to 15 ft (2.1 to 4.6 m) deep into subsoils consisting of fine sands. The water table was 8 to 9 ft (2.4 to 2.7 m) below top of grade during excavation.[54] Final grading based on the rough guidelines provided by reviewing agencies and UNC-W occurred simultaneously with the excavation of borrow. The 50 ac (20.25 ha) basin thus created includes an area of unvegetated, shifting sand at the eastern end, approximately 5 to 7 ac (2.02 to 2.84 ha) in extent. This material was left after all the material that was required for road construction had been removed.

The majority of the remaining area consists of open water and sparsely vegetated sand flats. There were no wetland species planted, nor was any kind of topsoil spread. Banks are very steep (approximately 2:1) and gullies have eroded in many places.

The land surrounding the pond is located on a local topographic high point, although there is little overall topographic variation in the vicinity. The pond's watershed is approximately 50 ac (20.25 ha), but surface water inlets are absent. Groundwater seeps are common, especially on the east end of the mitigation pond. The pond's uncontrolled outlet is located in its southwest corner. It flows as an ill-defined, discontinuous channel through the transitional forest towards Smith Creek. Samples for basic water quality indicators were collected at the pond's outlet.

The boundary of the mitigation AA is at the edge of the excavated basin. Any wetlands occurring on the surrounding high ground are considered to be hydrologically discontinuous from the AA due to the large difference in elevation. The mitigation AA's service area is the same as that of the control.

The width of the emergent zone is quite variable around the pond's perimeter. The southwestern corner supports the most extensive emergent stand consisting mostly of cattails (*Typha latifolia* and *angustifolia*). The southeast corner supports a 30-ft (9.1-m) band dominated by rushes. The rest of the pond's perimeter supports a 2- to 5-ft (0.6- to 1.5-m) band of low density emergents including: rushes (*Juncus polycephalus, J. diffusissimus, J. el-*

liotii and *Juncus* spp.), spikerushes, sedges (*Carex* spp.), cattails, woolgrass (*Scirpus cyperinus*) and goldenrod (*Solidago* sp.). An occasional shrub has gained a foothold on the pond's banks. Species include waxmyrtle (*Myrica cerifera*), maleberry (*Lyonia ligustrina*), chokeberry (*Aronia* sp.), willow (*Salix* sp.) and shadbush (*Amelanchier* sp.). Bladderwort (*Utricularia inflata*), a submergent, occurs in some near-shore deepwater areas in the AA.

Chimney swifts, killdeer, an osprey and a great egret were observed in the mitigation area. The only other wildlife in the area were observed or heard at the forest edge adjacent to the open mitigation area. These included indigo bunting, prairie warbler, tufted titmouse, kingbird and tree swallow.

Control

According to the Environmental Assessment, the wetlands filled during construction of the interchange consisted of a seasonally flooded bottomland forest community along Smith Creek and a transitional community located further upslope.(51) Dominant bottomland canopy species listed were: bald cypress (*Taxodium distichum*), blackgum (*Nyssa sylvatica*), water oak (*Quercus nigra*), Sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*) and water ash (*Fraxinus caroliniana*). Species listed for the understory were sweet bay (*Magnolia virginiana*), red titi (*Cyrilla racemiflora*), pepper bush (*Clethra alnifolia*), alder (*Alder* sp.), sparkleberry (*Vaccinium arboreum*) and wild grape (*Vitis* sp.). Species common to the transitional forest were pond pine (*Pinus serotina*), red maple, sweet bay, red bay (*Persea borbonia*), red titi, gallberry (*Ilex coriacea*), American holly (*Ilex opaca*) and loblolly bay (*Gordonia lasianthus*). The transitional community had a lower canopy, a more dominant shrub layer and less herbaceous ground cover than the lowland community.

Undisturbed palustrine forested wetlands located directly adjacent to the filled area are very similar to the communities described in the EA. Wetland functions were assessed in this area to provide an approximation of functional value in the impacted wetland. This control assessment area (AA) includes approximately 380 ac (154 ha) of contiguous wetlands along a 2-mi (2.3-km) stretch of Smith Creek upstream of NC 132. The upstream boundary of the AA is a constriction formed by a culverted crossing of an unnamed road (figure 20). Conductivity and pH were analyzed from a sample taken near the downstream boundary (the interchange).

Canopy vegetation in the control was dominated by sweetgum, sweet bay, red maple and black gum. The understory, quite open near the creek but very dense in the upper floodplain, consisted mostly of waxmyrtle (*Myrica cerifera*), ironwood (*Carpinus caroliniana*), alder, red maple, sweetgum and pepperbush. Lianas such as poison ivy (*Rhus radicans*) and wild grape were also common. The herbaceous ground layer was made up mostly of ferns, especially chain fern (*Woodwardia areolata*) and also cinnamon (*Osmunda cinnamomea*) and sensitive ferns (*Onoclea sensibilis*). *Sphagnum* moss was commonly encountered. Songbirds (wood thrush, cardinal and prairie warbler) were the only wildlife observed in the control wetland.

Smith Creek is entrenched in a channel having 3- to 5-ft (0.9- to 1.5-m) banks. One perennial tributary and several ephemeral ones join the creek within the AA. The creekbed is sandy. Johnston soils predominate on the floodplain.(55) These poorly drained soils are characterized by a thick layer of black loam (42 in [106.7 cm]) underlain by sandy loam and sand layers.

The watershed of the control AA is predominantly flat, sandy pineland. Residential development is expanding, however. Much of it is quite close to the upper reaches of Smith Creek where the floodplain wetlands are narrow. The service area for the control AA is designated as Smith Creek from NC 132 downstream to Cape Fear River. This portion of the creek flows through commercial, industrial and residential parts of Wilmington. The lower portion of Smith Creek is tidal.

General

There were no permit conditions or plans dealing with design details for relocating the segment of Smith Creek flowing through the highway interchange. However, the creek was relocated to an oversized channel north of Gordon Road. This allowed the creek to seek its own meandering flow path and for wetland to begin developing in the rest of the channel. The area is adjacent to remnants of the original Smith Creek wetlands and appears to be restoring itself nicely. Detailed observations were not made in this area.

Methods

Field work at Smith Creek and the UNC-W mitigation area was conducted May 20 through 22, 1989. Since the mitigation pond was intended to partially offset wetland losses due to construction, field investigations centered on obtaining enough information to compare functions performed by each of the wetlands in order to assess mitigation effectiveness. Informational resources included: the UNC-W Biology Department, New Hanover County Planning Department, the North Carolina Department of Natural Resources and Community Development (DNRCD) and NCDOT.

Functional Analysis

Results of the evaluation models are presented in appendix A.

Summary

Although none of the mitigation plans or requirements specifically called for the creation of a wetland, permit requirements did specify the purpose of the borrow area as "partial mitigation for wetlands lost." When the permit was issued in 1982, it was apparently not the Corps' practice to require functional replacement or in-kind mitigation. Based on available information, it appears that the project's permit conditions were satisfied by the construction of the UNC-W Mitigation area. However, the purpose of this study is to consider the effectiveness of the mitigation effort in terms of functional replacement.

Development of fish and wildlife habitat, NCDOT's goal, is not progressing well. The basin's substrate is unstable and not conducive to vegetative colonization. As a result, fish and wildlife cover is severely lacking.

According to WET 2.0 results, the mitigation pond equals and in some cases exceeds the social value of, and the capability to provide many of the functions evaluated for the impacted (control) wetland. However, this level of analysis ignores many important ecological aspects of both sites such as productivity and structure. The mitigation area more closely resembles a lake than a wetland, although average water depth probably is shallow enough for a wetland rather than a deepwater classification.[3]

A healthy stand of emergent vegetation can be expected to develop around the pond's perimeter with time. However, judging from its condition after four growing seasons, many more years will be required. This process could have been accelerated through the incorporation of certain design elements. An irregular shoreline would reduce erosive forces and encourage the trapping of seeds. A layer of wetland topsoil over a more gradual slope at the water level would provide a better substrate for plant establishment than the existing sandy subsoil.

The UNC-W mitigation pond lends diversity to an inland landscape in which open water is uncommon. The area is likely to perform certain wetland functions as well as the wetland it was intended to replace. Other functions can be expected to develop or improve with time.

13. Nehalem Bay, Oregon

Introduction

Nehalem Bay is located on the northern Oregon coast at the mouth of the Nehalem River in Tillamook County. The Nehalem River drains a rural, forested region where predominant land uses are logging and dairy farming. At the northeastern end of Nehalem Bay, the widening of U.S. 101 at the crossing of Gallagher Slough involved filling 2.4 ac (0.9 ha) of palustrine and estuarine wetland. Gallagher Slough is a brackish tidal waterway entering the bay in the Town of Wheeler. The impacted wetlands included freshwater wet meadow and shrub swamp, brackish emergent marsh, and salt marsh (figure 21).

Mitigation Design

The mitigation goal was to create both freshwater and brackish water wetlands similar in type and function to the wetlands impacted, with particular attention to waterfowl habitat. The original mitigation plan was changed due to technical reasons and the amended plan for mitigation was two-fold: (1) create a freshwater emergent wetland offsite on the Nehalem Spit, and (2) clear sand and debris from a small (2.9 ac [1.1 ha]) embayment on the spit to allow greater tidal flushing in an adjacent wetland and enlarge the embayment by 0.2 ac (0.1 ha).

The plan was agreed upon by U. S. Fish and Wildlife Service, the Tillamook County Planning Office, the Oregon Department of Fish and Wildlife (DFW), the Oregon Division of State Lands, and the Oregon Department of Transportation (DOT).

On a barrier sand spit on the western side of Nehalem Bay, a 1-ac (0.4-ha) closed basin was excavated to the groundwater elevation. The ponded fresh water is subject to some tidal fluctuation. There were no wetland plantings and no spreading of topsoil or muck. Sand and drift logs deposited by wind and tides were removed from a nearby embayment. The grading at both sites was completed in March 1985. The cost of the mitigation project to the Oregon DOT was $40,000.

Site Descriptions

General

Nehalem Bay is located on the northern Oregon coast in, a rural, hilly, forested region. The climate is mild and humid, with 93-in (236.2-cm) average annual precipitation.[56] The Coast Range Mountains east of the bay

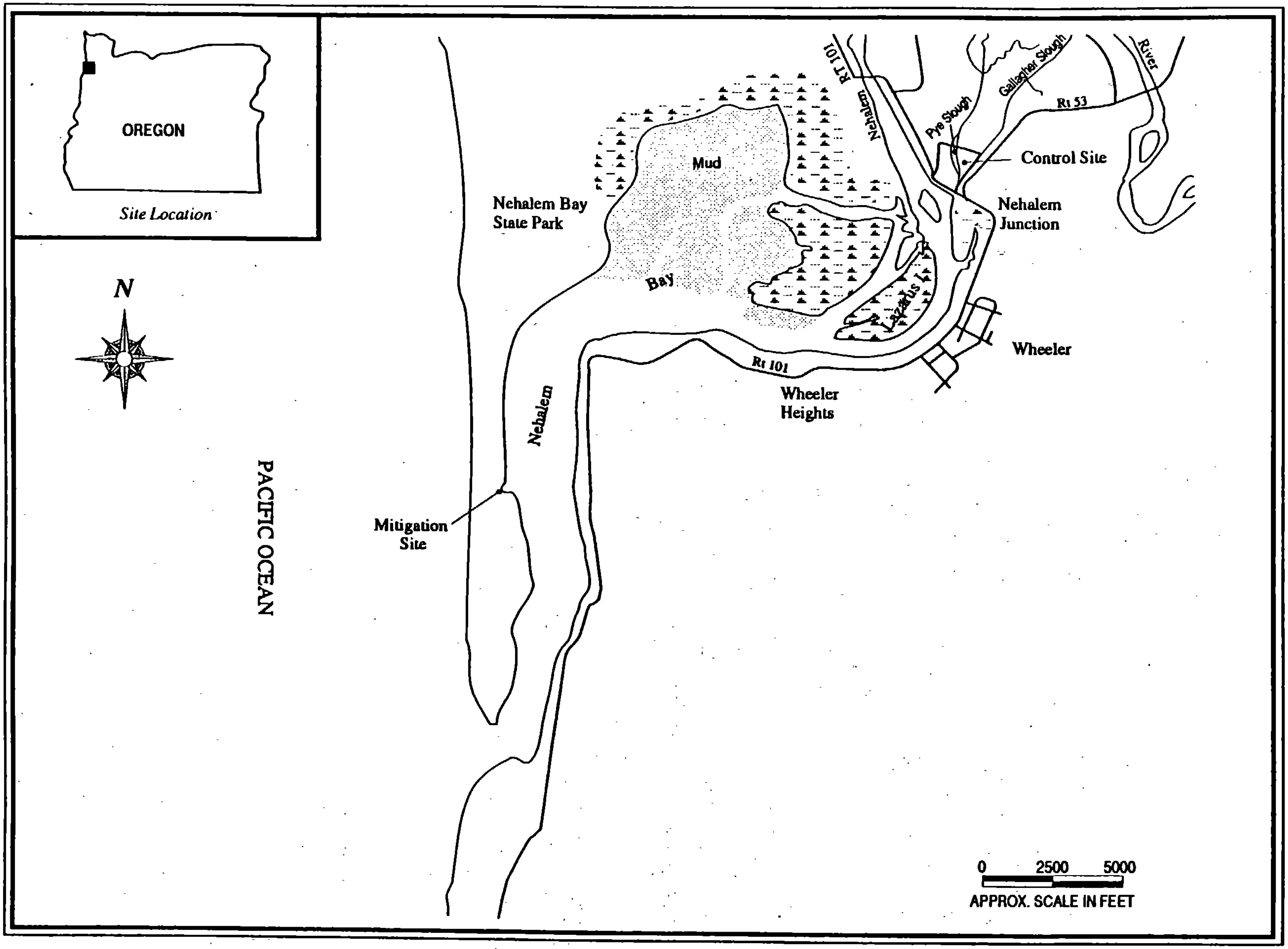


Figure 21. Locations of control, and mitigation sites, Nehalem Bay, Oregon.

are underlain by sedimentary rock with a cap of volcanic materials in many areas. The most common upland soils are silt loams formed in shale or igneous rocks. Lowland areas around the bay are underlain by active or stabilized dunes or, in tidal areas, stratified silt loams over marine clays. The Coast Range Mountains have been intensively logged; forest product industries dominate the regional economy. There are a few small towns and settlements on the coast and on the bay's perimeter, but no large population centers and little heavy industry.

Mitigation

The Nehalem Spit, located in Nehalem Bay State Park, is a sand peninsula running approximately 2.5 mi (4.0 km) north to south and defining the western shore of Nehalem Bay (figure 22). It is 1000 to 2000 ft (304.8 to 609.6 m) wide with a vegetative cover of dune grasses, scotch broom (*Cytisus scoparius*), and shore pine (*Pinus contorta*). The mitigation site is located on the bayside of the spit about 1 mi (1.6 km) south of the park's parking area; it is accessible to the public from there only by ft path. In the spring of 1985 an approximately 1-ac (0.4-ha) basin was excavated to the groundwater elevation. There were no wetland plantings and no spreading of topsoil or muck. The spoils banks and access roadway were graded to simulate natural dune contours, and the banks were planted to European beach grass (*Ammophila arenaria*) for stabilization. Since its completion in March 1985, the Oregon DOT has conducted annual monitoring from permanent ground photograph stations.

At the time of the site visit, standing water at the mitigation site was limited to two small, shallow disjunct pools. The pool at the northwestern end covered approximately 35 ft^2 (3.3 m^2) and had a maximum depth of 4 in (10.2 cm). The pool in the southwest corner covered approximately 150 ft^2 (13.9 m^2) and had a maximum depth of 6 in (15.2 cm). These are freshwater pools (conductivity 370 to 490 µmhos) but the Oregon DFW wildlife biologist has observed a daily tide-influenced fluctuation. No fluctuation was observed during the site visit. DOT monitoring photographs show much more standing water during other seasons. In June 1986 and May 1987 the basin was inundated to a depth of 3 ft (0.9 m) or more. In October 1988 and August 1989 the basin was nearly dry. At the time of this study, three-stamened rush (*Juncus ensifolius*) was the overwhelming dominant throughout most of the basin, with western lilaeopsis (*Lilaeopsis occidentalis*) also growing abundantly. Few other species were present. Much bare substrate was visible in the wetland and on the banks.

There was evidence (tracks and feces) of very heavy use of the pools by elk; deer and horse tracks were also present. Fresh surface water is scarce at times on Nehalem Spit, and these pools may be quite valuable to elk

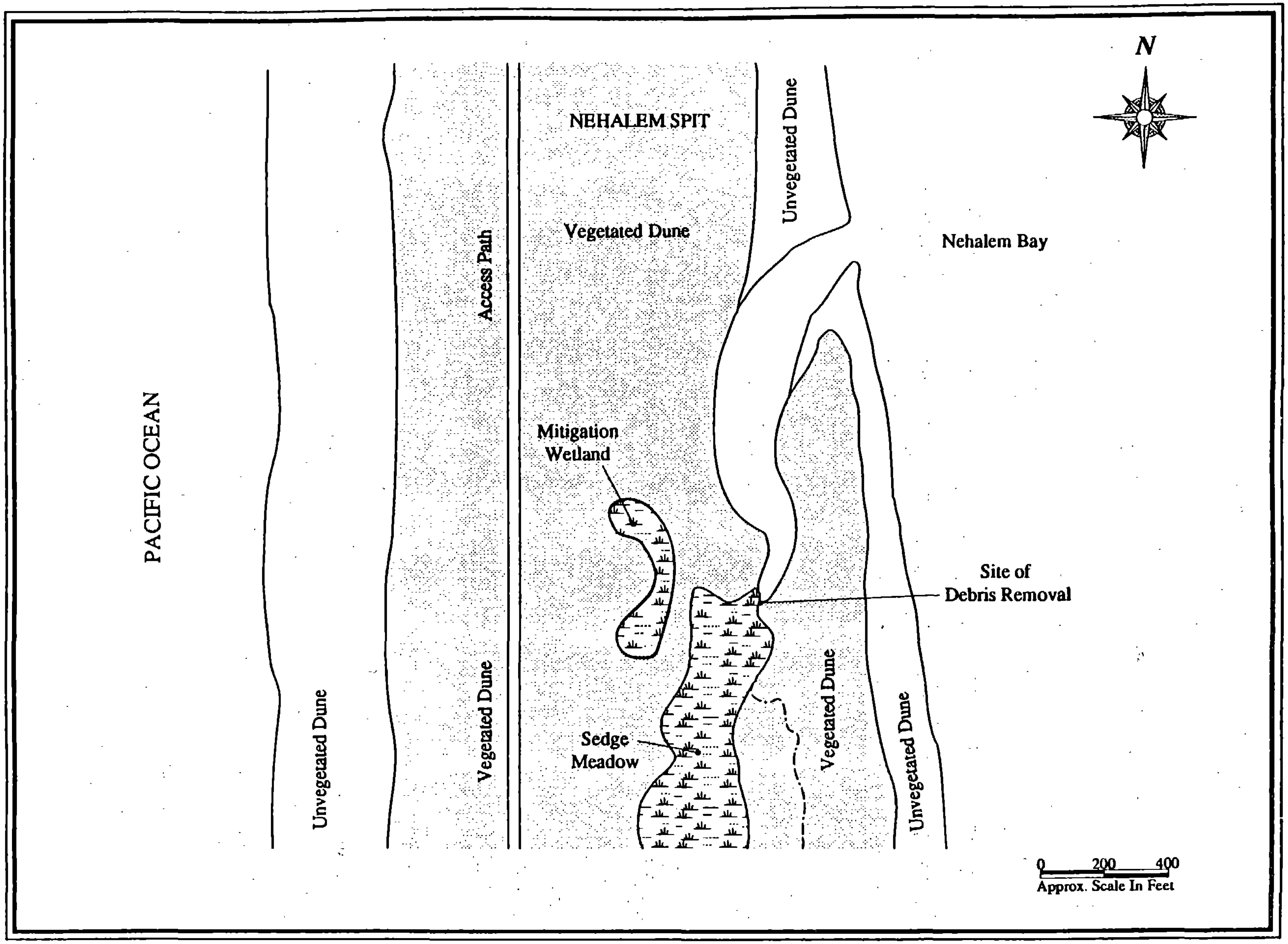


Figure 22. Setting of Nehalem Spit mitigation wetland, Nehalem Bay, Oregon.

and other wildlife. Minnows were observed in the larger pool but many were dead or dying. The Oregon DFW has reported incidental use of the site by peregrine falcon.

The watershed of the mitigation wetland is limited to the dune banks immediately surrounding the basin, and comprising less than 1 ac (0.4 ha). The mitigation was assigned no service area for WET 2.0 assessment due to its lack of an outlet.

Control

Gallagher Slough and a tributary, Pye Slough, drain approximately 900 ac (355.5 ha) of agricultural land within a large oxbow of the Nehalem River. These were formerly tidelands but have for many years been protected by dikes, ditches, and a tide gate at the mouth of Gallagher Slough. The impacted wetlands were located along a narrow (40 to 80 ft wide [12.2 to 24.4 m]) strip of land adjacent to the original U.S. 101 embankment. These wetlands were part of a larger wetland area that included portions of Gallagher Slough, Pye Slough, and contiguous grazed meadows and shrub swamps.

For purposes of WET 2.0 assessment, the control wetland was delineated as the approximately 17-ac (6.7-ha) wetland area bounded by Route 53 on the east, a tractor road (and town sewer line) on the northeast, a dike on the west, and U.S. 101 on the south (figure 21). Much of the control area is wet meadow pastureland dominated by freshwater herbaceous species, such as soft rush (*Juncus effusus*), velvet grass (*Holeus lanatus*), fescue (*Festuca sp.*), bentgrass (*Agrostis sp.*), and water parsley (*Oenanthe sarmentosa*). There are freshwater shrub wetlands along the road embankment and east of the Gallagher Slough channel; common shrub species are willows (*Salix spp.*), twinberry (*Lonicera involucrata*) and elder (*Sambucus spp.*). Lower terraces support brackish marsh species including spike-grass (*Distichlis spicata*), Lyngbye's sedge (*Carex lyngbyei*), three-square (*Scirpus americanus*), saltmarsh bulrush (*Scirpus maritimus*), and brass buttons (*Cotula coronopifolia*). A more complete list of species is presented in volume II.

Mudflats border portions of the slough channels. Gallagher Slough is controlled by a tide gate, but leakage at flood tide keeps water in the slough channels salty. In samples taken September 18, 1989 at flood tide, the salinity was 25.5 ppt. The normal tidal fluctuation in these channels is approximately 1 ft (0.3 m). The landowner reports only two floods during the last 5 years, when south winds and high tides carried the seas over U.S. 101.

No fish sampling has been undertaken in Gallagher and Pye Sloughs, but according to the district fish biologist, such areas provide rearing habitat for salmonids, notably Chinook salmon. Blueback salmon, coho salmon, steelhead and cutthroat trout are known to use the Nehalem River, and may also occur in these sloughs at some time during their life history. Wildlife observed at the control site include great blue heron, yellowlegs, western sandpiper (observed by the contractor), nutria, elk (reported by landowner), whistling and trumpeter swans (reported by Oregon DFW). Bald eagles are known to nest nearby.

Due to its tidal nature, the watershed of the control wetland was considered to be the watershed of Nehalem Bay. This watershed encompasses approximately 750 mi^2 (1207.5 km^2). It includes no towns with populations greater than 5000; most are small towns and settlements with populations less than 1000. The watershed contains a portion of the Oregon Coast Range, a range of low ridges and peaks (average elevations 1500 to 2500 ft [457.2 to 762.0 m]) formed from sedimentary materials with a basalt overburden. Much of the watershed is commercial forest land that has been subject to intensive logging in recent decades. This may account, in part, for the heavy silt load carried by the Nehalem River into the bay. About 40 percent of the watershed land area lies within the Tillamook and Clatsop State Forests. The dominant forest communities are Douglas-fir (*Pseudotsuga menziesii*) and western hemlock-Sitka spruce (*Tsuga heterophylla - Picea sitchensis*), with a smaller deciduous component of red alder (*Alnus rubra*), cottonwood (*Populus* sp.) and willows (*Salix* spp.)

The service area for the control wetland is the portion of Nehalem Bay within 1000 ft (304.8 m) of Gallagher Slough, delineated according to WET 2.0 instructions for non-fringe tidal wetlands. The 36-ac (14.2-ha) service area occupies a delta area at the mouth of the Nehalem River that includes open brackish water, saltmarsh, and mudflats. Development is sparse here and on the bay's perimeter in general. Although its water quality is considered to be better than that of other bays to the south, commercial shell fishing is restricted in Nehalem Bay due to high fecal coliform levels. The primary coliform sources are dairy farms, failed septic systems, and a sewage treatment plant near the mouth of the Nehalem River. Little water quality data for Nehalem Bay was available. An elutriate of sediment samples from the Nehalem River (in DOT files, date unknown) was in violation of Federal water quality standards for copper, mercury, and zinc for freshwater aquatic life (Cu), marine aquatic life (Cu,Hg), and fish habitat (Zn). Heavy silt inputs from the Nehalem River have reportedly damaged clam beds.

Methods

Field work at the Nehalem Bay sites was carried out during September 18 and 19, 1989. Plant species lists and descriptive notes on the impact and mitigation sites were compiled and field information necessary for WET 2.0 and Hollands-Magee evaluations was collected. Incidental observations of wildlife and sign were noted. pH was measured in Gallagher Slough near the tide gate; a salinity sample was collected there and later analyzed in the laboratory. Specific conductivity and pH were measured in the ponded areas of the mitigation site. General features of the mitigation and control sites were recorded on videotape and 35-mm color slides.

The contractor met at the impact site with the Oregon DOT biologist involved in the design and implementation of the mitigation project. Scientists also spoke with the farmer who owned the impacted property and adjacent lands, and discussed agricultural use, tidal flooding patterns and wildlife use. Other persons and agencies contacted included the Oregon Department of Fish and Wildlife, the Oregon Department of Environmental Quality, the Tillamook County Soil Conservation Service, and the District Fisheries and Shellfish Biologists. Additional resources included the Oregon DOT Wetland Analysis for the impact site, preconstruction aerial and ground photographs of impact and mitigation sites, NWI maps, USGS topographic maps, and the 1964 SCS Tillamook County Soil Survey.

Functional Analysis

A functional comparison of the wetland impacted by road construction (control) with the mitigation wetland, using WET 2.0 and Hollands-Magee evaluation models is described in appendix A.

Summary

The goals of the mitigation project were to create fresh and brackish water wetlands similar in type and function to the wetlands impacted. Particular attention was paid to waterfowl habitat. The brackish water wetland was to have been created by the removal of sand and debris from an embayment; but in fact, only the open water area was expanded and no additional wetland created at that site. A freshwater wetland was created in the dunes on Nehalem Spit. There were no wetland plantings and no spreading of topsoil or muck.

The wetland's water level is subject to high seasonal fluctuations. By later summer of 1989, surface water was reduced to two tiny pools of several in depth. The wetland was vegetated throughout with a very low diversity of emergent plant species in moderate densities. There was much bare sandy substrate between stems. The wetland appears to be an important drinking water source for wildlife on the spit. Other habitat values are limited by the poor interspersion of water and vegetation, the low plant species diversity, and the near absence of surface water by late summer. The wetland is located in a quiet spot, remote from human activities, so it is likely to be attractive to wildlife species that avoid human disturbances.

The wildlife habitat values of the wetland would have been improved by ensuring more permanent surface water, and interspersion of open water areas with vegetated areas. Deeper excavation at some places might have accomplished both. Wetland plantings, including shrubs and a variety of emergent species, would have encouraged the development of greater species and structural diversity. Placement of muck or topsoil might have made the substrate hospitable to a greater variety of naturally deposited propagules.

Over time, propagules of other plant species may be deposited by birds and wind, and the species and structural diversity may improve. In the meantime, although it has not duplicated many of the biological, chemical and physical functions that were lost to Route 101 expansion, it will provide some wildlife habitat values. The final grading of the wetland and spoils banks were carefully done to provide an aesthetically pleasing site simulating the natural dune landscape.

In summary, the mitigation project resulted in a net loss of brackish water wetland and freshwater shrub swamp types, and a net loss of approximately 1.4 ac (0.6 ha) of total wetland area. It is likely to have resulted in net gains in groundwater recharge, recreation, and educational functions; and net losses in floodflow alteration, hydrologic support, nutrient removal/transformation, and aquatic habitat functions. The wildlife habitat features, though very different in each wetland, may be equally valuable.

14. Noti-Veneta, Oregon

Introduction

The Towns of Noti and Veneta are located in the Willamette River Valley, west of Eugene in Lane County, Oregon. Construction of Route 126 on a new alignment between Noti and Veneta involved the filling of 14.1 ac (5.6 ha) wetland at eleven locations. The filled wetlands included 6.5 ac (2.6 ha) of deciduous wooded swamp, 4.5 ac (1.8 ha) of emergent marsh, 3.0 ac (1.2 ha) of deciduous shrub swamp, and 0.1 ac (0.04 ha) of riverine wetland.

Mitigation Design

The wetland mitigation plan was drawn up by the Oregon DOT and agreed to by the Oregon DFW and the USFWS. The mitigation goals set forth in the EIS (1986 revision) were (1) to restore as quickly as possible the functions of the filled wetland, namely groundwater discharge, flood storage and desynchronization, sediment trapping, nutrient retention, wildlife habitat, and aesthetics; and (2) to create wetland areas exceeding by 10 percent the acreage lost to road construction, in order to compensate for the time-costs of wetland habitat development.

Three ponds with islands were created to mitigate for the wetland losses. The mitigation plan included the following design features: irregularly shaped shoreline and islands to maximize shore length; variable shoreline slopes of 3:1 to 6:1; 2 to 3 islands per basin located where the water is deepest, each at least 1500 ft^2 (139.4 m^2) with elevations 2 to 4 ft (0.6 to 1.2 m) above water during nesting season; maximum water depths of 7 to 8 ft (2.1 to 2.4 m); randomly distributed loafing logs, 4 to 6 per ac (1.6 to 2.4 per ha); tree and shrub plantings to form a visual and audio screen from the road, to form a windbreak at the western ends, and for windbreak and erosion control at the eastern ends; plantings of wild millet and smartweed on the frequently flooded shore zone, and inoculations of duckweed; upland bank plantings of bird and waterfowl food species: proso millet, buckwheat, smartweed; erection of a fence at the boundary of private property; and prohibition of grazing, mowing or burning, to protect nesting cover. A monitoring program was outlined that included field reviews during construction, and at least annual inspections until the sites are well established. The plan included no requirement for corrective action in the event of failure or non-fulfillment of any aspect of the project.

In the fall of 1987, three basins (ponds 2, 3, 4) totalling 15.5 ac (6.1 ha) were excavated in the right-of-way of the new Route 126 alignment (figure 23). All were excavated in cultivated or fallow fields underlain by McBee silty clay loam a moderately well drained soil formed in stratified alluvium.[57] All are located within the 50-year floodplain of the Long Tom River, but only one, pond 3, has an immediate stream connection to the river. Pond 2 was constructed south of Route 126 and is connected via culvert to an agricultural ditch system north of the road. Pond 3 was constructed north of Route 126 and connected via intermittent stream to Long Tom River. Pond 4, also north of Route 126, was constructed as a closed basin receiving only intermittent surface water inputs from a roadside drainage ditch. Water levels in all ponds are maintained by the local water table. Two to three small islands were left in each basin. No muck or topsoil was spread in the excavated areas. A total of 203 Lombardy poplar (*Populus nigra*) saplings were planted along the upland banks to form a screen from the road. Approximately 19,500 willow cuttings (probably *Salix sitkaensis*) and approximately 1340 red-osier dogwood cuttings (*Cornus stolonifera*) were planted along shorelines and on islands. Duckweed (*Lemna minor*) was introduced to each basin. Other wetland and upland plantings specified in the DOT Wildlife Mitigation Plan were not carried out. No loafing logs were distributed. Shorelines were not irregularly sculpted. Oregon DOT monitoring was minimal during construction of the mitigation ponds and was largely limited to photo-documentation.

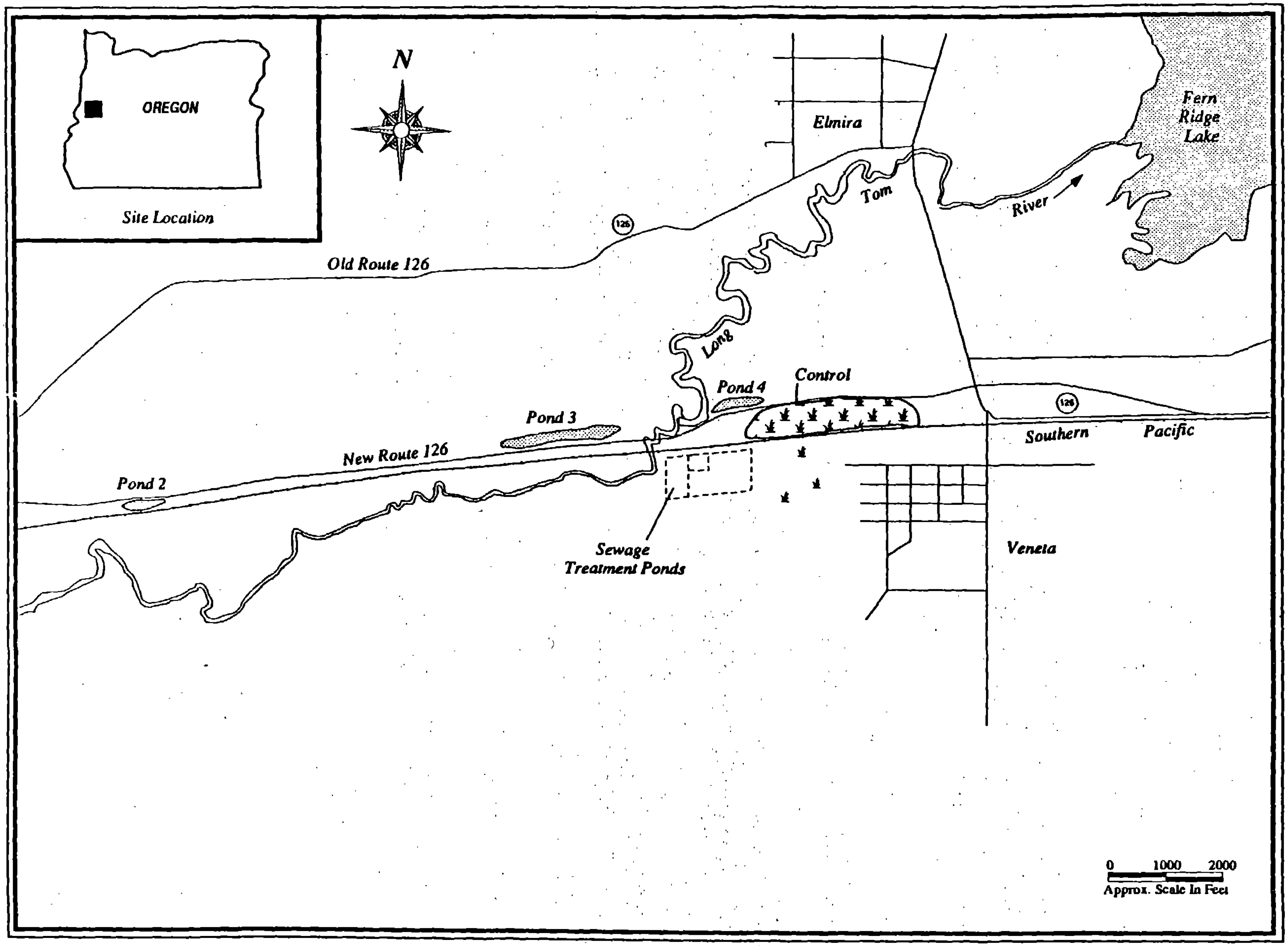


Figure 23. General Location of Noti-Veneta mitigation and control wetlands, Veneta, Oregon.

Annual inspections since construction have included collection of vegetation data from transects and taking of ground photographs from permanent stations. These inspections have been discontinued. The cost of the mitigation project is unknown, because it was included in general Route 126 ROW acquisition, road construction and landscaping costs.

Site Descriptions

General

The project area is located in west-central Oregon in a transition zone between the forested Coast Range Mountains to the west, and the predominantly agricultural Willamette Valley to the east. This is a rural, forested and agricultural region of temperate climate, with warm, dry summers and cool, wet winters. The average annual precipitation is 46 in (116.8 cm), most of which occurs during the fall and winter. The extremely light rainfall in summer (less than 2 in [5.1 cm], May through August) necessitates irrigation of crops. Irrigation water is pumped from wells and streams. The Long Tom River drains a portion of the Coast Range, flows east into Fern Ridge Lake, and then north to join the Willamette River about 25 mi (40.3 km) north of Eugene. Although there are some remnants of glacial outwash terraces near Veneta, soils in the immediate project area are formed in alluvium or volcanic colluvium.(57) Floodplains and terraces in the area are used for vegetable cash crop production and grass seed production. Livestock are raised on higher terraces and foothills. The Coast Range Mountains are deeply dissected volcanic hills supporting primarily coniferous forests which provide the resource base for the large wood products industry in the region. Fern Ridge Lake, a large Army Corps of Engineers (COE) flood control reservoir, dominates the immediate landscape. This is a large shallow lake 1 mi (1.61 km) east of the mitigation area with very extensive emergent wetlands.

The alignment of the new Route 126 between Noti and Veneta closely parallels the Southern Pacific railroad tracks and passes through agricultural fields and forested tracts. This is a sparsely settled rural area with scattered residences and no industrial sites.

Mitigation

All three mitigation basins were characterized by very straight shorelines; a large expanse of very turbid open water; steep-sided islands; a 1- to 2-ft (0.3- to 0.6-m) zone of practically bare substrate just above the waterline, suggesting large water level fluctuations; a narrow, sparsely vegetated emergent zone; and upland banks with much bare substrate.

Pond 2 is approximately 5 ac (2.0 ha) with three small islands. Its intermittent outlet is connected to an agricultural ditch system that drains ultimately into the Long Tom River. Water levels are maintained by groundwater. The water was very turbid with a whitish-blue opacity. The shoreline slopes (not measured) are quite gradual with less exposed soil than the other two ponds. The dominant plants were spikerush (*Eleocharis* spp.) and rushes (*Juncus* spp.). Most of the planted Lombardy poplar were dead. The basin is bordered along the south edge by upland deciduous forest. The Oregon DOT reports consistent use of this pond by Canada geese in the winter and by domestic geese in summer.

Pond 3 is a long, narrow basin of approximately 5.5 ac (2.2 ha) with three small islands. During storm events, flood waters from the Long Tom River often back up into the pond through the connecting stream channel. There is scarcely any vegetation growing below the waterline, and the bank vegetation is very sparse. The dominant genera on the banks are *Juncus*, *Eleocharis*, and *Bidens*, with small willows (*Salix* spp.) growing at higher elevations. Many of the Lombardy poplar planted along the upland road embankment are doing well. The Oregon DOT reports occasional use of pond 3 by fishermen. Crappies and bullheads, that have intermittent access to the pond from Long Tom River, are the usual catch.

Pond 4 was chosen as the mitigation assessment area for WET 2.0 and Hollands-Magee evaluation. It was chosen among the three mitigation wetlands more or less at random; all are quite similar in their design and development.

Pond 4 is a closed basin of approximately 5 ac (2.0 ha) with two small islands (figure 24). Shoreline slopes measured along the southern shore varied between 6:1 and 9:1 at the base of a 3:1 bank. The islands are steep-sided with elevations approximately 5 ft (1.5 m) above the water level at the time of the site visit. Emergent growth below the waterline is extremely sparse around most of the perimeter. Vegetative cover estimated in three of eight quadrats sampled around the perimeter at random locations was 2 percent or less. The average cover was 17 percent but appeared to be much sparser due to the low-growing, matted, or creeping habit of these pioneer plants. Spikerush (*Eleocharis ovata*), toad rush (*Juncus bufonius*), and a tiny unidentified composite were the most common species present. No duckweed or submergents were found. At the east end of the pond is a broad area of densely growing (97 percent cover) cattail (*Typha latifolia*) and spikerush (*Eleocharis bufonius*, *E. acuminatus*, and other species). The planted willow cuttings high on the banks around the perimeter appeared to be doing well. A more complete species list is presented in volume II. Many of the planted poplars have been killed by beaver. Other wildlife and sign observed at pond 4 during the site visit include great blue heron, bullfrog, and tracks of deer and a large canine.

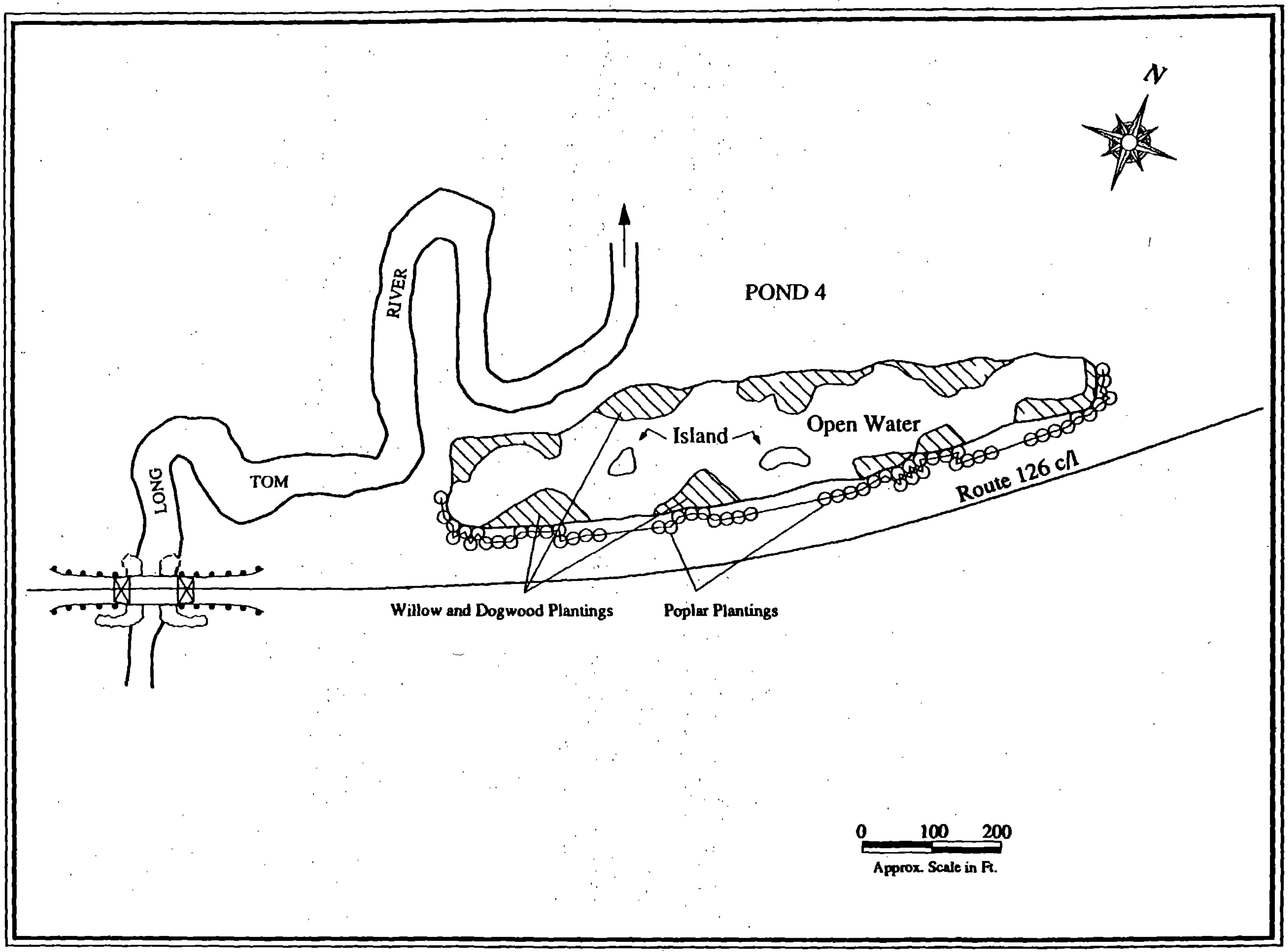


Figure 24. Mitigation pond 4, Veneta, Oregon.

Pond 4 receives surface water inputs only from the immediate surrounding area. Its watershed might total 2 ac (0.8 ha). The upland portions are disturbed but well-vegetated meadow. Mitigation pond 4 has no outlet so was not assigned a service area for WET evaluation.

Control

The area chosen to be the control assessment area for WET 2.0 and Hollands-Magee evaluation was a 28-ac (11.1-ha) deciduous wooded swamp just south of the new Route 126 alignment and north of the Southern Pacific railroad tracks (figure 23). This wetland was chosen because the largest proportion of the total wetland acreage filled for road construction was wooded swamp, and a portion of this wetland had been filled.

The control wetland was dominated by a nearly monotypic canopy of Oregon ash (*Fraxinus latifolia*) with average diameters at breast height of 8 to 18 in (20.3 to 45.7 cm). Young ash, hawthorn, and blackberries were common in the shrub layer; sedges (*Carex* spp.), mint (*Mentha piperita* and others), and water-parsley (*Oenanthe sarmentosa*) were common ground layer species. A more complete species list is presented in volume II. There were numerous standing snags and blowdowns, 8 to 15 in (20.3 to 38.1 cm) dbh (diameter at breast height). The wetland is bisected north to south by a powerline right-of-way containing areas of wet meadow and shrub swamp. It is drained by an intermittent stream channel that flows from Bolton Hill, a small hill to the south. The stream drains the wetland via a culvert under Route 126, flowing ultimately into the Fern Ridge Reservoir. At the time of the site visit, the stream channel, a barely discernible swale, was dry. The only surface water in the wetland was in a small (600 ft^2 [55.7 m^2]) wooded depression just east of the powerline.

The watershed of the control wetland is an approximately 350 ac (142 ha) area that includes the wooded northeast slope of Bolton Hill, and a heavily settled portion of the Town of Veneta. Bolton Hill is underlain by Bellpine silty clay loam, a moderately deep, well drained soil on 12 to 20 percent slopes, formed from sandstone, siltstone, and volcanic residues. At the base of Bolton Hill is a broad swale underlain by Noti and Linslaw loams, poorly to somewhat poorly drained alluvium.[57] This swale is part of a large, formerly contiguous wetland, that once included the control. The construction of the railroad and then Route 126 divided it into small constricted parcels. Effluent from sewage disposal ponds located within the natural watershed does not drain into the control, but is discharged to the Long Tom River in winter, and is applied to agricultural land north of Route 126 in the summer.

The service area for the control wetland was identified as Fern Ridge Lake, a large, shallow flood control reservoir with a summer pool of 9300 ac (3766.5 ha) that is drawn down in the fall to 1500 ac (607.5 ha). The average depth of the reservoir is 4 to 6 ft (1.2 to 1.8 m). It contains more than 2000 ac (810 ha) of emergent wetland, and it receives extensive seasonal use by waterfowl, notably tundra swan, Canada goose, mallard, pintail, ring-necked duck, and woodduck. It supports warmwater game fish including a native population of cutthroat trout who spawn upstream in the Long Tom River. Peregrine falcon and a bald eagle pair frequent the Reservoir. It also harbors one State-listed rare plant species, Bradshaw's lomatium (*Lomatium bradshawii*), and two species proposed for the State list: *Pacific fleabane (Erigeron decumbens)* and white-topped aster (*Aster curtis*).[58]

The water quality is generally good but it is subject to elevated nutrient levels from agricultural run off, and high turbidity due to the clay substrates in its watershed and on the southeast shore. There is not much nuisance algae, but there is excessive milfoil in some areas.[59] The reservoir's watershed comprises approximately 300 mi^2 (483.0 km^2) of agricultural and forested land, including a portion of the Coast Range to the west. Twenty-five ac (10.1 ha) of a South Eugene industrial area lie within the watershed and provoke some concern in reservoir managers over potential pollution problems.

Methods

Field work for this study was carried out during September 20 and 21, 1989. All wetland units were visited and photo-documented, and general observations were made regarding dominant vegetation, vegetation density and hydrology. Incidental observations of wildlife and sign were noted. Shoreline slopes were measured here and there around the pond perimeters using ruler and tape. At pond 4, the site selected for WET 2.0 and Hollands-Magee assessment, overall vegetative cover was estimated in 2.25-ft^2 (0.2-m^2) quadrats at nine random locations 4 to 10 ft (1.2 to 3.0 m) upslope of the waterline along the shore. Conductivity and pH were measured in pond 4.

The contractor spoke with the Oregon DOT biologist involved in the design and implementation of the wetland mitigation plan; supervisory and technical staff at the Fern Ridge Reservoir; soil scientists with the Lane County Soil Conservation Service, and an official at the Veneta Department of Public Works. Other resources included USGS topographic maps, NWI maps, preconstruction aerial photographs, the SCS Soil Survey of the Lane County Area, and preconstruction water quality, biology, and wetland mitigation plan reports prepared by the Oregon DOT.

Functional Analysis

This study made a functional comparison of the impacted wetland (control) with the mitigation wetland, using WET 2.0 and Hollands-Magee evaluations models. The results are included in appendix A.

Summary

The goals of the mitigation project were to (1) restore the functions of the wetland lost to road construction; specifically, groundwater discharge, flood storage and desynchronization, sediment trapping, nutrient retention, wildlife habitat, and aesthetics; and (2) to create wetland areas exceeding by 10 percent the acreage lost to road construction.

Shrub swamp, riverine, emergent and forested wetlands were filled during construction of Route 126. The mitigation project was designed to replace shrub swamp and emergent habitats, but not riverine or wooded swamp (Lombardy poplar was the only tree species planted, and it was planted in upland areas). The vegetation on these sites has been slow to recover from the disturbance of construction. There is much bare soil on the banks and islands, and the shallow, inundated areas are poorly vegetated. This slow reestablishment of vegetation may be due to (1) the erosive nature of these silty clay soils, that were not reseeded after grading; (2) the lack of organic matter in the surface substrate; (3) a possible lack of nutrients, and/or (4) the extreme turbidity of these waters, that may inhibit germination or development of plant propagules. The dense area of spikerush and cattail growth at the east end of pond 4 suggests, first, that large numbers of propagules were deposited there by the prevailing west-northwest winds and waves; and secondly, that nutrients are probably not limiting in these waters. Erosion and turbidity are the most likely causes of the poor revegetation elsewhere in these basins. Revegetation is occurring, however, and the gradual buildup of organic matter in the substrate will hasten its development. Some of the shrub cuttings are flourishing, and given time, these basins can be expected to develop emergent, shrubby and open water habitats suitable for use by numerous wildlife species.

The discharge and flood storage functions appear to have been adequately replaced by the mitigation ponds. Although they will provide no resistance to flowing waters during large storm events, they will serve as catchment areas during normal flood occurrences. Only pond 4 will be effective at sediment trapping because it has no outlet. Ponds 2 and 3 will be increasing the silt load to downstream systems until their vegetation becomes well established. Likewise, pond 4 will act as a nutrient trap because it has no outlet, but ponds 2 and 3 have little vegetation to take up nutrients and no organic substrate to foster denitrification.

The wildlife habitat provided by these ponds is likely to be inferior to the mature natural habitats lost to road construction. The vegetation is low-growing and sparse in most areas. There is little visual or physical cover. The silty clay substrate and turbid waters will not encourage the rapid development of aquatic and benthic communities. Over time, however, many of these conditions are likely to improve. Furthermore, small open water ponds are not common in the region, and these will contribute to the local habitat diversity.

These ponds do not now constitute an aesthetic advantage to the region. The bare soils, the regular configurations, the steep-sided islands, the cloudy waters, and the low-growing pioneer vegetation make them look like sites of recent construction. When the vegetation becomes more profuse and diverse, it will cover the bare soils and stabilize the eroding shores. Then these ponds are likely to provide a pleasing aesthetic diversion.

Although the excavated area does exceed by 10 percent the acreage of wetland filled for road construction, the basins are simply open water ponds with narrow wetlands at their perimeters. Wetlands are defined by the presence of vegetation even though they may contain large areas of open water. Where proportions are such that the open water becomes the dominant feature, as at these sites, the area is better described as a pond with a wetland fringe. By this interpretation, the mitigation project replaced much less wetland acreage than was lost to road construction. This too will improve, however, if emergent vegetation becomes established in the shallow water areas.

The mitigation project was particularly notable in that the guidelines in the mitigation plan set forth exceptional and detailed specifications for construction of varied and interspersed wetland habitats, but somewhere between the DOT and the contractors these guidelines were misinterpreted or neglected, and no corrective action was ever taken to implement the plan as designed.

The success of these wetlands might have been hastened and enhanced by the following measures: (1) construction of irregular shorelines and irregularly shaped islands as specified in the plan; (2) construction of more gradual slopes on banks and islands; (3) spreading of topsoil or muck on all disturbed soils; (4) transplanting of emergent plants to stabilize soils soon after construction; (5) dewatering to expose shoreline until vegetation has become established; (6) planting of bushy shrubs and/or trees to form a screen from the road, instead of Lombardy poplar with its linear growth form; (7) detailed instructions to contractors, and careful monitoring of all phases of construction and planting; and (8) commitment to any remedial measures necessary to implement the mitigation design and ensure its success, including such measures as regrading and replanting.

Restoration Sites

15. Sharptown, Maryland

Introduction

Construction of a new bridge for Route 313 over the Nanticoke River at Sharptown required the filling of forested tidal floodplain wetlands for the bridge approach on the north side of the river. To mitigate this loss, the approach to the old bridge was restored to wetland by removing the old road bed fill and planting with tree, shrub and some emergent species. The old bridge approach is located approximately 1000 ft (304.8 m) downstream of the new bridge, within the same freshwater tidal forested wetland. The intent was to bring the grade of the restored wetland area down to the elevation of the existing adjacent swamp. However, the sand and gravel old road bed was not completely removed and the crown of the road was left approximately 2 ft (0.6 m) above the elevation of the adjacent forested wetland. Removal of the length of the old road bed totaled approximately 1 ac (0.4 ha) of attempted mitigation, which was approximately the same area filled for the new bridge.

Mitigation Design

The original road was built in colonial times and probably piled with additional fill over the years as necessary. It is unlikely that any peat was removed and replaced with mineral soil as was the case with the new road. The peat has apparently been compressed under the mineral fill added over the years. Rebound is not a likely explanation for the height of the remaining fill in light of its soil mechanics.[60] The Maryland State Highway Administration (MSHA) construction supervisor said the only contract specification was to remove fill to the elevation of the adjacent undisturbed wetland. This elevation was determined, according to MSHA, by measuring the elevations at the toe of slope of the old roadbed. Measurements were made after fill removal to determine pay quantity but not necessarily to ensure that proper elevations were restored. The raised area constitutes 1/3 to 1/2 of the width of the restored strip. The remaining width (along both edges) appears to have been graded as intended and has standing water at high tide.

No topsoil or peat was incorporated into the restoration site. Surface soils are the remnants of the old fill material, and range from gravelly sands to clayey silts. Patches of bare mineral soil and old road debris (concrete, asphalt, refuse) are common. A broad 100-ft (30.5-m) levee, approximately 4 ft (1.2 m) high, was left at the end of the mitigation site near the Nanticoke River. Rock riprap was placed at the river's edge. This berm was possibly intended to reduce the possibility of erosion of the wetland restoration, but it impedes tidal water exchange.

The site was planted with tree and shrub species typical of the adjacent forested and shrub wetlands: red maple (*Acer rubrum*), green ash (*Fraxinus pensylvanica*), seaside alder (*Alnus maritima*), silky dogwood (*Cornus amonium*), buttonbush (*Cephalanthus occidentalis*), winterberry holly (*Ilex verticillata*). Switchgrass (*Panicum virgatum*) was seeded throughout.

Removal of the old road bed and planting were completed in the spring of 1987. There are no environmental reports that discuss the goals of this project or follow up studies that we know of. There are plans drawn for the planting project, however it is not clear to what extent these plantings were accomplished. An attempt was made to reconstruct this information and inventory plant survival during the site visit.

Site Descriptions

General

The Nanticoke River flows southwest through the flat Atlantic Coastal Plain of south central Maryland's Eastern Shore to Tangier Sound and the Chesapeake Bay. These waters originate in extensive forested swamps and agricultural flatlands. There are broad expanses of tidal marsh on the lower reaches of the river. This area represents one of the least developed major river valleys in Maryland. The longest unbroken pine forest on the peninsula occurs along this corridor. The river and extensive wetlands are important for migratory birds and several rare plant and animal species. The Sharptown area is significant for sport fishing for largemouth bass, striped bass and white perch. The river and its tributaries are nurseries for many freshwater anadromous and semi-anadromous fish species. The lower Nanticoke is considered to be one of the most important areas in Maryland for spawning and production of striped bass. This section of the river is also important for oyster cultivation with 1,630 ac (660.2 ha) identified as shellfish areas.

Mitigation

The mitigation site was evaluated as an impact area (IA) within the natural forested floodplain wetland (AA). The IA is the 1 ac (0.4 ha) area where the old road bed was restored to wetland (figure 25). The goal of removing the old road bed to the elevation of the surrounding wetland was not completely attained, leaving a raised crown (approximately 2 ft (0.6 m) above the natural wetland) of the sand, gravel, and bits of pavement still evident. The dominant hydrologic connection is with Mill Creek to the south which floods into the mitigation wetland at high tide. A berm separates the mitigation wetland from the river.

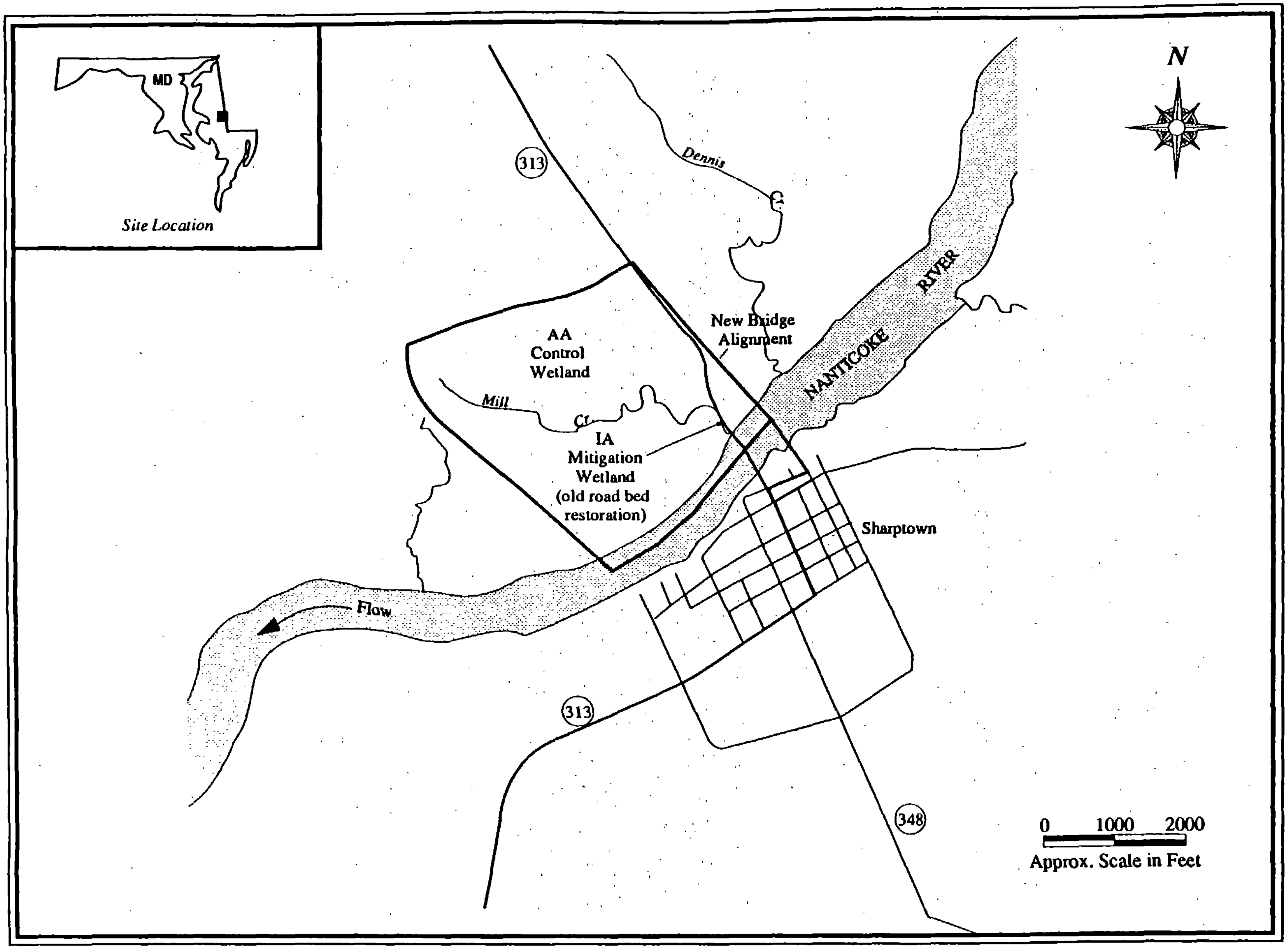


Figure 25. General location of mitigation and control wetlands, Sharptown, Maryland.

A detailed planting plan exists but it is unclear to what extent this was carried out. Survival of the tree and shrub plantings were tallied during the field visit. The results are given in table 1. The planting plan indicated that several emergent species were also planted, but there was no evidence of these. They may have blended into the natural vegetation which has volunteered on the site. Willows (*Salix spp.*), buttonbush, and chokeberry (*Pyrus arbutifolia*) have volunteered throughout the site. Common herbaceous species include cattail (*Typha augustifolia*), sedges (*Carex spp.)*, sweetflag (*Acorus calamus*), switchgrass, and jewelweed (*Impatiens capensi*). A complete species list can be found in volume II.

Table 1. Shrub and tree plantings at the mitigation site tallied during site visit.

Scientific Name	Common Name	Total Plants Found	Percent Survival
Acer rubrum	red maple	57	57
Chamaecyparis thyoides	Atlantic white cedar	73	24
Fraxinus pennsylvanica	green ash	56	90
Alnus maritima	seaside alder	100	49
Cornus amomum	silky dogwood	35	68
Nyssa sylvatica	black gum	19	0
Cephalanthus occidentalis	buttonbush	20	75

Control

The control site used for comparison was the undisturbed forested floodplain wetland adjacent to both the new bridge approach and the mitigation (old road bed removal). Following WET 2.0 instructions for fringe wetlands, it was delineated to include the Nanticoke River to the center of its channel. Typical of the extensive wetlands bordering this section of the Nanticoke there is an emergent zone of variable width at the river edge. In our area this zone is approximately 100 to 300 ft (30.5 to 91.4 m) wide and vegetated by a dense stand of sweetflag (*Acorus calamus*). Other plants along the edge of the river and the numerous creeks are spatterdock (*Nuphar advena*), cattail (*Typha angustifolia*) and arrow arum (*Peltandra virginica*). Beyond the emergent marsh zone is a wide expanse (approximately 3500 ft [1066.8 m]) of deciduous forested floodplain wetland extending to the upland transition to agricultural fields and upland forest. Red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), American holly (*Ilex opaca*) and sweet bay (*Magnolia virginiana*) are the codominant species growing on root mounds developed on the deep (>6 ft [>1.8 m]) humic peat substrate. A diverse shrub understory includes: southern arrowwood (*Viburnum dentatum*), winterberry (*Ilex verticillata*), swamp azalea (*Rhododendron viscosum*), highbush blueberry (*Vaccinium corymbosum*) and several other species. Common herbaceous species include jewelweed (*Impatiens capensis*), royal fern (*Osmunda regalis*), cinnamon fern (*Osmunda cinnamomea*) and sensitive fern (*Onoclea sensibilis*). A complete species list can be found in volume II. The areas between the root mounds of the trees have standing water. Normal tidal fluctuation within the floodplain forested wetland is approximately 1 ft (0.3 m) in elevation. Much of this is probably ground water back up. There are several creek channels but the floodplain forest does not appear to have tidal channels.

The watershed of the control AA was delineated in accordance with WET 2.0 guidelines. It includes the watershed of the Nanticoke upstream of the AA, an area of 390 mi^2 (1010.1 km^2) of wetlands, agricultural fields and forests. This area is generally flat. Soils with slow infiltration rates are predominant so the precipitation run-off can be fairly rapid. The major non-point source of pollution is from agricultural operations.

The service area of the control and mitigation wetlands is designated as the Nanticoke River to 2-mi (3.2-km) downstream. The watershed of this service area is approximately 480 mi^2 (1243.2 km^2) and is characterized by the same land use as the watershed of the assessment area, i.e., agriculture, forestry and wetlands.

Methods

Field work was conducted at the site on May 2 and 3, 1989. Conductivity was measured in Mill Creek. The mitigation and control wetland areas were visited and photodocumented, and general observations made regarding dominant vegetation, vegetation density, morphology and hydrologic connection. WET 2.0 and Hollands-Magee wetland evaluation model data was collected for the control (AA) and mitigation (IA) areas. On-site interviews were conducted with representatives of MSHA. Other information sources included MSHA site plans and the Route 313 Bridge Access Channel Environmental Assessment along with soil surveys, NWI maps, and topographic maps.[61]

Functional Analysis

WET 2.0 and Hollands-Magee evaluation results are shown in appendix A.

Summary

The primary goal of the Sharptown mitigation project was to restore an old road bed to the natural condition of the surrounding floodplain forest. This was attempted by excavation and partial removal of the old road bed and the planting of tree and shrub species which would eventually develop into a forested wetland similar to those in the surrounding forest wetland.

The attainment of this goal was obstructed by the incomplete removal of the old road bed to the elevation of the natural wetland. The center of the road was left too high, and sand, gravel and bits of pavement remain. The overall survival rate for plantings, however was reasonably good: approximately 75 percent according to the tally. Volunteer willows, chokeberry and several herbaceous species have also revegetated the site to some degree. With time the difference in vegetation type will soften somewhat and blend into the surrounding natural floodplain wetland. Indeed creating a forested wetland by total removal of the road substrate and replacement with humic peat may have been impossible to accomplish because of the unconsolidated nature of the substrate. The development of the natural tree root mounds and a natural humic substrate takes decades to hundreds of years and may never occur on much of this site.

The wetland functional analyses indicate that with the exception of some minor and obvious differences such as the substrate and separation of the mitigation wetland from the river by a berm and riprap evidently left to protect the tree planting from erosion, the WET 2.0 results indicate the same wetland functions occur as in the surrounding natural wetland. This is due to the small narrow and linear nature of the mitigation wetland enclosed within the large and diverse natural (control) tidal wetland system.

Attention to several measures would have made this project more successful: (1) Monitoring of the road bed excavation by MSHA personnel; (2) excavation to an elevation more closely approximating that of the adjacent natural wetland; (3) commitment to remedial measures, as necessary, to correct errors in excavation or grading.

16. Willapa Bay, Washington

Introduction

The City of Hoquiam is located on the north shore of Gray's Harbor in southwestern Washington (figure 26). Construction of the SR 109 bypass in West Hoquiam involved the filling of 5.1 ac (2.0 ha) of clearcut riparian wetland bordering the Little Hoquiam River. A Memorandum of Agreement between the Washington State Department of Transportation (WSDOT), the Washington Department of Game (WSDG), and the U.S. Fish and Wildlife Service (USFWS) called for numerous on-site mitigation measures, and the restoration of a 2 ac (0.8 ha) portion of estuarine wetland at a WSDOT waste disposal site on Willapa Bay, 65 mi (104.7 km) south of Hoquiam. An Army Corps of Engineers wetland fill permit was issued with no mitigation requirements. The goals of the mitigation restoration were not clearly stated in the project's Memorandum of Agreement, but appeared to be the restoration of general wetland values with particular emphasis on wildlife and fisheries habitat. In project correspondence and letters of agreement, there was no discussion of replacement ratio by acreage or function, nor any discussion of or rationale for out-of-kind mitigation.

In addition to the problem of wetland loss, the main environmental concern raised by the road project was the obstruction of wildlife access to the Little Hoquiam River and the adjacent wetland. The road alignment traverses at midslope a hillside bordering the riparian wetland. Along a 1.5-mi (2.4-km) stretch the roadway crosses at least nine draws that drain into the wetland from the hillsides to the north (figure 26). At this location the road was expected to create a significant barrier to elk, deer, native cats, and other wildlife known to use wetland and river. The interagency Memorandum of Agreement specified the following on-site mitigation measures: (1) construction of two game crossings under SR 109; (2) a 1470-ft (448.1-m) bridge spanning the Little Hoquiam and a broad wetland area, to reduce wetland filling and allow free movement of animals along the River; (3) roadway fill slopes of 2:1 or greater, and fencing along the entire road length to discourage human access to the wetland; and (4) individual culverts at each draw to allow unimpeded storm and tidal flows.

The Willapa Bay estuarine marsh restoration project involved breaching a dike to an adjacent slough and excavating waste material fill to create a 2-ac (0.8-ha) intertidal lagoon. A J-shaped wetland was excavated to an elevation that permitted daily tidal flushing. The excavated area provided a secondary slough connection to a preexisting tidal pool located at the toe of the "J" (figure 27 and 28). This pool had formerly been fed only through a breach in the dike surrounding a defunct oyster impoundment. No muck or topsoil was spread in the excavated area. No plantings were done initially. One year after the grading was completed some saltmarsh bulrush (*Scirpus*

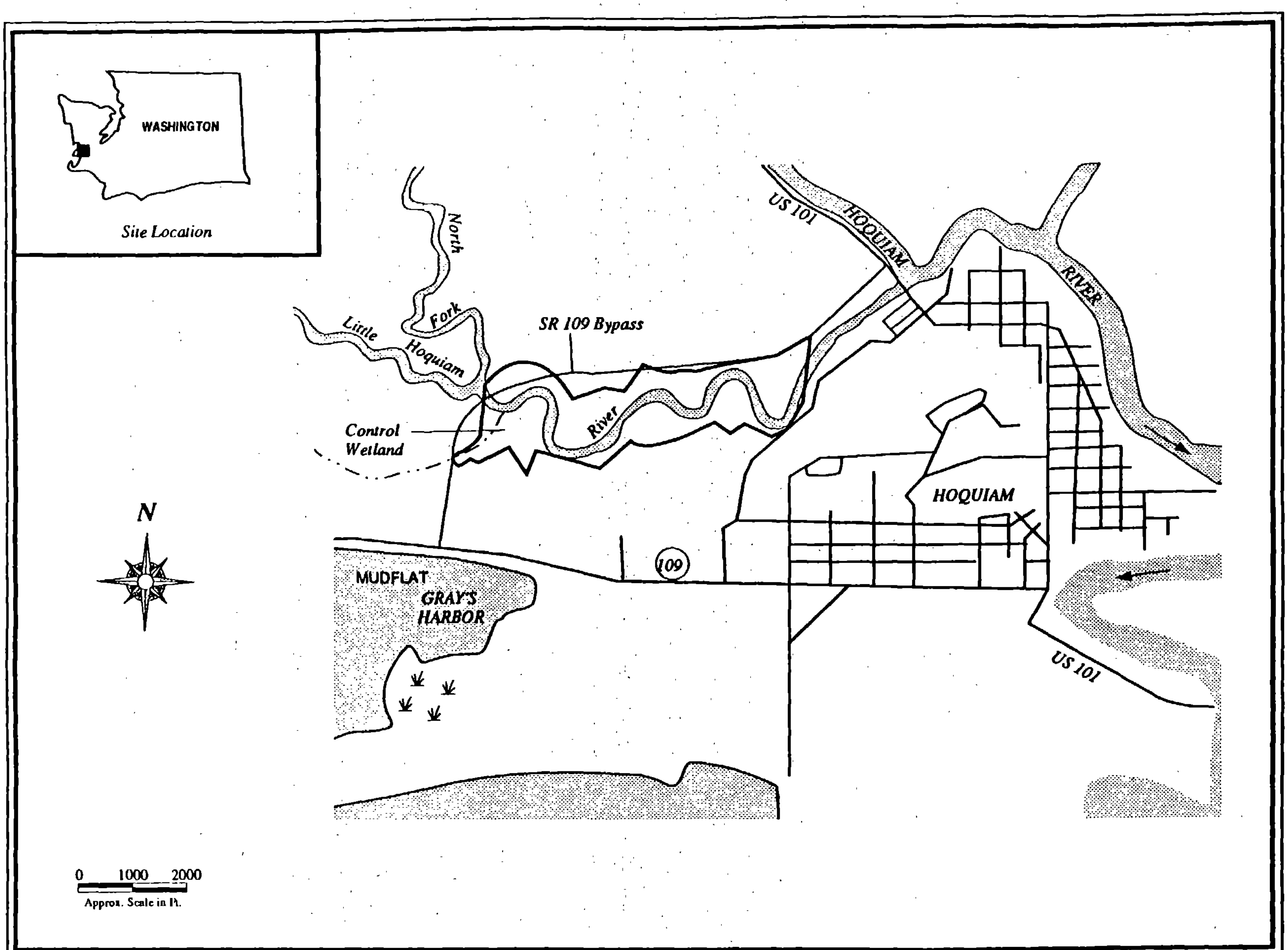


Figure 26. Location of Hoquiam control wetland, Hoquiam, Washington.

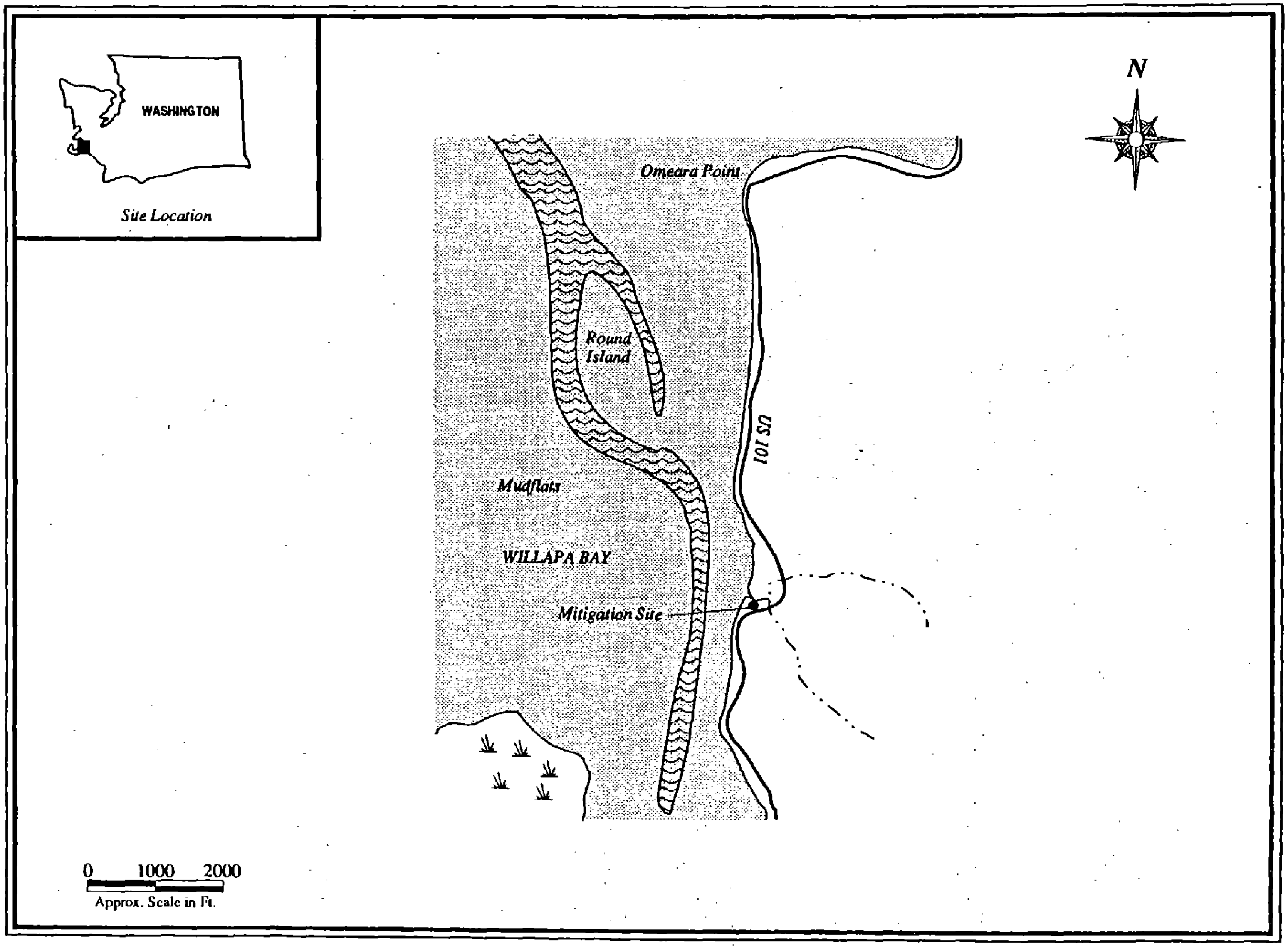


Figure 27. Location of Willapa Bay mitigation wetland, Ilwaco, WA.

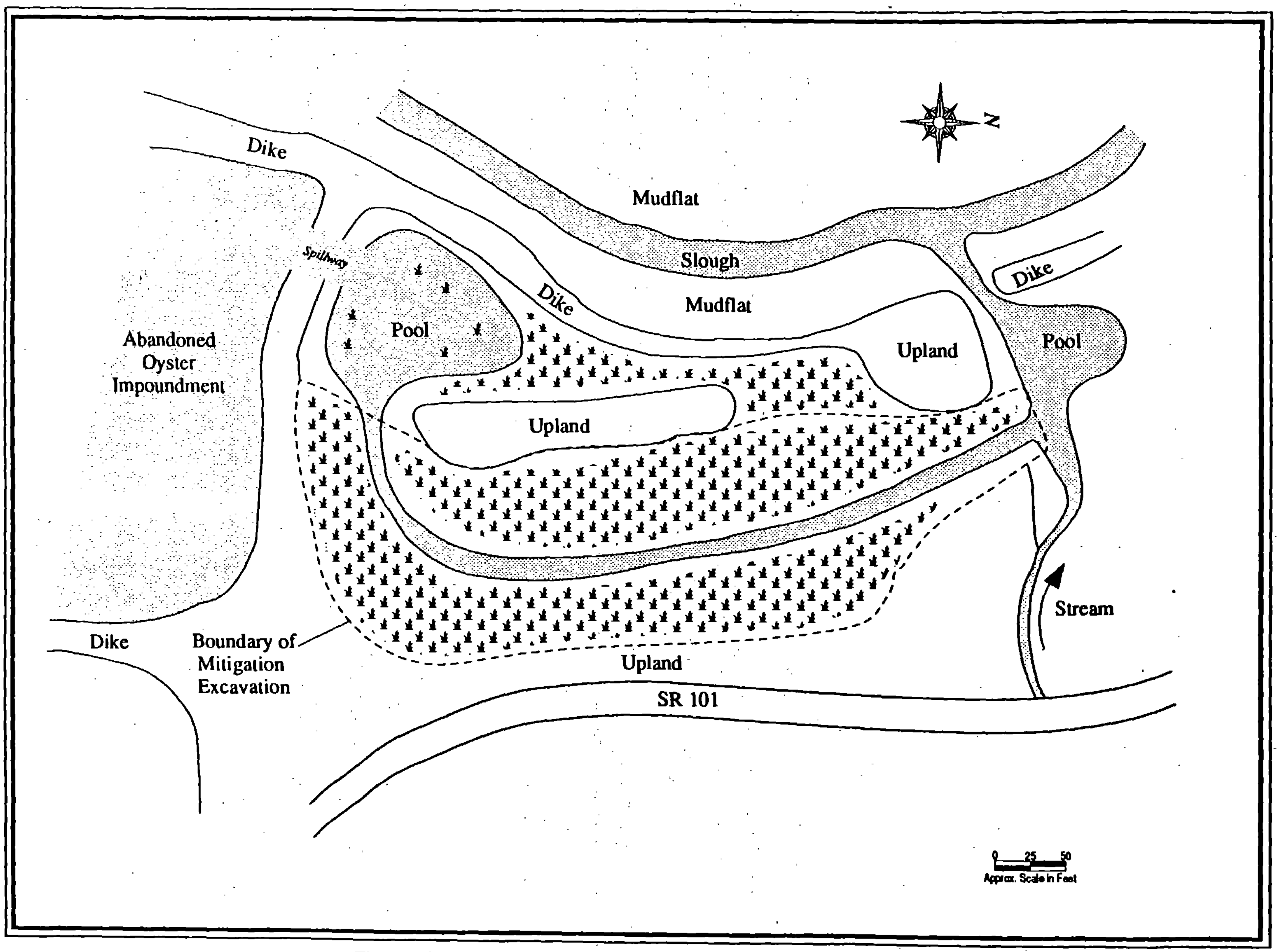


Figure 28. Willapa Bay mitigation site, Ilwaco, Washington.

maritimus) and spikegrass (*Distichlis spicata*) were transplanted from a nearby marsh to areas where vegetation was especially poor. The grading was completed in the spring of 1985. The planting was completed in the spring of 1986. WSDOT monitors all of its wetland mitigation sites. The fall 1988 monitoring work included collection of transect data on vegetation, soils, and invertebrates; water quality sampling; and incidental wildlife observations. Photographs were taken at permanent stations.

The goal of the mitigation project was to restore a filled area to estuarine wetland habitat, and to thus enhance its value for fisheries and wildlife. The participating agencies were not attempting to replace in function, type, or acreage, the wetland lost to construction of SR 109 in Hoquiam. The focus of the present study, however, is a comparison of the functional capability of the impacted wetland with that of the mitigation wetland, without regard for the actual mitigation objectives.

Site Descriptions

General

The Hoquiam impact site and the Willapa Bay mitigation site are located in the southwestern coastal region of Washington. The landscape is hilly and forested. Soils in the region are derived from diverse parent materials. Pleistocene era glaciers reached as far south as northeastern Gray's Harbor, and deposited till and outwash. Soils in the mountains were formed in basalt, sandstone, shale, and siltstone; soils on coastal terraces were derived from sedimentary rock, silt, clay and sand. Floodplain soils are from recent, local alluvium.

Since the late 1800's the regional economy has been dominated by the lumber industry. Forestry-related land uses still predominate, although lumbering has declined in recent decades due to timber depletion. Second growth western hemlock/Sitka spruce (*Tsuga occidentalis/Picea sitchensis*) forest communities constitute the primary vegetative cover. Fishing, shellfishing, tourism and farming are the other economic staples. Most of the farmland is in pasture or hay, but there is also some cultivation of grains and cash crops. Summers in the region are cool and dry; the winters are mild, wet, and cloudy. The average annual temperature range is very narrow, 34 to 72°F (22°C). The annual average annual precipitation is 65 to 85 in (165.1 to 215.9 cm) on the immediate coast, and 100 in (254.0 cm) in the hills.[62] Snowfall is very light along the coast, and generally melts soon after falling. Snowfall increases with elevation and distance from the coast.[63]

Mitigation

The mitigation site is located in the Town of Ilwaco on the southeastern shore of Willapa Bay. The site had been used for many years by WSDOT as a waste disposal area for road fill material, asphalt, concrete and miscellaneous debris. According to the SCS Pacific County Soil Survey, the site was underlain by Ocosta silty clay loam, the typical substrate for Willapa Bay saltmarshes and mudflats. For purposes of WET 2.0 analysis, the mitigation assessment area was delineated as the approximately 2.5-ac (1.0-ha) wetland that includes the restored wetland area, the preexisting tidal pool, and an area of adjacent high marsh wet meadow (figure 28). During construction of the mitigation area, the fill was not excavated down to the pre-fill soil, so remnant fill material constitutes the present wetland substrate. It is gravelly or sandy soil with no organic matter except that contained in the recently deposited silt. Vegetation densities vary greatly throughout the wetland. Areas of gravel, cobble, or coarse sand are poorly vegetated. The best vegetative cover is in the low marsh zones along the channel where there is the greatest frequency and duration of flooding, and the greatest silt deposition (1 to 3 in [2.5 to 7.6 cm]). Higher marsh areas with a significant medium sand component are also well vegetated.

The dominant species in the wetland are tufted hairgrass (*Deschampsia caespitosa*), pickleweed (*Salicornia spp.*), spikegrass (*Distichlis spicata*), creeping bentgrass (*Agrostis stolonifera*), and saltmarsh bulrush (*Scirpus maritimus*). Eelgrass (*Zostera marina*) and widgeongrass (*Ruppia maritima*) grow in the channel. A more complete species list is presented in volume II. The upland islands encircled by the wetland contain gravel and coarse sand, asphalt and other debris. They supported grasses and forbs along with alder and spruce saplings. Elk and deer track, and a kingfisher were observed at the mitigation site during the field visit. WSDOT has reported use of the wetland by northern harrier, red-tailed hawk, killdeer, glaucous-winged gull, semi-palmated plover, and song sparrow.

The watershed of the mitigation site was identified as the watershed of Willapa Bay, following WET 2.0 instructions for delineation of watersheds for non-fringe tidal wetlands. This is an approximately 750 mi^2 (1942.5 km^2) area of unglaciated forested, hilly terrain. The geologic parent material is predominantly volcanic bedrock at varying depths, overlain by weathered rock and, at lower elevations, beach sands, alluvial soils, and terrace deposits of clay, silt, sand, and gravel.[64,63] Most of the upland soils are deep, well-drained silt loams. The vegetative cover is predominantly conifer forest (western hemlock, Sitka spruce, western red cedar).

The service area for the mitigation site was identified according to WET 2.0 instructions for small tidal wetlands, as the portion of Willapa Bay within 1000 ft (305 m) of the mitigation wetland's outlets. Willapa Bay is a large (100+ mi^2 [259.0 km^2]), shallow bay with very extensive mudflats and much smaller areas of saltmarsh. Over 30 percent of the original wetlands on the Bay have been lost to diking or filling for agricultural use.(62) It is an important migratory waterfowl area, supporting large concentrations of black brant, Canada goose, American widgeon, canvasback, scaup, bufflehead, scoter, loons, grebes, mergansers, comorants, and many species of shorebirds.(65) Willapa Bay may be the most important oyster production area on the entire west coast. Almost 20 percent of the bay area is used for oyster production, mostly in the northern and western portions. There are also large crab and clam fisheries. Oyster populations have declined since their peak in 1946. High mortalities have been attributed to high nutrients which initiate toxic phytoplankton blooms; tannic acid and lignin from log processing operations; and siltation. Large numbers of chum, silver, chinook, and coho salmon are caught in the bay and tributary streams.

Salinities in the bay are in the range of 18 to 28 ppt. The water quality is generally considered good. There is little heavy industry in the immediate watershed. The greatest threats to water quality are tannin and lignin leachates from wood processing, siltation from logging operations, agricultural and forestry pesticides.(62) In 1978 to 1979 surface water samples from two streams entering the northern part of the Bay, concentrations of organic chemicals such as Aldrin, DDD, DDT, and Dieldrin, exceeded EPA standards for protection of marine life. Similar concentrations are likely to occur in other inlet streams around the bay. In addition, the pesticide Sevin is applied to portions of the bay to combat ghost and mud shrimp who threaten commercial oyster beds. Sevin is also toxic to crabs and other organisms, but is not very persistent.

The service area within 1000 ft (305 m) of the mitigation site contains an abandoned oyster lagoon, mudflat, small slough channels, and a portion of the primary channel (unnamed) draining this part of the bay. That channel is approximately 200 ft (61.0 m) wide and 6 ft (1.8 m) deep at this location. There is some algal and sparse emergent growth within the oyster impoundment, but otherwise the service area is substantially unvegetated. Slough channels in the bay reportedly support eelgrass (*Zostera*) which attracts large numbers of black brant. The slough channels within the service area were inaccessible for inspection. American widgeon, gadwall, and mallard were observed using the area during the field work. WSDOT reports observations of great blue heron, northern pintail, green-winged teal, widgeon, bald eagle, western sandpiper, and Caspian tern in the fall of 1988.

Control

For purposes of the WET 2.0 analysis, the control was identified as the 170-ac (67.2-ha) riparian wetland adjacent to the SR 109 bypass alignment, and occupying both sides of the Little Hoquiam River. Following WET 2.0 instructions for assessment area delineation, its southwestern boundary was identified at a topographic constriction on a small tributary, and its northwestern boundary was drawn at the confluence of the Little Hoquiam with the North Fork (figure 26).

The control wetland contains numerous parcels, variously owned by the City of Hoquiam, Gray's Harbor County, and private landholders. For this study it was assessed in its estimated condition prior to construction of the SR 109 bypass. Much of the wetland located south of the river had been clearcut in the 1970's; the area north of the river was cut in the early 1980's. Prior to cutting, both areas had been dominated by red alder (*Alnus rubra*) and big leaf maple (*Acer macrophyllum*) with a substantial component of western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*). Sedges (*Carex* spp.), salmonberry (*Rubus spectabilis*), skunk cabbage (*Lysichitum americanum*), vine maple (*Acer circinatum*), and devil's club (*Oplopanax horridum*) were common in the understory.[66] Now the wetland is characterized by very rough, hummocky terrain with well-spaced saplings and shrubs, and dense herbaceous cover. The ground cover is predominantly slough sedge (*Carex obnupta*), skunk cabbage, water-parsley (*Oenanthe sarmentosa*), lady fern (*Athyrium filix-femina*), and soft rush (*Juncus effusus*). Young red alder, western hemlock, and Sitka spruce, along with vine maple, blueberry (*Vaccinium ovalifolium*), salmonberry, spiraea (*Spiraea douglasii*), and salal (*Gaultheria shallon*) constitute most of the shrub layer. A few mature spruce, hemlock and alder remain standing. A more complete species list is presented in volume II.

According to the SCS Soil Survey of Gray's Harbor County Area, the control wetland is underlain by Ocosta silty clay loam, a very deep, poorly drained alluvial soil common on river floodplains and mudflats in the vicinity of Gray's Harbor.[63] Soil borings taken during the September field visit showed a 4-in (10.2-cm) surface layer of silt loam with a high organic content; over 8 in (20.3 cm) of mottled silty clay loam; over a dense, gray, silty clay.

This reach of the Little Hoquiam is brackish water tidal, but apart from a narrow emergent band along the river channel supporting Lyngbye's sedge (*Carex lyngbyei*), there is no evidence of saltwater intrusion into the wetland. Flooding during the heaviest storms undoubtedly carries tidal waters into much of the wetland, but its dilution with freshwater and its short residence time prevents it from damaging or altering the freshwater-adapted vegetation.

The Little Hoquiam River is meandering and slow here with a muddy bottom and an average channel width of 60 to 100 ft (18.3 to 30.5 m). Logging and agriculture in the watershed contribute to a heavy silt load that has covered any gravel areas that might otherwise have been suitable for fish spawning. The river is used by numerous anadromous fish species, but only for transportation and rearing grounds: chinook and coho salmon, chum, sea-run cutthroat and steelhead trout. Resident species include rainbow, cutthroat, eastern brooktrout, whitefish, squawfish, dace, shiners, suckers, and mudminnows.[66] The Little Hoquiam provides likely habitat for the Olympic mudminnow, (*Novumbra hubbsi*) a rare endemic species known to occur in a nearby river. It is associated with wetlands along slow-moving streams. Riparian corridors are considered to be very important mudminnow habitat.[67]

Wildlife and signs observed in the control wetland during the field visit include black bear scat, coyote scat, elk track, black-tail deer track, and five river otters. Bald eagles use similar riparian areas in the region and are likely to use this wetland for hunting.[66] Peregrine falcon are known to use Gray's Harbor just downstream.[68]

The control's watershed is approximately 10 mi^2 (25.9 km^2) of low rolling hills on the north shore of Gray's Harbor. Most upland soils in the watershed are silt loams of various origins; some are from sandstone colluvium; some formed in old alluvium on glacial terraces; others formed in alluvium deposited over dense glacial drift which acts like a hardpan. The landscape is substantially undeveloped but it has been subject to much clearcut logging in recent decades. The natural upland vegetation is primarily coniferous (western hemlock, Sitka spruce, western red cedar), with deciduous communities inhabiting disturbed or wetter sites.

The control's service areas were identified as the City of Hoquiam for the floodflow alteration function, and the lowest reach of the Hoquiam river for food chain support. Portions of residential and industrial areas of West Hoquiam lie within the 100-year floodplain of the Hoquiam River, downstream of its confluence with the Little Hoquiam. The Hoquiam River is larger, but otherwise similar in character to the Little Hoquiam. It is expected to support a similar array of anadromous and resident fish.

Methods

Field work for this study was carried out during September 12 through 15, 1989. Plant species lists were compiled as were descriptive notes at each site, along with field information necessary for WET 2.0. Hollands-Magee evaluations were not conducted because those models are not designed for saltwater tidal wetlands. Incidental observations of wildlife and sign were noted. In the Little Hoquiam River, pH was measured on September 12 during ebb tide, approximately 1 hr before slack water, and at mid-tide (flood). At the mitigation site, pH was measured on September 15 near the outlet at low tide. General features of the impact and mitigation sites were recorded on videotape, and on 35-mm slides.

Wetland scientists met with WSDOT staff at both sites and at the WSDOT office in Olympia. General regional information was obtained from numerous other sources including the Washington Department of Fish, The Washington Department of Ecology, the Willapa National Wildlife Refuge, the Washington Non-game Wildlife Program, the Soil Conservation Service, the U.S. Fish and Wildlife Service, the Gray's Harbor Regional Planning Commission, and the Gray's Harbor Conservation District. Additional resources included stereo aerial photographs of the impact and mitigation sites, NWI maps, USGS topographic maps, and many documents from the WSDOT project files, including: agency correspondence; the 1980 Biological Assessment of the impact site; the 1981 Environmental Assessment; and the 1989 WSDOT Willapa Bay Monitoring Report.[69]

Functional Analysis

The WET 2.0 analysis and model results for the Hoquiam and Willapa Bay wetlands are presented in appendix A.

Summary

The goal of the mitigation project was to restore a filled area to estuarine wetland habitat, and to thus enhance its value for wildlife and fisheries. The project was to some degree successful at restoring the estuarine wetland. The tidal flushing is adequate and saltmarsh vegetation is developing well in some areas, particularly where daily tides have deposited silt and organic matter. The channel supports eelgrass and widgeongrass, two important fish and waterfowl food species. Areas of coarse sand or coarser substrate, however, have been slow to revegetate. Even after five growing seasons since the grading was completed, much bare soil is still evident. Transplanted bulrushes have formed a small, dense monotypic stand. Transplanted spikegrass has scarcely spread from the transplanted plugs whose row formation is still visible. The wetland is, however, located in a highly productive estuarine system. It is well juxtaposed with mudflats and saltmarshes which get much waterfowl use. It is accessible to waterfowl and fish. Vegetation densities and associated functional capability, are expected to improve over time.

The wetland's development might have been hastened and enhanced by the following measures: (1) excavation to pre-fill soils, if possible; otherwise, deeper excavation with more gradual slopes, to permit daily tidal inundation over a greater area; (2) spreading of muck in the excavated area to promote emergent growth; (3) transplanting of greater numbers of emergents to hasten reestablishment of vegetation.

17. South Beltline, Wisconsin

Introduction

The relocation of Madison's south beltline (U.S. Highway 12 and 18) necessitated filling 22 ac (8.9 ha) of an extensive wetland system consisting of shrub-swamp, sedge meadow, shallow and deep marsh, and open water along the Yahara River in the vicinity of Upper Mud Lake (figure 29). Since the turn of the century areas of wetland along the northern edge of Upper Mud Lake Wetland in the vicinity of the relocated highway corridor had been filled. The mitigation plan involved restoring 20 ac (8.1 ha) of filled former wetlands, enhancing 5 ac (2.0 ha) of existing degraded wetlands by creating wildlife ponds and preserving 122 ac (49.4 ha) of wetlands through placement into public ownership.

Planning for the south beltline began in the 1960's and drew the interest of citizens and organizations concerned with protecting the important Upper Mud Lake wetland system. The Wisconsin Department of Transportation (WDOT) made several major design adjustments over the years to reduce wetland impacts. The alignment was shifted north toward the edge of the wetland reducing the area of wetland impact. Median width was reduced from 40 to 24 ft (12.2 to 7.3 m) and interchanges were designed as compact diamond-types. The bridge spanning the Yahara River was lengthened to span more of the adjacent wetlands. As a result, 0.5 mi of the 1.5-mi (2.4-km) roadway section through the wetland is raised on concrete pillars, instead of having been constructed on fill. In response to public comment on the 1983 Draft Environmental Impact, WDOT in cooperation with the Wisconsin Department of Natural Resources (WDNR) and the U.S. Fish and Wildlife Service (USFWS), developed wetland mitigation plans, making final approval of the project possible. On May 2, 1984, the U.S. Army Corps of Engineers accepted the mitigation plan.[70]

Mitigation Design

The intent of the mitigation plan was to restore the sedge meadow and shallow/deep marsh communities that occur naturally in the Upper Mud Lake basin by removing overlying fill. The goal set by WDOT was to create high quality wetlands.[71] Wildlife habitat was considered to be a natural benefit of the "quality wetland" objective. Characteristics of high quality wetlands were to include the following:

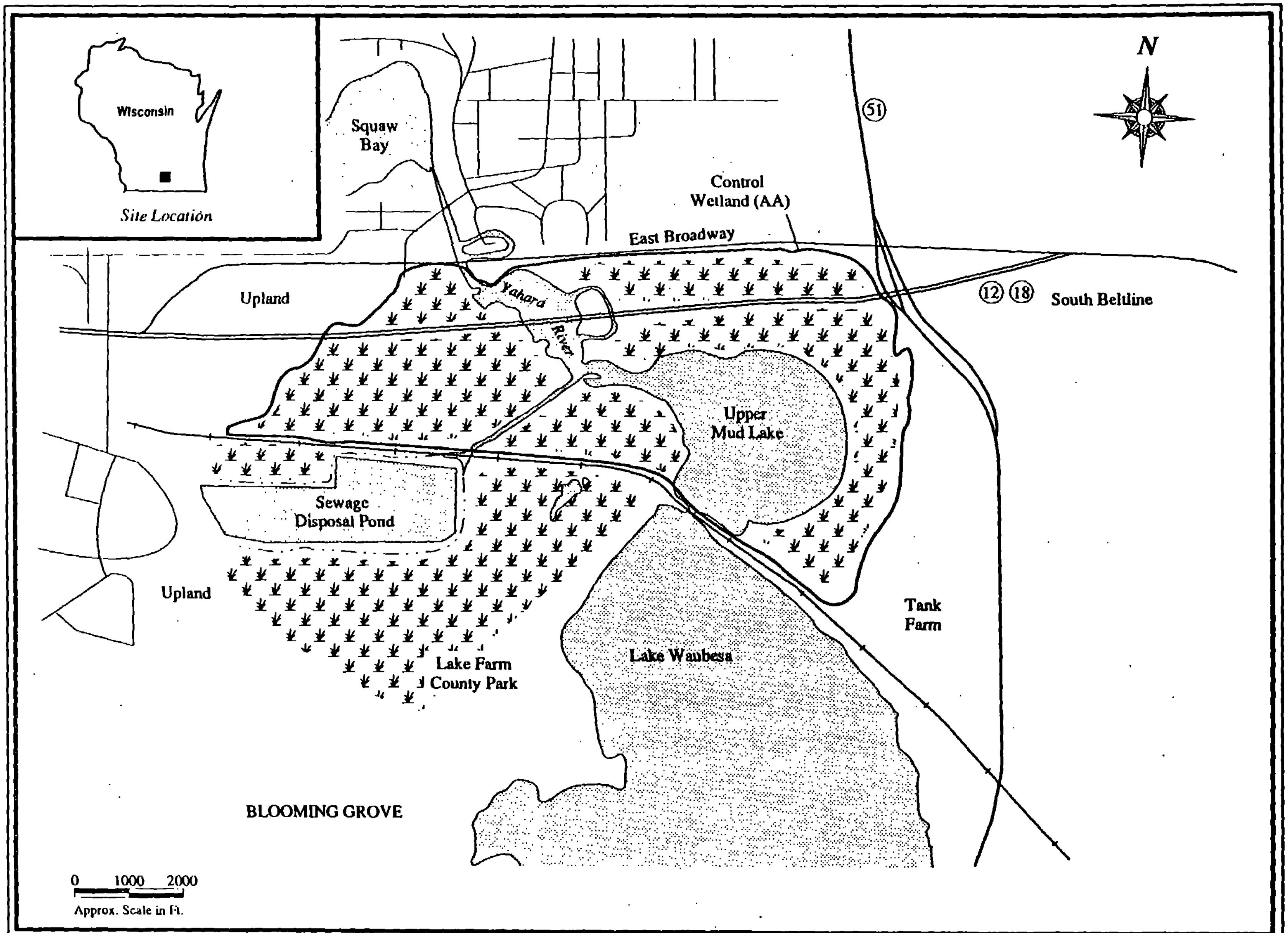


Figure 29. General location of South Beltline control wetland, Madison, Wisconsin.

- High water quality (including lack of silt or excess nutrient input).

- Natural water level cycle.

- Plant and animal species diversity.

- Structural diversity (i.e., mix of tall and short plants, open water and marsh.

- Edge gradation (created by gradual slope).

- Lack of non-native or exotic species.

Proposed elevations, slopes, basin configurations and species lists for the mitigation areas were developed based on preconstruction field studies concerning land use, hydrology, soils and vegetation aspects of adjacent high quality wetlands. It was determined by WDOT that the best way to ensure revegetation of desired species was to dress restored areas with wetland topsoil. This topsoil was obtained from wetland areas that were to be filled for highway construction.

Work began on the first wildlife ponds and restoration areas 1 through 4 in September of 1985. Most of the wetland restoration and marsh excavation for the new road occurred in the fall and winter of 1985 to 1986. Excavated marsh surface was spread on upper elevations in the wetland restoration areas during the winter; wetland rootstock were planted in shallow and deep marsh zones in June 1986. Areas 3A, 3C, 5, 6, and 7 were under construction and planting in early 1988. All work on wetlands was completed in mid-1988 and the highway opened for traffic in December 1988.

Cost for restoring the first 12.5 ac (4.9 ha) of wetland and enhancing 3 ac (1.2 ha) of existing wetland was calculated at $610,000, or $39,000 per acre. This amount includes grading, placement of wetland topsoil, excavating of wildlife ponds and planting costs. It excludes design, real estate and monitoring costs. Construction of the remaining 6.5 ac (2.6 ha) brought the total to approximately 0.75 million dollars exclusive of real estate costs.

Site Descriptions

Mitigation

The mitigation project for the south beltline consisted of several restoration and enhancement areas located along the highway corridor within the Upper Mud Lake wetland (figure 29 and 30). These areas are described below, and with the exception of area 6, collectively comprise the impact area (IA) for the purposes of WET 2.0 functional analysis. Important design and construction aspects along with field observations are described below for each of the seven mitigation areas. A list of dominant species observed in the IA is in volume II.

Area 1 (2.2 ac [0.9 ha]) was an old foundry sand dump located just south of the new Beltline in the north central portion of Upper Mud Lake Marsh. Restoration included the removal of a seven ft layer of foundry sand to the level of the adjacent natural marsh and replacement with salvaged marsh surface from the highway excavation. Three wildlife ponds totalling 1.25 ac (0.5 ha) were excavated in the adjacent wet meadow. Depths ranged from 3 to 6 ft (0.9 to 1.8 m).

The foundry sand had compacted the underlying peat and therefore was not completely removed by excavating to the surface of the adjacent undisturbed marsh. Recent hydrologic studies indicate that the remaining sand causes area 1 to dry out during times of low water to a greater extent than the adjacent natural peat wetland.(71) This is due to the different hydraulic and physical properties of the two materials and is only of concern during extended drought. Surface drying and a shift in species composition could occur because of the narrow capillary fringe zone in sand compared to the large capillary fringe in peat. There is no evidence that this has been a problem yet.

Area 1 was graded nearly level and supports a shallow marsh community with a minor sedge (*Carex* spp.) component. Dominant species observed include cattail (*Typha* spp.), bluejoint grass (*Calamagrostis canadensis*), pale smartweed (*Polygonum lapathifolium*), burreed (*Sparganium eurycarpum*) and arrowhead (*Sagittaria latifolia*).

Area 2 (0.5 ac [0.2 ha]) was also part of the old foundry fill. It is located on the north side of the beltline opposite area 1. The same problem occurred as in area 1 with incomplete removal of the old foundry sand. Area 2 was graded with approximately 30:1 slopes to form a shallow pool (1 ft [0.3m] maximum) in its center. The edges were spread with salvaged marsh topsoil but the center pool--lower in elevation than the source of the topsoil--was planted with roots and tubers of six shallow marsh species (zone 1) including river bulrush (*Scirpus fluviatilis*) and arrowhead.

Dominant species observed in area 2 were burreed, arrowhead, reed canary grass (*Phalaris arundinacea*), bluejoint grass and aquatic sedge (*Carex aquatilis*). With the exception of burreed and arrowhead, planted species were not evident. Growth from the marsh topsoil has resulted in a sedge-bluejoint

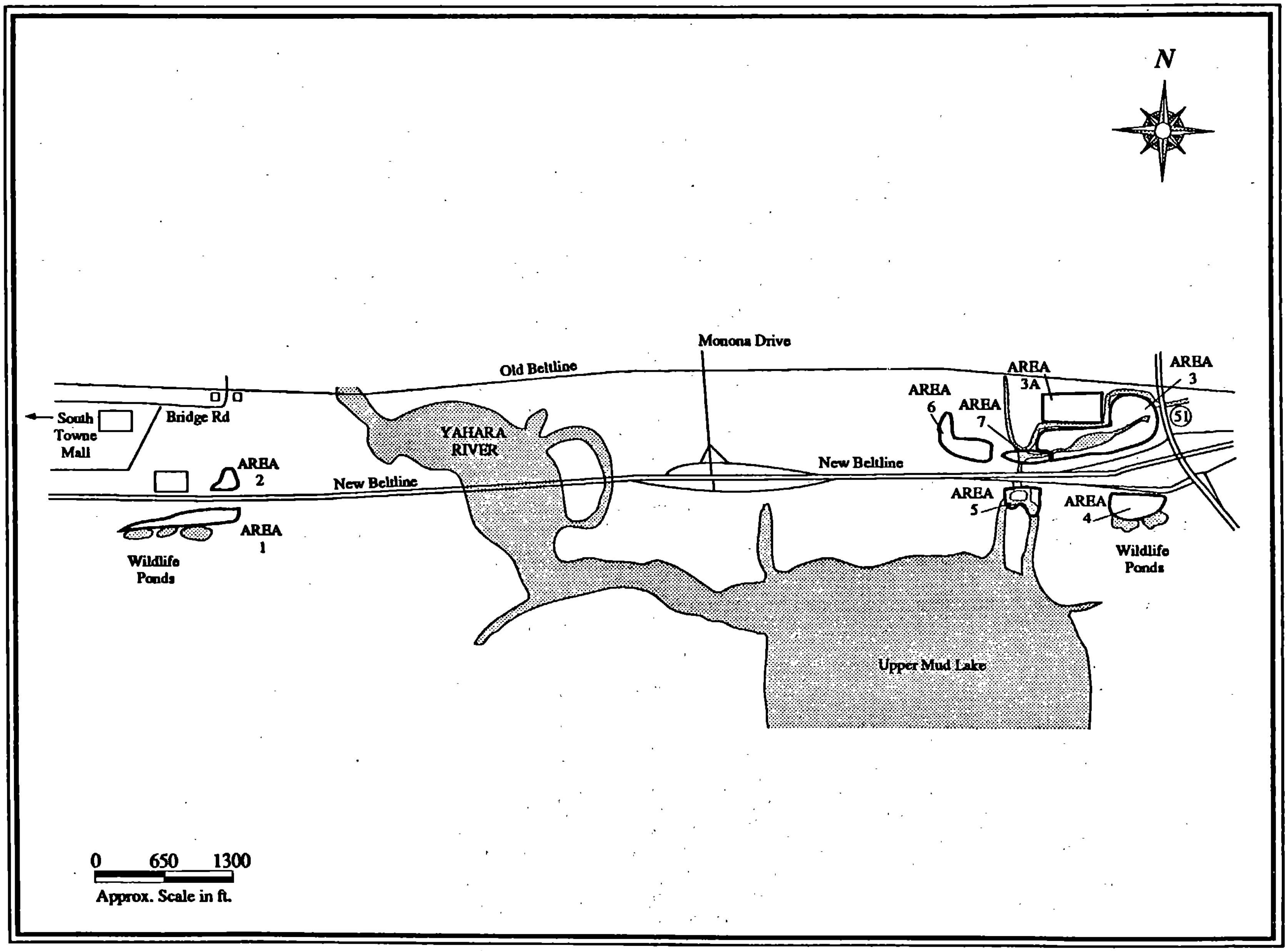


Figure 30. South Beltline wetland restorations, Madison, Wisconsin.

meadow that is common in the natural marsh. However, an adjacent disturbed area dominated by reed canary grass (an agressive non-native) is invading this small area.

Area 3 (7.6 ac [3.1 ha]) was constructed by removing fill from a miniature golf course which was developed on sandy fill placed in the 1960's. An open water pond of approximately 3 ac (1.2 ha) surrounded by deep shallow emergent marsh zones which grade into a sedge meadow wetland was designed for this area. Salvaged marsh surface was spread in the areas intended for sedge meadow; the other areas (zones 1 and 2) were planted. A list of species planted is included in tables 2, 3 and 4. The pond has an outlet to Yahara Branch and thence to Upper Mud Lake. The Yahara Branch was routed around area 3 to avoid the possibility of sedimentation of the wetland from upstream agricultural and paved areas.

The salvaged marsh surface on this area and on the other areas where it was spread (areas 1 through 4) resulted in dense wetland vegetation development from the abundant source of seeds and rhizomes. The eastern end of area 3 is dominated by spike rush (*Eleocharis* spp.) and supports significant amounts of aquatic sedge (*Carex aquatilis*) and bluejoint grass (*Calamagrostis canadensis*) which were the codominant species in the natural sedge meadow which served as the source for the "mulch" material.[72] The western end of area 3 was graded about 6 in (15.2 cm) too low for sedge meadow. As a result, the dominant species is cattail which probably developed from the seed bank.

The zone 1 and 2 plantings were not highly successful. Excessive water depths and herbivory are the apparent causes. However, other species have colonized these areas including bullhead lily (*Nuphar variegatum*) and curly pondweed (*Potamogeton crispus*). Duckweed (*Lemna minor*) is the most common cover.

Area 4 (2.3 ac [0.9 ha]) was an extension of the old fill for the miniature golf course that extended to the south side of the new beltline. The fill was removed and a shallow bowl was graded and spread with wetland topsoil. A low berm around area 4's perimeter separates it from the adjacent natural marsh and two excavated wildlife enhancement ponds similar to those adjacent to area 1. The berm was original ground retained to provide woody cover for wildlife using the pond. The inside slope of the berm was planted to common reedgrass (*Phragmites communis*) and prairie cordgrass (*Spartina pectinata*).

The area treated with marsh topsoil was observed to have developed a healthy stand of burreed with smaller amounts of cattail, aquatic sedge and lake sedge (*Carex lacustris*). However, two high areas toward the western edge are being colonized by cottonwood (*Populus deltoides*) that is of sapling size. High marsh vegetation, planted at 6-ft (1.8-m) intervals had not spread as

Table 2. Wetland species planted for phase 1 mitigation: south beltline, Madison, Wisconsin.

Common Name	Scientific Name
	Zone 1: Shallow Marsh (0.5 to 1.0 ft of water)
Burreed	*Sparganium eurycarpum*
Duck Potato	*Sagittaria latifolia*
Marsh Smartweed	*Polygonum muhlenbergii*
Pickerel Weed	*Pontederia cordata*
River Bulrush	*Scirpus fluviatilis*
Sweet Flag	*Acorus calamus*
	Zone 2: Deep Marsh (1 to 2 ft of water)
Deepwater Duck Potato	*Sagittaria rigida*
Hardstem Bulrush	*Scirpus acutus*
Sago Pondweed	*Potamogeton pectinatus*
White Water Lily	*Nymphaea tuberosa*
Wild Celery	*Vallisneria spiralis*
	Zone 3: High Marsh (0 to 1.5 ft above water table)
Common Reedgrass	*Phragmites communis*
Prairie Cordgrass	*Spartina pectinata*

Table 3. Wetland species planted for phase II mitigation: south beltline, Madison, Wisconsin.

Species	Common Name	Zones*
Carex lacustris	lake sedge	H, M
Carex stricta	tussuck sedge	H, M
Carex hystericina	sedge	H, M
Calamagrostis canadensis	bluejoint grass	H, M
Spartina pectinata	prairie cord grass	H
Iris shrevei	blue flag iris	H
Sparganium eurycarpum	burreed	M, L
Scirpus fluviatilis	river bulrush	M, L
Scirpus validus	soft stem bulrush	M, L
Sagittaria latifolia	duck potato	M, L
Sagittaria rigida	arrowhead	L
Scirpus acutus	hard stem bulrush	L

* H = high marsh, M = medium or shallow marsh, L = low or deep marsh

Table 4. Wetland species seeded on phase II mitigation: south beltline, Madison, Wisconsin[1]

Species	Common Name
Annuals	
Impatiens biflora	jewelweed
Polgonum lapathifolium	willow weed
Polygonum pensylvanicum	smartweed
Perennials	
Angelica atropurpurea	angelica
Asclepias incarnata	marsh milkweed
Aster novae-angelica	New England aster
Calamagrostis canadensis	bluejoint grass
Eupatorium maculatum	joe-pye weed
Eupatorium perfoliatum	boneset
Polygonum coccineum	water smartweed
Polygonum hydropiperoides	mild water pepper
Pycnanthemum virginianum	mountain mint
Rumex orbiculatus	marsh dock
Scirpus cyperinus	woolgrass
Thalictrum dasycarpum	meadow rue

[1]Seeding rate = 2 lb/ac; seeded on high and medium marsh zones

intended, resulting in colonization by weedy species such as reed canary grass, nettle (*Urtica dioica*), and thistle (*Cirsium* spp.). Common reedgrass may have been an inappropriate species for this zone as it is most commonly observed in shallow marshes in Wisconsin.

Areas 5 through 7 including 3A and 3C were constructed during the second phase of the mitigation wetland development. These areas were completed in May 1988. In most cases, these areas were excavated down to preexisting organic soil. No salvaged marsh surface was available so this second phase relied on rootstock and wetland cover seeding to establish vegetation. Species were grouped according to elevation zone.

Areas 5 and 7 (±2 ac [0.8 ha]) were restored by removing fill that supported an auto salvage yard. Most of area 7 consists of the Yahara Branch channel at its junction with another drainage ditch which enters from the north (figure 30). Space was limited; therefore, slopes are steeper than on the rest of the project. As a result, wetland plantings did not do well. Reed canary grass and smartweed are the dominant cover. The area is screened from the adjacent remaining salvage yard by a fence and planted shrubs.

Area 5 consists of a sedimentation pond for the Yahara Branch surrounded by a nearly level grade designed to match the elevation of the surrounding natural wetlands. Wetland rootstock were planted in high, medium and low marsh zones. All planted species in the low marsh zone became established. Lake sedge (*Carex lacustris*) survived in the medium marsh, but no planted species survived at the high marsh elevation. This was probably due to the substrate at the higher grade which did not retain moisture well.[72]

Area 6 (±3 ac [1.2 ha]) was restored by removing demolition debris that had been discharged to a portion of the Upper Mud Lake system. The area has no surface water connection but is adjacent to area 5 with which it has a connection via the ground water table. High, medium and low marsh rootstock were planted. Initial success was hampered by drought conditions in 1988. Cattails eventually seeded in and have become well-established. River bulrush and prairie cordgrass are also doing well. Drought conditions allowed early colonization of higher marsh zones by cottonwood seedlings. Construction debris was not completely removed as some had embedded itself in organic soil below the design elevation for area 6.

Area 3A was a parcel of abandoned agricultural land dominated by non-native reed canary grass which is not favored by wildlife for food or cover.[73] This 1-ac (0.4-ha) area was enhanced by grading it down to remove reed canary grass roots. High and medium marsh rootstock were planted and the area was seeded with a wetland cover mix. Some reed canary grass has become re-established despite treatment with herbicide.[74] However, cattail, smartweed and a diverse mixture of early successional sedge meadow species predominate.

Area 3C is a small area (<1 ac [0.4 ha]) east of area 3 that was restored in the second phase due to construction staging requirements at the U.S. 51/beltline interchange. It received the same planting and seeding treatment as area 3A after old highway fill had been removed. It is now contiguous with the wet meadow portion of area 3. The substrate is a mixture of mineral and organic soil and was observed to be only sparsely vegetated primarily with smartweeds, prairie cordgrass and river bulrush. The latter two species were planted. The slightly alkaline nature of the substrate at this location may be suppressing the further establishment of typical wetland vegetation.(72)

In addition to the mitigation areas described above, the balance of the mitigation acreage consisted of low native prairie seeding along the bases of the roadway embankments and at the edges of areas 1, 6 and 3. Some of the desired species have become established, but the plantings are in need of management to encourage further development and weed control.

Control

The Upper Mud Lake wetland between East Broadway and the railroad grade at the south end of the lake is the assessment area (AA) delineated for WET 2.0 evaluation and functional comparison with the mitigation areas (figure 29). The dominant covertype is shallow marsh dominated by cattail. Open water (average depth 3 ft [0.9 m]) is the next largest area. Wet meadow dominated by bluejoint grass and sedges in undisturbed areas and reed canary grass in areas disturbed by agriculture is predominant along the edges of the system. Limited areas of shrub and forested wetland occur along drainage ditches. Red osier dogwood (*Cornus stolonifera*), speckled alder (*Alnus rugosa*), black willow (*Salix nigra*), cottonwood, and box elder (*Acer negundo*) are the primary species.

The Yahara River, which flows through the AA, is the area's dominant hydrologic element. The watershed of the AA and IA (the mitigation areas) is approximately 65 ac (26.3 ha). It is delineated only as far as the first upstream dam located on Lake Mendota according to the WET 2.0 method. It includes urbanized portions of the City of Madison as well as other large wetland systems and agricultural land.

The downstream service area of both the AA and IA has been designated as Lake Waubesa and the Town of McFarland which is located on the lake. Lake Waubesa is a 2000-ac (810-ha) waterbody with a maximum depth of 34 ft (10.4 m). It supports a productive and diverse warm water fishery dominated by panfish and is a valuable recreational resource.(75)

Methods

Field work was conducted on August 8 through 10, 1989. Environmental and construction personnel from WDOT were consulted, as well as local wetland experts from the University of Wisconsin. Observations focused on mitigation areas 1 through 4. The other areas had less than two growing seasons of development since construction.

The natural Upper Mud Lake wetland between the railroad grade and Broadway conceptualized as it existed prior to construction of the south beltline was evaluated as the control. Pre-construction aerial photographs and environmental assessment data were utilized to estimate past conditions. Since a portion of this wetland was filled for road construction, compensating for the impact to these functions was the purpose of the mitigation measures. The wetland mitigation areas are now part of the Upper Mud Lake Wetland system by virtue of surface and ground water connections. Collectively (with the exception of area 6) these areas were conceptualized as the IA.

Water quality measurements for the control were made in a sample taken from standing water in a cattail stand located north of the bridge on the west side of the Yahara River. For the mitigation IA, readings from three samples were averaged together. These were collected at the outlet from area 3A, the pond in the center of area 2, and in the outlet of area 3.

Functional Analysis

The results of the WET 2.0 and Hollands-Magee wetland functional evaluations are given in appendix A.

Summary

The Wisconsin Department of Transportation restored 20 ac (8.1 ha) of wetland that support a range of plant communities from wet meadow to deep marsh as was its goal. To a large extent, species composition of both flora and fauna match that of the wetlands that were impacted by the highway. This conclusion is supported by research conducted in 1989.[71]

The mitigation plans and specifications were also designed to address other specific goals such as structural diversity and improved wildlife habitat, good water quality and discouragement of non-native species. Many of these goals were achieved to some degree. Slopes appear to have been constructed as designed although elevations are slightly off in parts of area 3. The individual mitigation sites (with the exception of area 6) have direct hydrologic connection with the Upper Mud Lake system and are therefore subject to the same fluctuations. Area 4 is separated from the natural wetland by a berm but appears to have a good ground water connection.[71] Contouring and open water areas were constructed so as to provide both habitat and cover for wildlife using these areas. Water quality maintenance was addressed through the construction of sedimentation ponds north of area 3 and in area 5. This issue was ignored, however, in the westernmost wildlife pond and in area 2 which receives large inputs of stormwater.

Use of wetland topsoil as a revegetation method appears to have been a reasonably effective method for precluding exotic species. Reed canary grass is present in the mitigation areas but does not appear to be dominating over the native plant community.[73] When respread at the correct elevation, the marsh surface salvaged from impacted wetland areas was very effective at re-establishing a similar plant community in the restored wetland.

Wetland plantings may not have been cost effective on this project. A large percentage of the propagules were destroyed by muskrat and waterfowl. Others were planted at incorrect water depths. Still others simply did not grow for reasons that are unknown. The location and character of the restored site are such that adjacent propagule sources and seed banks may have been adequate for revegetation without purchasing additional plant material.

The effectiveness of the south beltline mitigation measures must also be considered based on degree and effectiveness of functional replacement. According to model results, the mitigation is likely to be slightly less effective at providing certain functions than the control. However, the appropriateness of the control is questionable due to a major difference in size. In addition, certain model predictors seem to carry undue weight.

Observations made at the restoration sites in the summer of 1989 indicate that the physical isolation of these areas created by their being surrounded by roads is the dominant factor which limits their level of functional performance. Although substrate, slope, vegetational and hydrologic characteristics of the restored areas are similar to the area impacted, certain wetland functions cannot be fully realized due to the construction of the highway. For example, floodwaters from the Yahara River cannot freely spread to the replacement wetlands. This also reduces its value for water quality improvement services. Wildlife migrations are also limited by the highway. On the other hand, the quality of the land in these isolated areas has been much improved over the dumps and debris that existed prior to restoration. If the isolation issue is overlooked in considering the functional performance of the restored and enhanced areas, overall effectiveness of mitigation measures appears to be good.

Secondary Sites

18. Basso's Ferry, California

The 1911 steel truss bridge on State Highway 132 over the Tuolumne River (Basso's Ferry Bridge) was replaced in 1986 by a new concrete deck bridge immediately upstream. The project is located in central California approximately 3 mi (4.8 km) west of the small town of LaGrange. The region is characterized by grassland and savannah on which cattle and other livestock graze.

The Tuolumne River floodplain in the area of the project has been mined hydraulically for gold which has left a series of dredge ponds and tailings piles. These ponds vary in size from 0.1 ac (0.04 ha) to several acres and in depth from less than 1 ft to 6 ft (0.3 to 1.8 m) or more. Construction of the bridge approaches required destruction of 0.5 ac (0.2 ha) of riparian habitat and 0.25 ac (0.1 ha) of fill in a small dredge pond.

The mitigation plan developed by the California Department of Transportation (CALTRANS) in cooperation with the U.S. Fish and Wildlife Service and the California Department of Fish and Game called for creating a 0.5-ac (0.2-ha) replacement pond and planting shrubs common to riparian communities in the area. Excavation and planting were completed in the summer of 1987. The site was visited on October 24, 1989.

Site Description

The mitigation wetland was excavated in a U-shape to a depth of 5 to 6 ft (1.5 to 1.8 m). It was connected in two places to the remaining portion of the impacted pond. These ponds are flooded by the river every 1 to 2 years. Water levels are maintained by groundwater.

A 3-ft (0.9-m) wide band of emergents dominated by bur marigold (*Bidens cernua*) rings the replacement wetland. The remainder of the pond supports submergents and a surface layer of water meal (*Wolffia* spp.) and water velvet (*Azolla* spp.). No plantings were made in the pond. Seedlings of white alder (Alnus rhombifolia), cottonwood (*Populus fremontia*), willow (*Salix* spp.) and Himalaya blackberry *(Rubus procerus*) were planted in five areas around the pond. Valley oak (*Quercus lobata*) and interior live oak (*Q. wizlenzii*) were also planted in several areas near the river to replace riparian habitat. No topsoil was spread at the mitigation site. The shrubs were planted in the cobble and gravel substrate that occurs over most of the floodplain. Due to the timing of the contract, the shrubs were planted in midsummer and did not survive. They were replanted the following winter, only to be destroyed by beaver. The bases of many of the shrubs are still alive, however.

The site is now owned by Stanislaus County which maintains a boat ramp and parking lot. The old bridge has historical significance and remains in place as a fishing platform and bicycle crossing.

Evaluation and Summary

The Basso's Ferry replacement wetland appears to be a successful duplication of the impacted wetland. Dominant emergent species are similar as are other features such as side slopes, substrate and shoreline configuration. Adjacent riparian habitat can be expected to develop with time.

The wetland being replaced was originally man-made and its physical aspects were easily duplicated by mechanical means. Establishment of a hydrologic connection with the original wetland supplied identical water quality and fluctuation patterns, and provided plant propagules to the new wetland.

19. Edina, Minnesota

Edina is a residential suburb located southwest of Minneapolis. An interchange was constructed in the mid-1970's between TH (Trunk Highway) 100 and Edina's 70th Street necessitating the handling of increased stormwater runoff quantities. A small pond was created in the intersection's northwest quadrant in 1978/79 to retain stormwater and trap sediments headed for nearby Ninemile Creek. There is no record of any wetlands impacted by construction of the interchange. However, the retention pond was constructed to fulfill a secondary goal of wildlife habitat creation.

Site Description

The 1.1-ac (0.4-ha) pond is surrounded by roads and residences. Prior to excavation, the site had homes on it which were removed to allow construction of the ramps. The banks of the pond have 25 to 30 percent slopes to just below the normal water line. According to the Minnesota Department of Transportation (MNDOT), mean water depth is 1.2 ft (0.4 m) and maximum depth is 2.2 ft (0.7 m) with an underwater grade of 13 percent. An island of about 0.1 ac (0.04 ha) in size and several small loafing mounds were constructed for use by waterfowl.

Four culverts carry stormwater inflow to the pond from TH 100, its ramps and frontage roads, and 70th Street. The pond's only outflow pipe, located at its south end, is designed to convey clarified water to Ninemile Creek by skimming water off the surface. Between storms, the water becomes stagnant. Duckweed (*Lemna* spp.) was present in a solid mat on July 18, 1989, when field observations were conducted.

The pond's limited buffer zone (30 to 50 ft [9.1 to 15.2 m]) has been well landscaped to provide cover for small mammals and waterfowl. Several mallard broods were observed. The City of Edina maintains the area. The level ground between the surrounding roads and the top of the banks is mowed turf with scattered trees such as Norway and silver maple (*Acer platanoides, A. saccharinum)*. The steepness of the banks has prevented mowing and a dense vegetative cover has developed. The banks support weedy growth consisting of small willows (*Salix*), elms (*Ulmus americana*), boxelder (*Acer negundo*), reed canary grass (*Phalaris arundinacea*) and goldenrod (*Solidago*). The meandering perimeters of the pond and the island support some emergent vegetation including cattails (*Typha* spp.), blue vervain (*Verbena hastata*) and swamp milkweed (*Asclepias incarnata*). Woody growth on the island is quite dense and has reached an average height of 10 to 15 ft (3.0 to 4.6 m). Willows and poplar (*Populus tremuloides*) are the dominant species.

Evaluation and Summary

The pond constructed at the intersection of TH 100 and 70th Street is performing the intended function of sediment trapping and pollution control according to studies conducted by the Ninemile Creek Watershed District.[76] In addition, it is providing important, though limited and isolated, wildlife habitat in a heavily developed area. Although there are no project records indicating that the pond was a replacement for wetlands lost, it is functioning as a wetland (waterfowl habitat, sediment and toxicant retention) and may therefore represent a small net gain in wetland area.

20. Cicero Swamp, New York

The 5.4-mile (8.7-km) extension of I-481 from the New York Thruway (I-87) to I-81 northeast of Syracuse required the placement of fill in approximately 16.5 ac (6.7 ha) of wetlands. Approximately 15 ac (6.1 ha) were wetlands contiguous to the 5,300 ac (2146.5 ha) Cicero swamp and 1.5 ac (0.6 ha) was associated with the relocation of a section of Mud Creek. Red maple swamp was the dominant cover type impacted. The draft EIS notes the presence of some old field wet meadows within the alignment. However, no such areas are mentioned in the permit. Pre-construction documentation of impacted areas is not detailed enough to judge whether the site included wetland areas.

Mitigation activities were included as special conditions to the project's Section 404 permit. The Corps requested that a 160 to 170 ac (64.8 to 68.8 ha) parcel acquired by NYSDOT for borrow be turned over to the

Department of Environmental Conservation (NYSDEC) for inclusion in that agency's adjacent Cicero Wildlife Management area. The permit conditions required that the area first be "restored" by creating two large ponds from the borrow pits that would have 50 to 60 ac (20.2 to 24.3 ha) of open water. The goal of the mitigation appears to have been creation of waterfowl habitat. No mention was made in the available project documentation of any effort to replace functions of the wooded swamp that were lost due to highway construction.

In addition to the ponds, the conditions specified that the relocated segment of Mud Creek be constructed in a meandering fashion with some deeper spots to form pools, and landscaping to provide a natural appearance. Field work did not include a site visit to the relocated stream as its existence was not apparent to us at the time.

The permit conditions specified water depth and elevation, water level control structure type, construction of numerous nesting islands, an irregular perimeter, placement of organic topsoil, and planting of a shrub buffer. Side slopes were not specified, nor were in-pond plantings.

Site Description

Mitigation work was completed in the spring of 1984. The site was visited on June 27, 1989. The coarse substrate in the mitigation ponds has allowed for only sparse emergent growth. The 2-in (5.1-cm) organic layer specified by the permit has apparently dispersed through wave action. A discontinuous band of emergent vegetation, averaging 5 ft (1.5 m) in width, occurs around the perimeter of the south pond which is approximately 18 ac (7.3 ha). The vegetation consists of cattails (*T. latifolia* and *augustifolia*), purple loosestrife (*Lythrum salicaria*), rushes (*Juncus* spp.), sedges (*Carex crinita*), soft-stemmed bulrush (*Scirpus validus*), woolgrass (*Scirpus cyperinus*) and spikerush (*Eleocharis* spp). The north pond (37 ac [14.98 ha]) supports very spotty emergent growth of the same species composition. Canada geese were observed using one of the islands. The type of use was not evaluated.

The two ponds are separated by a power line supporting low vegetation. Upland vegetation at the water's edge offers very little cover for wildlife. Lack of topsoil may be the reason for slow recolonization. A 50-ft (15.2-m) band of shrubs was planted between the south pond and I-481 to act as a buffer. The shrubs are now approximately 5 ft (1.5 m) in height and survival appears to be high. Species planted include willows, dogwoods, viburnums, cedar and spruce. Many of the species are high in wildlife food value.

The ponds apparently intersect the groundwater table as no surface water inlets were observed. The south pond flows into the north pond through a culvert; the latter drains to Cicero Swamp.

Evaluation and Summary

Mitigation goals were not clearly stated. However, many of the Corps' specifications such as extent of wetland topsoil spreading, water depth and provisions enabling the adjustment of water levels imply that a pond ringed by a deep marsh was envisioned. One-third of the standing water areas were to receive a layer of organic topsoil. However, no instructions or specifications were included for managing water levels to encourage growth from this substrate. This mitigation project is difficult to evaluate further given the lack of documentation.

21. Little River, North Carolina

Replacement of the U.S. 401 bridge and approaches on new alignment over the Upper Little River in rural Harnett County (40 mi [64.4 km] south of Raleigh) required placement of approximately one ac of fill in deciduous forested wetlands. The work was covered by a COE Nationwide Permit and no mitigation was required. However, the North Carolina Department of Transportation (NCDOT) proposed to remove the old southern approach fill "to natural ground elevation for a distance of 300 ft from the river to allow for restoration of wetland vegetation."[77] This mitigation work was completed in 1985 and involved an area of approximately 0.26 ac (0.1 ha). Cost is not known.

Site Description

The project is located in the Inner Coastal Plain Region of east-central North Carolina. The Upper Little River flows west to east, draining portions of two counties before joining the Cape Fear River about 4 mi (6.4 km) east of the project. Local topography is flat to gently rolling, with plateau-like uplands that slope down to valley floors containing wooded wetlands and their associated drainageways. Floodplain soils consist of silty loam and silty clay loam. Gravel pits are abundant at the upper reaches of the floodplain.

The forested wetlands impacted by the new bridge were dominated by river birch (*Betula nigra*), sweetgum (*Liquidambar styraciflua*), water oak (*Quercus nigra*), willow oak (*Q. Phellos*), red maple (*Acer rubrum*), overcup oak

(*Q. Lyrata*) and ironwood (*Carpinus caroliniana*). Understory vegetation consisted of holly (*Ilex opaca*), honeysuckle (*Lonicera* spp.) and cat brier (*Smilax* spp.).[77]

The new bridge was constructed immediately to the west of the old bridge. The old structure was removed after the new bridge was opened. The northern approach fill was graded for use as a boat ramp in response to a request from the North Carolina Wildlife Resources Commission.[77]

The southern approach fill was the focus of the mitigation effort. After erecting silt fencing to prevent siltation of the river and adjacent wetland, the southern approach fill was removed and graded on a more or less even slope from top of grade to the river's edge. Resulting elevations in the mitigation area range from 2 to 3 ft (0.6 to 0.9 m) higher than the elevation of immediately adjacent natural wetlands. The area was planted with an erosion control seed mixture and is mowed by NCDOT along with other roadside areas. No wetland species were planted.

When the site was visited on May 19, 1989, river birch and willow seedlings were observed growing at the river's edge. A 30-ft (9.2-m) wide zone that showed evidence of inundation in a recent flood, supported a sparse growth of smartweeds (*Polygonum* sp.), sedges (*Carex* spp.) and rushes (*Juncus effusis*). The remainder of the mitigation site supported grasses (*Bromus, Dactylus*), clovers and pine seedlings. Further identification of vegetation was impossible due to mowing activities.

Evaluation and Summary

The voluntary effort to restore previously impacted wetlands along Upper Little River was conducted without benefit of detailed plans. As a result, grading work was not executed as proposed in the conceptual plan for the site. The original intent had been to match the elevation of the adjacent natural wetland for a distance of 300 ft (90 m) from the river.[77] This would have restored the proper hydrologic regime and flooding frequency. Recolonization of the restored area could then have been expected based on the proximity of available plant propagules and the accessibility of the site to these propagules. The outcome of this mitigation effort emphasizes the importance of developing plans that allow the desired intent to be realized on the ground.

22. North River, Washington

Replacement of the State Road (SR) 101 bridge over the North River required placement of fill in 0.75 ac (0.3 ha) of seasonally flooded palustrine scrub-shrub wetland. The site is located 8 mi (12.9 km) south of Aberdeen in Grays Harbor County, Washington. In cooperation with the U.S. Fish and Wildlife Service, Washington State Department of Transportation (WSDOT) developed plans to enhance approximately 2 ac (0.8 ha) of the adjacent forested wetland to the southwest of the new bridge. Creation of open water areas with meandering shorelines adjacent to landscaped upland berms was intended to increase waterfowl habitat and aquatic productivity over the site's pre-existing conditions, increase plant diversity by providing upland and wetland sites in close proximity, and increase edge habitat.(78) Site grading and upland plantings were completed in the fall of 1985 at a cost of $57,855. Field observations were made on September 13, 1989.

Site Description

The impacted wetland was dominated by red alder (*Alnus rubra*) with an understory of sedges, rushes and reed canary grass. The forested wetland that was enhanced as mitigation for the impact supported a similar plant community. These areas are 30 to 40 ft (9.1 to 12.2 m) higher than the normal water elevation in North River and are seasonally flooded by sheetflow from adjacent uplands and by highway runoff. Subsoils contain a clay component.

A hand-shaped pond was excavated with slopes ranging from 4:1 to 6:1. Four small areas of existing vegetation were left between the pond's "fingers." Upland areas were seeded with Manhattan Rye for controlling erosion. Approximately 750 12- and 18-in (30.5- and 45.7 cm) shrubs were planted on adjacent uplands. These included Douglas fir, western hemlock, western red cedar, serviceberry and red elderberry. No topsoil was spread in the pond area, nor were there any wetland species planted.

The plant community observed to be slowly colonizing the wetland portion of the mitigation site was dominated by spikerush (*Eleocharis ovata*). Softrush (*Juncus effusus*), reed canary grass (*Phalaris arundinacea*), and horsetail (*Equisetum* sp.) along with red alder and willow seedlings were also present. Total plant cover was very sparse and much bare soil was observed. Black-tailed deer tracks were the only sign of wildlife observed during the short visit.

Water appears to be provided to the pond by way of a swale which brings runoff under the bridge from the east side. The pond apparently contains some standing water year round, although fluctuation is great ($\pm$ 3 ft [0.9 m]) as evidenced by the observed difference in elevation between standing water and the developing vegetation. Excess water can exit the pond by way of a swale which flows north to the river.

Evaluation and Summary

The North River mitigation site is well-configured to provide for a variety of plant communities and wildlife habitat as intended. However, after four growing seasons, revegetation is minimal and the site's productivity is low.

A layer of wetland topsoil would have provided the organic matter, nutrients and plant propagules necessary for more rapid revegetation of the site. The basin's slopes may be too steep for emergent plant establishment given the high degree of water level fluctuation that is evident at the site. Waterfowl may utilize the site during migration, but the high quality habitat envisioned for this site will likely take many more years to develop, at current rates.

23. Kenosha County, Wisconsin

Improvements made to a 23-mi (37.0-km) segment of State Trunk Highway (STH) 50 in southeastern Wisconsin impacted 59 ac (23.9 ha) of wetlands including riverine aquatic bed and emergent as well as palustrine sedge meadow, shallow marsh and shrub wetlands. The mitigation site was designed by Wisconsin Department of Transportation (WDOT) in cooperation with Wisconsin Department of Natural Resources (WDNR) to provide fish and waterfowl habitat and flood storage functions. The EPA and COE were also involved in coordination activities. Three ponds were excavated in 1988 on a parcel of poorly drained agricultural land in the floodplain of the Fox River between the towns of New Munster and Silver Lake (TIN, R19E, Sec. 1 and 2). Wetland vegetation was planted in the spring of 1989. Additional enhancement measures on adjacent wetland sites included termination of use by grazing animals and restoration of hydrology by destruction of drainage tiles. The total area of the mitigation package is 91.7 ac (37.1 ha) of which 70 percent is enhancement and 30 percent is creation from upland. Costs for excavation, seeding, planting and water control items were $746,000. Field observations were made on August 11, 1989.

Site Description

Groundwater, influenced by the level of the Fox River, is the water source for the STH 50 mitigation ponds. Palmer Creek, a tributary to Fox River, runs nearby and was originally intended to provide a surface water supply to the three interconnected ponds. However, this part of the plan was eliminated due to concern over associated maintenance costs.[79] A structure at the eastern end of the easternmost pond controls its water level.

Two zones of wetland vegetation, separated by elevation relative to the water table, were planted early in the 1989 growing season. The lower zone was planted with roots and tubers of the following species: burreed (*Sparganium eurycarpum*), cattail (*Typha latifolia*), arrowhead (*Sagittaria latifolia*), river bulrush (*Scirpus fluviatilis*), sweet flag (*Acorus calamus*) and smartweed (*Polygonum coccineum*). The upper zone was seeded with a wet prairie/sedge meadow mixture including grasses such as big bluestem (*Andropogon gerardii*), bluejoint (*Calamagrostis canadensis*) and switchgrass (*Panicum virgatum*); and forbs including swamp milkweed (*Asclepias incarnata*), New England aster (*Aster novae-angliae*) and blue vervain (*Verbena hastata*) among many others. These plantings were made in the subsoils exposed during excavation; no topsoil was placed.

Side slopes of the largest (easternmost) pond range between 4:1 and 6:1. The water level had recently dropped and some areas of bare soil were present. Approximately 20 Canada geese were observed in this pond. Turbidity was high due to the presence of carp.

The middle pond's slopes were graded more gradually and a denser growth of emergents had resulted than in the eastern pond. The westernmost pond was intended to be graded with 50:1 slopes but was actually constructed with almost vertical scarps along portions of its perimeter. The proximity of the Palmer Creek wetlands to this site appears to have provided some benefit. The shallower areas of the pond support a healthy stand of cattails and sweet-flag. Pondweed (*Potamogeton* spp.) is abundant in the open areas. Evidence of muskrat was observed in this pond. The only other wildlife observed during the brief visit besides the geese were killdeer. According to WDOT two broods of geese were observed in the center pond in its first season.[72]

Evaluation and Summary

Near the end of the first growing season, emergents (both planted and volunteer) are showing positive signs of successful development. Although the ponds were designed with meandering shorelines, they were not excavated as such. This will probably preclude the development of desirable patterns of emergent vegetation. The eastern pond is quite large and may have been made more desirable to nesting waterfowl had some islands been constructed.

The site is quite exposed to the adjacent highway. Wildlife habitat development could be enhanced by the planting of some small trees and shrubs to provide a buffer and some structural diversity. Currently owned by WDOT, the site is to be transferred to and managed by WDNR. The DNR has plans to utilize the ponds as northern pike rearing areas for fry from hatcheries. Further development of emergent vegetation is necessary before the ponds will be useful for this purpose. The lack of topsoil can be expected to slow the overall development of emergent cover, especially in the largest pond where wave action may prove to be a frequently-occurring disturbance factor.

The project goals of fish and waterfowl habitat improvement can likely be attained at the STH 50 mitigation site given time and proper management. This cursory evaluation was undertaken at the excavated ponds less than one full growing season after construction. Early indicators of success are positive. However, remedial measures may be necessary to address physical limitations (e.g. slope and shore configuration) that have resulted due to poor communication and inattention to plan details. No evaluation was made of the additional enhancement measures undertaken on adjacent parcels as these areas will take several years to show any changes.

DISCUSSION OF RESULTS AND CONCLUSIONS

The current wetland mitigation literature includes concerns that an artificial wetland restoration or creation project cannot fully duplicate all the functions and values of a naturally occurring wetland. At the same time, however, it is generally acknowledged that it is possible to restore or create individual wetland functions or to approximate some wetland systems.[7] Josselyn, et al found that "the majority of completed projects [that they studied] did create some wetland habitat."[9]

It was the purpose of this study to determine the level of success of the 23 highway-related wetland mitigation projects. Conclusions about the success or failure of the mitigation projects were based on both the informal goals and expectations of the biologists who worked on these projects, and the model assessments of wetland functions and values. Twenty-three projects located around the country were studied during the summer of 1989 (17 in detail and 6 in a cursory fashion) to determine their effectiveness in terms of goal attainment and replacement of wetland functions. Site specific evaluations were made in the previous section and functional assessment results can be found in appendix A.

This section summarizes the most important conclusions, addresses regulatory influences on mitigation effectiveness, and presents discussions on the appropriateness of mitigation activities, unanticipated impacts, cost effectiveness and the applicability of wetland models to the task of assessing mitigation effectiveness.

1. Study Results

Tables 5 through 8 broadly summarize the degree to which informal goals and expectations were met for each primary mitigation site, as well as

Table 5. Goal attainment and replacement of wetland functions for the six enhancement sites.

Site	State	Size (ac)	Goals Met?[1]	WET 2.0[2]	Hollands-Magee[2]
Lake Hunter	FL	4.0	P	=/+	+
Wetland D	IA	6.5+	P	-/=	-
Galesburg	IL	18.4	P	=/+	=
Schaumburg commuter lot	IL	3.0	Y	=	=
Patuxent River	MD	12.0	P	-/=	-
Stoll Road	MI	6.0	P	-/=	-

[1]P = partial, Y = yes, N = no
[2]=, + and - refer to functional value of the mitigation site as compared with the control

Table 6. Goal attainment and replacement of wetland functions for the two enhancement/creation sites.

Site	State	Size (ac)	Goals Met?[1]	WET 2.0[2]	Hollands-Magee[2]
So. Tier Expressway	NY	78.0	P	-/+	+
French Creek	PA	12.5	P	-/=	-

[1]P = partial, Y = yes, N = no
[2]=, + and - refer to functional value of the mitigation site as compared with the control

Table 7. Goal attainment and replacement of wetland functions for the six creation sites.

Site	State	Size (ac)	Goals Met?[1]	WET 2.0[2]	Hollands-Magee[2]
Sweetwater River	CA	2.0	P	=	=
Lake George	MN	12.5	Y	=/+	=
Rancocas Creek	NJ	4.45	Y	=	-
Wilmington	NC	50.0	P	-/+	-
Nehalem Bay	OR	1.0	P	-/=	-
Noti Veneta	OR	15.5	P	-/=	=

[1]P = partial, Y = yes, N = no
[2]=, + and - refer to functional value of the mitigation site as compared with the control

Table 8. Goal attainment and replacement of wetland functions for the three restoration sites.

Site	State	Size (ac)	Goals Met?[1]	WET 2.0[2]	Hollands-Magee[2]
Sharptown	MD	1.0	P	-/=	-
Willapa Bay	WA	2.0	P	-	N/A
So. Beltline	WI	25.0	P	-/=	-

[1]P = partial, Y = yes, N = no
[2]=, + and - refer to functional value of the mitigation site as compared with the control

the general extent to which the wetland functions of the impacted wetland (control) were replaced by the mitigation project. Each table addresses a different mitigation category, i.e. enhancement, creation, restoration. If the majority of the functions ranked lower for the mitigation than the control site, a "-" sign is shown. A "=/+" indicates that some of the mitigation site's functions ranked equally with and others ranked higher than the control.

Goals were partially met in five of the six enhancement sites and fully met in one (table 5). Goals were partially met in the two enhancement/creation sites (table 6). Two of the six creation sites were successful while the others were only partially successful (table 7). The three restoration sites were only partially successful in fulfilling their goals (table 8). These tables summarize results of the full range of wetland functions and informal goals and are therefore necessarily general. However, they indicate that very few of the sites studied resulted in the full replacement of all functions lost to construction.

2. Study Conclusions

Mitigation type (i.e. whether wetlands were enhanced, created or restored) did not appear to be a factor in determining mitigation effectiveness. Rather, the level of effort at the planning phase, the inclusion of certain design elements in detailed mitigation plans, and the precision with which plans were implemented were found to be the most important keys to effectiveness.

Planning Considerations

The sequence of activities involved in mitigation of wetland impacts for the projects reviewed typically began with the formulation of a conceptual plan based on interagency negotiations. These negotiations were sometimes based on analysis of the functions of the wetlands being filled, but often were not. If they were, chances were better that the conceptual mitigation plan would be focused on goals and functional objectives related to the resource being impacted. If not, more generic goals such as "wildlife habitat" or "replacement of wetland values" guided the remainder of the planning process. Conflicting goals of negotiating parties sometimes contributed to the weakening of a good conceptual plan if too many compromises had to be made.

The formulation of firm mitigation objectives is necessary to provide a well-founded framework for the formulation of detailed plans (e.g. Patuxent, MD). Without well-defined goals and objectives, the mitigation process tended to lack focus (e.g. Wilmington, NC) and functional replacement and original intentions were often disregarded (e.g. wetland D, IA). On the other hand, well laid mitigation goals and design features were sometimes forgotten or misinterpreted in the plan formulation stage, resulting in a poorly implemented wetland design (e.g. Noti-Veneta, OR).

Thoughtfully drafted, detailed plans are necessary to ensure that good ideas are clearly communicated to the construction crews. Construction sequencing is often of critical importance and must be carefully considered and planned. Construction monitoring (to be discussed below) is equally necessary, to ensure that plans are carried out in the field as intended. Under certain situations, ideas can be successfully implemented without detailed plans. An example is the Lake George (MN) site where the construction supervisor and the equipment operator had a clear understanding of the intent of the mitigation work. This situation is rare and should probably not be relied upon to take the place of good plans. North Carolina's Little River site and Maryland's Sharptown site were not constructed as intended due to lack of plan specificity about final elevations and construction monitoring.

Design Elements

Certain design considerations emerged as being of primary importance to successful enhancement, creation or restoration of wetlands based on analysis of functions. These design factors include:

Location and Hydrologic Connection

The location of mitigation wetlands in relation to surface water systems and other wetlands was found to have major impacts on the performance of social significance functions; an isolated wetland has fewer opportunities to provide off-site services. The connection of a man-made wetland with a natural waterway or wetland also improves its viability due to the influence of natural water level fluctuations, natural flushing and circulation, availability of nutrients, migration of invertebrates, inflow of plant propagules and organic matter, and many other factors. A successful example is the Rancocas (NJ) fresh water tidal site. Such factors can aid in the development of functions such as biological support and water quality maintenance.

Resource agencies often advocate the deliberate separation of man-made wetlands from natural systems due to fears that mitigation work will create downstream disturbances in the natural system. If it is necessary to incorporate some type of barrier, it is desirable to utilize a measure that reduces erosive energy rather than a structure that precludes all flow from adjacent systems. An example of the former is the French Creek (PA) site which incorporated rock rip-rap at inlets and outlets. The earthen berm at Sharptown (MD) protected the mitigation site from wave action, but also isolated the site from tidal flushing.

Slope and Elevation

Hydrology is the driving force of wetlands and should be considered during the initial planning phase of mitigation projects. This factor is best addressed by means of the closely related design elements slope and elevation. Wetland creation and restoration plans should be based on final elevations that are appropriate for the development of the desired plant community.

Several of the sites reviewed (Wetland D, IA; Galesburg, IL, STE-Reservation Road, NY; Noti-Veneta, OR) either stated or implied in conceptual plans or goal statements that emergent vegetation zones would be created. However, water depth, a function of slope and elevation, was in these cases too great to support the desired plant community. An exception was the Lake Hunter (FL) site which is located in a region where emergent vegetation is adapted to deeper water.

In general, steep slopes provide limited opportunity for development of emergent vegetation because the zone of suitable water depth is narrow. In many cases, either preconstruction investigations were not adequate regarding expected water levels, goals were not adequately considered during plan formulation, or plans were not successfully implemented. If a high degree of water fluctuation is expected (Noti-Veneta, OR), gradual slopes are even more important because a larger variety of plant habitats (based on water level) are available than on a steep slope.

Misconceptions about what constitutes a "gradual" slope for purposes of emergent zone establishment were a pervasive problem in mitigation designs. Slopes of 3:1 or 6:1 were specified in most of the mitigation plans as the target slopes for the emergent zone. In most cases, however, such steep slopes are guaranteed to produce only a narrow band of emergent vegetation, particularly where water level fluctuations are large or unpredictable. Slopes of 10:1 or 20:1 or gentler will provide a broad zone of water depths suitable for emergent growth under various flooding conditions.

Restoration of three sites (Sharptown, MD; Willapa Bay, WA; and Little River, NC) were not effective because incomplete excavation resulted in final elevations that were too high for establishment of the desired wetland community. At Sharptown (MD), coarse fill and debris left at an elevation at least 2 ft (0.6 m) higher than the surrounding wetland was planted with wetland trees, shrubs and herbaceous species. Survival of plantings was adequate but development of herbaceous ground cover is proceeding at a very slow rate. A similar problem occurred at Little River. In both cases, incomplete grading resulted from lack of plan detail. Portions of the Willapa Bay site have developed and are functioning as planned. However, less than the planned acreage of wetland was restored because fill material was removed to an elevation adequate for wetland establishment in only a portion of the 2 ac (0.8 ha).

Proper elevations are also crucial for tidal sites and were graded at the Rancocas Creek (NJ) site. As a result, at that site there is twice-daily tidal flushing, and planted and native volunteer vegetation has become established and characteristic silt deposits are building up.

Substrate

A topdressing of some type of topsoil appears to be a key factor in mitigation effectiveness. The source of the material (i.e. upland or wetland) is not as important as the presence of organic matter and nutrients that characterize all topsoil. Subsoils may have neither, and may have concentrations of minerals in a quantity or form unsuitable for plant nutrition. Mitigation projects that did not incorporate a surface dressing of topsoil were consistently less effective than those that did. Subsoils exposed during excavation of mitigation sites in Iowa, Galesburg (IL), Noti-Veneta (OR), parts of New York's Southern Tier project, North River (WA), the Sweetwater River (CA) and the Wilmington (NC) sites were observed to be developing vegetative cover at very slow rates. Large areas of completely bare or very sparsely vegetated soil were observed at these sites even after five or six growing seasons. Erosion was often observed at such sites (NC, WA, IA).

In contrast, emergent vegetation in Lake Hunter (FL) had apparently been developing quite nicely from the wetland 'mulch' and plantings until the lake's fish population decimated the deepwater vegetation. The Birch Run portion of the Southern Tier (NY) mitigation wetlands, dressed with wetland topsoil, has developed a dense and fairly diverse emergent zone. Use of marsh topsoil in Wisconsin for the south beltline wetlands has allowed the rapid restoration of wet meadow zones including a native sedge component.

Other sites utilized different types of topdressings which were also effective at promoting revegetation. The wetland soil mixture utilized in the French Creek (PA) replacement area was obtained from the highway right-of-way. The Lake George (MN) mitigation wetlands incorporated mulch and topsoil stripped from the upland site prior to construction.

The freshwater tidal wetland creation on Rancocas Creek (NJ) and portions of the tidal site in Washington were effective without the placement of topsoil due to daily influxes of organic-rich silt. Vegetation which colonized the Nehalem Spit mitigation (OR) is adapted to growth in a sandy environment without topsoil.

Configuration

Performance of functions such as waterfowl and aquatic habitat, and water quality maintenance (sediment, toxicant and nutrient retention) depend heavily on the presence of a well-developed emergent vegetation zone and good interspersion of vegetation and open water. A properly configured basin shape is often conducive to these characteristics. The Patuxent (Bowie, MD) mitigation site was constructed with a meandering shoreline which forms several coves. These protected coves have developed healthy emergent zones and provide secluded areas for waterfowl. Many of the other sites evaluated consisted of ponds with regular shorelines which provide little shelter for developing vegetation or for wildlife. Narrow rights-of-way, often the only area available for mitigation activities, can impose limitations on basin configuration (Noti-Veneta, OR; Galesburg, IL).

Implementation

The most well-conceived and detailed mitigation plans are useless if they are ignored or improperly implemented in the field. Planned construction sequencing should be carefully followed as it is often crucial to proper implementation. Construction monitoring proved to be highly beneficial for the New Jersey, New York, California and Wisconsin primary sites. Monitoring of grading activities in New Jersey ensured that costly plantings were applied to an appropriate growth medium. Important remedial measures were applied at the New York site as a result of monitoring activities. Complex mitigation plans were implemented in Wisconsin with a higher degree of accuracy than would have been likely without monitoring. Postconstruction monitoring conducted at the two California sites resulted in remedial activities that improved mitigation effectiveness. In both cases, shrubs were replanted to replace those that were improperly planted or for some other reason did not survive.

3. Regulatory Influences

Mitigation Goals

In evaluating whether mitigation efforts were appropriate given the resources impacted, it is important to acknowledge the window of time in which many of these projects were initiated. In the late 1970's and early 1980's, mitigation plans negotiated by interagency groups (i.e. DOT, regulatory and resource agencies) were not always directed at replacing the wetland resource or functions lost. Rather, they were more often focused on getting something in return for the wetland lost. Often, it seemed that this "something" was fish and wildlife habitat, namely fish rearing and waterfowl habitat. These were the most well-known wetland functions and were easiest for a diverse group to understand. However, mitigation projects designed for these uses ended up being short on wetlands functions, per se. In general wetland definitions emphasize the need for shallow water and vegetation. Many of the mitigation projects reviewed in this study had very little of either of these wetland characteristics (MI, parts of NY, NC, OR-Noti-Veneta, IL-Galesburg) because of the emphasis on open water to provide the fish and wildlife habitat.

Fish and wildlife habitat creation or enhancement are appropriate goals for mitigating wetland impacts if other wetland characteristics are incorporated into mitigation plans. Open water in the absence of other structural characteristics is not entirely adequate for fish and waterfowl habitat. Fish need cover and a substrate that will support a food source. Waterfowl require sheltered open water, food sources and isolated islands for predator-free nesting. These needs can all be filled by wetlands that have extensive, vegetated zones along with enough open water to fill basic needs. The key is variety -- variety of vegetation cover types, water depths and basin configuration. High values for certain functions can mean that other functions will be lower (for example: flood storage and hydrologic support; groundwater recharge and discharge). However, it is not necessary for certain functions to preclude all others. In the 1990's, as knowledge of wetland functions increases, interagency groups should consider the full range of wetland functions in mitigation plans.

Location

Another important mitigation issue is the practice of constructing replacement wetlands within highway rights-of-way. This was often done due to cost considerations and on-site replacement requirements. The constraints of the right-of-way encourage the creation of narrow, steepsided basins with straight borders. Such wetlands are also subject to highway disturbances, hazards, runoff, and sometimes limited accessibility to wildlife. These characteristics do not encourage wildlife habitat development or other wetland values. Often these areas are smaller than 1 ac (0.4 ha) and are isolated from other surface waters. Small wetlands can be valuable if located in groups or near larger wetlands, but a singular isolated pocket of open water may have limited value. Preliminary siting studies that examine a variety of on-site and other replacement areas are important steps in successful mitigation programs. Siting studies need to evaluate the factors discussed above such as hydrology, soils, and connection to existing water sources. For those projects which must rely on groundwater, a minimum of one year of monitoring data is generally required to determine design parameters.

Mitigation Ratios

Mitigation ratios of 1:1 or more based on replacement acreage are often required as part of wetland permits. Josselyn, et al felt that these replacement acreage ratios were intended to compensate for delays in wetland establishment at the mitigation site and for loss of wetland acreage overall.[9] In reviewing the permits and in conversations with biologists associated with the wetlands in this study, it appeared that mitigation ratios greater than 1:1 were required for most recently constructed projects. However, it appears that these ratios are intended to help compensate for: (1) risk of failure of the mitigation project, and (2) net loss of wetland acreage and/or functions.

Such mitigation ratios were not based on scientific study or monitoring of success rates for functional replacement. Instead, ratios were usually set subjectively, often based on one or two examples of previous mitigation successes/failures, and varied greatly from region to region of the country.

Risk of Failure

One assumption behind requirements for high-ratio replacement is that the risk of failure of mitigation projects is high. That assumption has been born out by this study, which found that several of the mitigation efforts assessed were unsuccessful or only partially successful at attaining the goals set forth in mitigation plans, agreements, or permits (FL, IA, MI, OR-Noti Veneta, MD-Sharptown, WA).

At no site, however, were the causes of failure a mystery. They appeared to be directly linked to shortcomings or misconceptions in planning or design, or to failures of implementation, but not to gaps in the wetland information base. Had remediation requirements been integral to the mitigation plan, a greater number of these projects could have been successful at attaining at least their stated goals. A requirement for, or policy of, corrective action was absent in all but a few of the projects studied. The high rate of failure to reproduce one or several target functions is therefore not a result of limited knowledge about wetland dynamics, but rather to the lack of commitment to mitigation success. Although initial failures will still occur due to unforeseen circumstances, a policy of corrective action may reduce the risk of ultimate failure.

Based on the many functional analyses conducted during this study, such features as location and hydrologic connection, coupled with sound design parameters addressing slope, elevation, and substrate, emerged as being more important to functional replacement than acreage. Indeed two of the largest sites (Wilmington, NC and Noti-Veneta, OR) were among the least successful at reproducing wetland values.

The risk of failure in wetland mitigation projects can be minimized by attention to several measures: baseline studies of the wetland to be impacted and the wetland replacement area, realistic mitigation goals, careful design features aimed at broad wetland values, thorough monitoring both during construction and for several years after completion, and commitment to remedial measures as necessary. The latter is the element missing from most mitigation projects that could have transformed initial failures into ultimate successes. It is also the element that will greatly reduce the overall risk of failure, thus making high-ratio replacement requirements unnecessary.

Loss of Wetland Acreage

For mitigation projects in this study, very high replacement to impact ratios were often required for wetland enhancement projects. Using enhancement as mitigation for wetland losses raises concerns over net loss of wetland acreage. Regulators are understandably uneasy about permitting such losses, and as a result often insist on high acreage enhancement.

The most frequently observed type of wetland enhancement is excavation to produce open water areas in existing vegetated wetlands. Improvement of waterfowl habitat is the usual goal of this enhancement. The risk of massive failure in enhancement projects is low because the hydrology is well established, and there is high opportunity for exchange of nutrients and organisms with the adjacent wetland. However, tampering with natural, mature wetlands that may be serving a broad range of biological functions, as well as other wetland functions, can produce unforeseen or unnoticed results. For example, too much attention to the narrow goal of waterfowl habitat enhancement can result in significant losses to other important wetland habitats and values that enjoy less public recognition and appeal, such as water quality maintenance or flying squirrel habitat.

Enhancement projects should therefore be undertaken in degraded or otherwise dysfunctional wetlands to avoid further losses of wetland functions to healthy natural systems. Based on functional assessment, enhancement may also be appropriate in cases where a wetland lacks diversity. Enhancement could also involve modifying a wetland so that it performs a desired function, provided other functions are given adequate consideration. Acreage ratios and enhancement proposals should be based on a clear assessment of net gains and losses of total wetland values, not on a prescribed ratio or a narrow set of popular goals. The emphasis for enhancements, as for all other mitigation projects, should be on quality more than quantity. Mitigation ratios for enhancement should be negotiated on a case-by-case basis. Limited goals, such as waterfowl habitat improvement, should not be overemphasized at the expense of other important and well-established functions.

Summary

Mitigation ratios based on acreage are often advocated as means to guard against the risk of mitigation failure and to help guarantee functional replacement. Such ratios are rarely based on any definite formulae, although development of definite formulae may not even be possible or desirable. Based on the many functional analyses conducted and the observations made as part of this study, location and hydrologic connection coupled with sound design parameters addressing slope, elevation and substrate, emerged as being more important to functional replacement than acreage.

4. Unanticipated Impacts

Eight of the 17 primary sites involved mitigation measures that were carried out in existing wetlands. Usually, there was no acknowledgement of the existence or functions of these wetlands. Seasonally flooded wetlands were not always recognized as wetlands by regulatory authorities. The effects of mitigation measures were typically habitat diversification. However, the impacts of these activities--positive or negative--cannot be fully understood because baseline information was not collected from the preexisting wetlands in their undisturbed condition.

5. Cost Effectiveness

The introduction to each study site lists project costs whenever available. Every attempt was made to obtain cost information for each site, but such information was rarely available. The difficulty in obtaining mitigation costs is attributable to cost accounting methods. Mitigation costs were not typically differentiated from highway construction costs unless the State transportation agency had a specific interest in assessing these costs at the time the project was constructed. The south beltline (WI) project was the only site for which detailed costs were available for all aspects of the mitigation. This information is presented below and is compared with an estimate from New Jersey. In addition, general guidelines are provided concerning cost-effectiveness of some of the more common mitigation measures.

Borrow pits are often viewed as a cost-effective means for mitigating wetland losses because the excavated material can be utilized in highway construction or can be sold for other uses to offset costs. However, the obvious temptation is to remove a large quantity of material from a small area which tends to result in a deep, steepsided basin. These basic characteristics are quite different from those found in natural wetlands, and are therefore not conducive to cost effectiveness because they are not effective at replicating wetlands. An exception to this generalization among the sites studied is Lake George (MN). The deposits of suitable material were very shallow at the borrow pit/mitigation site; the wetlands were created with gradual slopes and a natural appearance. Open water is present, but it is shallow and is surrounded by broad emergent wetlands. Costs were minimal according to Minnesota DOT officials.

Planting versus the spreading of wetland topsoil (or "mulching" as it is sometimes called) is another important cost-effectiveness issue. Cost computations made by Wisconsin DOT for the beltline mitigation site, assuming 1,200 plants/ac (2964 plants/ha), showed a great difference between mulching and planting. The cost of excavating the marsh topsoil was \$4.10/yd^3 (\$5.36/m^3) and spreading on the mitigation site was \$2.40/yd^2 (\$2.87/m^2). This amounts to approximately \$14,600/ac (\$36,062/ha) for a 6-in (15.2-cm) layer of mulch. The cost for purchasing and planting marsh plants was \$0.92 for each propagule. At 1,200 propagules/ac (2964/ha), planting costs were approximately \$1,100/ac (\$2,717/ha) including labor costs. If the success rates of these two revegetation methods were similar, planting would obviously be the most cost effective. However, this is not the case. The success rate of planted materials was often low due to moisture and substrate problems, herbivory, harvesting and holding procedures and other unknown factors, whereas mulching is usually quite effective, given the same period of establishment. Thus, considering the monetary costs of planting and replanting, together with the time costs in years of delayed restoration of wetland values, mulching will in many cases be the most successful and therefore the most cost-effective.

The Rancocas Creek (NJ) site was revegetated by planting. Certain species were lost to herbivory but the overall planting was more successful than most, which was possibly due to the site's tidal connection. Rough planting cost was estimated at \$50,000 for 4.5 ac (1.8 ha) which amounts to approximately \$11,000/ac (\$27,170/ha) or 10 times more than the Wisconsin site.(47) Five times the number of plants per acre were planted in New Jersey, accounting for most of the cost differences between the Wisconsin and New Jersey sites.

The type of grading also has a bearing on cost effectiveness. The step-wise shelf grading employed on the Southern Tier Expressway (NY) mitigation ponds to encourage plant zonation involved the removal of twice as much material than for a continuous grade. It therefore follows that a step-wise grade was more expensive to excavate. A continuous grade is more likely to support emergent vegetation than a shelf because it provides a greater variety of plant habitats based on hydrology. Therefore a continuous grade is more cost effective than a step-wise grade.

False economy is often applied in wetland mitigation projects. The effectiveness of construction methods in producing a well-vegetated wetland must be considered as well as cost. Many of the projects evaluated have not developed good vegetative cover even after three or more growing seasons. Remedial measures have been neither required nor undertaken. Assuming that lost time equals lost wetland functions, cost effectiveness is low in many of the projects studied (FL, OR-Noti Veneta, etc.). Careful planning and goal setting can improve the relationship of cost to achieve wetland values.

6. Applicability of Models

Wetland mitigation projects in a wide variety of regions were evaluated in this study. Two sets of models aided the assessment of wetland functions in all regions. A model is by definition a simplification of a natural system. It is a tool for collecting a consistent set of observations in a variety of settings so that comparisons among similar, but diverse systems can be made. Models are never intended by their authors to stand alone without interpretation, because natural systems cannot be accurately simplified. Model results require interpretation to provide substance to the generalizations made necessary by the simplification process. Sometimes these generalizations produce model results that do not accurately reflect the natural system. This is true of both WET 2.0 and the Hollands-Magee models in certain situations. Model interpretations are presented in appendix A and are based on thorough understanding of the models and field observations made by wetland professionals with regard to wetland functions.

The models are most effectively utilized as tools for observing wetland functions. The insight into wetland functioning imparted by model application is more through involvement in the process than in the model results themselves. Both WET 2.0 and Hollands-Magee involve inputs that require comprehensive knowledge of a given wetland's components, processes and outside influences. This knowledge was obtained through detailed observations, interviews with local experts and review of informational resources from a variety of disciplines. By assembling this information the investigator cannot only run the model, but also has the knowledge to make an informed interpretation of model results.

The WET 2.0 and Hollands-Magee evaluation processes provide different types of insights about a given wetland. WET 2.0 emphasizes how a wetland interacts with its environment, i.e. downstream waterways, other nearby wetlands and wildlife resources in the general locality. Although structural aspects of the wetland itself are also considered, they are not the focus of the evaluation, as is the case with the Hollands-Magee models. Hollands-Magee considers aspects such as surrounding land use, topographic location and hydrologic connection but emphasizes ecological structure and function of the wetland itself. These differences in the two models together provide a more comprehensive look at each of the wetlands studied.

Despite the benefits described above, use of the models presents certain problems as well. WET 2.0 had the most constraints regarding delineation of an assessment area (AA) so the same area was used for both models. WET 2.0 is heavily based on the assumption that the AA is hydrologically distinct from adjacent areas. In order to delineate such an area that included the wetland of interest, it was sometimes necessary to delineate a very large area. The disadvantage is that this process could often result in comparison of a mitigation and control wetland of two vastly different sizes. Both models assign generally higher ratings to larger wetlands. The WET 2.0 model has a mechanism, the impact area (IA), for assessing a portion of an AA. However, it violates the hydrological contiguity assumption of the model and therefore does not give an accurate or informative picture of the IA.

The time required to conduct and interpret an assessment using WET 2.0 is 3 to 5 times that required for Hollands-Magee. Given the similar results provided in most cases by the two models, it appears that WET 2.0 could be streamlined without sacrificing its usefulness or accuracy.

The characteristics measured should be chosen to provide an indicator of the fulfillment of mitigation objectives. This is a labor-intensive method that cannot be accomplished on multiple sites in one field season without a large field crew. On the other hand, measurement of discrete wetland features may lead to narrow conclusions about mitigation effectiveness that ignore characteristics that are difficult to measure or for which quantitative measurement is too costly (e.g., nutrient removal or colonization by invertebrates). However, the designation of performance standards that address defined goals would provide the most reasonable basis for such measurements.

SUMMARY AND RECOMMENDATIONS

It is important to note that the projects evaluated in this study were planned and developed in a different "era of consciousness" with regard to wetlands and their regulation than that which exists today. Mitigation policies differed widely among regions. Mitigation goals were often limited to development of open water. The full range of wetland functions and the size of the wetland being impacted were often downgraded and inadequately addressed.

The sites studied in this report have been evaluated based on functional replacement. Although this is not a new concept, it represents a mitigation standard that has recently been more rigorously applied than in the past. As a result, many of the projects considered to be only partially successful in this report may have been considered entirely successful in their time based on the simple goals that had been set and the lack of attention to functional replacement in earlier times. These projects have been important "building blocks" of mitigation knowledge for the States in which they were undertaken. Many of the States participating in this study report that their current mitigation projects are much more sophisticated as a result. The level of sophistication varies from region to region. The information presented in this report has been developed to provide a consistent and comprehensive set of wetland mitigation building blocks for use on a nationwide basis.

The same types of wetland mitigation successes and failures were evident in different regions of the country. The results of this study indicate that many wetland functions can be replaced if the mitigation process is adequately focused on the task. Ineffective mitigation can usually be attributed to lack of attention to detail in the planning, design and/or implementation processes. Coordinated mitigation project management from planning through postconstruction monitoring is recommended as a mechanism to encourage a higher level of effectiveness. It may also be useful to handle mitigation under its own contract in order to avoid the "secondary importance syndrome" that can be a detriment to the implementation of mitigation projects attached to large construction contracts.

Our knowledge of wetland functions is still growing. At this point our overall goal in creating man-made wetlands ought to be duplication of the characteristics of natural wetlands. In other words, rather than attempting to replace wetland values by making a lake we should attempt to copy the flat terrain, hydrologic connection and extensive vegetative cover of natural wetlands. This provides a dual benefit of reducing the risk that mitigation will not be effective, while also reducing the potential loss of wetland acreage.

If appropriately located and implemented, indications are that certain wetland functions can also be replaced through out-of-kind mitigation. These usually fall in the social significance and opportunity categories. Performance capability or effectiveness functions are more effectively replaced through in-kind mitigation.

Review of 23 mitigation projects suggests that the effectiveness of future projects can be substantially improved through the use of recommended design guidelines and through attention to detail prior to construction, during construction and postconstruction management.

1. Preconstruction Studies

Baseline Monitoring

Establishing baseline functions and values of the wetland to be impacted is important in order to be able to make decisions on mitigation goals and methods with a reasonable expectation of success. Determining the value of the impact wetland in the regional wetland resource picture is also important.

Effort over a reasonably long period to define fluctuations in wetland hydrology is important to designing mitigation. Similarly, soil types should be mapped, the relation of the site to other wetland systems and surface waters should be determined, and chemical parameters which have a bearing on plant establishment should be measured in both water and soil as appropriate.

Mitigation Site Selection

Mitigation goals and objectives should be primary considerations in choosing a site. The site must be able to accommodate these goals. Whether mitigation is to be on-site or off-site, it is recommended that a mitigation site be chosen that can have maximum interaction with other wetlands and surface water systems. Conduct preconstruction monitoring of the mitigation site to the extent necessary to define hydrological parameters and site limitations.

Mitigation Plans

Mitigation designs should be detailed enough to provide sufficient direction to contractors. Good ideas can only be implemented if they appear on the working plans. Designs should specifically address the goals and limitations that are determined through baseline monitoring and site analyses. They should also include a detailed sequence of construction operations along with any special provisions needed to address special construction items. The following design guidelines are recommended:

(1) Delineate the boundaries of the proposed mitigation site.

(2) Provide pathways for natural water fluctuation patterns and for the influx of nutrients and organic matter from natural systems as appropriate. Identify water supply sources and connections to existing surface and groundwaters, including tidal fluctuations if appropriate.

(3) Determine the final grade elevations that are likely to support the desired plant community, based on hydrological investigations.

(4) Grading plans should use gradual, continuous slopes especially within portions of a site that are within 2 ft (0.6 m) above or below the expected average water table. "Gradual" means no steeper than 10:1 and preferably flatter than 20 or 30:1. Most natural wetlands are nearly flat. This basic characteristic makes possible the performance of typical wetland functions.

(5) Incorporate meandering shoreline configurations whenever possible to provide protected coves and cover, and to promote favorable interspersion of vegetation with open water and other vegetation covertypes.

(6) Plans should include a layer of topsoil (minimum 6 in [15.2 cm]) on the mitigation site that will provide a suitable growth medium for planted materials, or contains natural plant propagules which make planting unnecessary. Wetland topsoil alone can often be more effective at establishing the desired vegetative cover than plantings.

(7) Select plant species that are adaptable to the proposed hydrologic and substrate characteristics. Select materials from sources as near the site as possible to provide genotypes compatible with the site region. Specify planting schedules, methods and handling/storage protocols.

(8) Provide for a minimum 75-ft (22.9-m) band of woody vegetation or unmowed herbaceous vegetation, either by allowing existing vegetation cover to remain undisturbed or by planting and seeding. This buffer can be part of the wetland and need not increase the size of the mitigation project.

2. Construction Monitoring

Monitor construction activities to ensure that mitigation plans are accurately implemented in the field. A team consisting of a construction supervisor, surveyor and a biologist can best provide this oversight and suggest plan modifications that may be necessary to fulfill goals.

3. Remediation

Mitigation sites should be monitored after construction is complete to assess the effectiveness of design elements. Any problems encountered should be remedied to the extent possible. Some adjustments may be considered permit modifications and would require regulatory approval. Such remedies may include regrading, replanting, fertilizing, adjustment of water levels (where possible), irrigation and fencing. Remediation funds should be dedicated at the mitigation planning stage, so that an eventual lack of funds does not lead to the ultimate failure of the mitigation project. Remediation costs and activities can be minimized through careful planning, design and implementation. Highly engineered wetland creation projects (i.e., those having water control structures on uplands, etc.) are likely to require remedial measures as the "bugs" are worked out.

4. Postconstruction Management

Long-term postconstruction management and maintenance activities should be designed to promote the development of desired mitigation site characteristics. For instance, development of surrounding cover is important but cannot occur if a site is subjected to the normal right-of-way mowing regimen. Care and funds spent in seeding and plantings can be wasted if predation is not controlled (e.g. - geese, carp), or if herbicides are applied for aesthetic reasons.

Postconstruction monitoring should occur for as long a period as is necessary to determine that specific goals have been met. Generally a 3- to 5- year period is sufficient, but certain goals or wetland types (e.g., forested wetlands) may require longer time. If appropriate expertise and organizational mechanisms are not available, it may be desirable to transfer management and/or monitoring responsibilities to a resource agency or other appropriate party.

APPENDIX A:

FUNCTIONAL ANALYSES OF PRIMARY SITES

1. Lake Hunter, Florida

Results of the WET 2.0 and Hollands-Magee functional assessment or significantly different (>15 points) raw scores for the mitigation IA and the control are discussed. Results are shown in table 9.

Social Significance

Only one function differs in its probability rating between the mitigation and control sites. WET 2.0 rated the recreation function as low for Lake Bonnet and high for Lake Hunter. Lake Hunter has a walking path and is regularly used for recreation. Private land abuts most of Lake Bonnet's AA preventing regular, public, recreational use. All remaining social significance probabilities were identical among the sites assessed by WET 2.0. Hollands-Magee ranked the education value higher (18 points) in Lake Hunter than Lake Bonnet. All inputs were identical except vegetation subtype richness. The presence of a greater variety of emergent vegetation increases the education value of a wetland.

Effectiveness

Results of the WET 2.0 assessments for Lakes Hunter (AA) and Bonnet were identical. Probability ratings for the mitigation area itself (IA) were lower, however, for two of the wildlife diversity/abundance functions: breeding and wintering. The IA's small size was the reason for the low ratings. All other inputs applying to these two functions were identical to those for Lakes Hunter and Bonnet AA's.

Opportunity

Opportunity probability ratings were high for all three functions evaluated by WET 2.0. The rating for floodflow alteration was based on two presumptions: (1) that a high percentage of impervious surface area is present, and (2) the wetland is a small proportion of its watershed. This maximizes the opportunity to perform this function. The opportunity for performing the sediment/toxicant retention and nutrient removal/transformation function was rated high because sources of these pollutants are present.

Table 9. WET 2.0 and Hollands-Magee model results for the Lake Hunter, Florida mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0									Hollands-Magee
	Social Significance			Effectiveness			Opportunity			
	Mit		Ctl	Mit		Ctl	Mit		Ctl	IA
	IA	AA		IA	AA		IA	AA		Mit v. Ctl[1]
Groundwater Recharge	M	M	M	L	L	L	-[2]	-	-	0
Groundwater Discharge	H	H	H	L	L	L	-	-	-	-
Floodflow Alteration	H	H	H	M	M	M	H	H	H	0
Hydrologic Support	-	-	-	-	-	-	-	-	-	- 5
Sediment Stabilization	H	H	H	M	M	M	-	-	-	-10
Sediment/Toxicant Retention	M	M	M	L	L	L	H	H	H	-
Nutrient Removal/Transformation	H	H	H	L	L	L	H	H	H	-
Water Quality	-	-	-	-	-	-	-	-	-	0
Production Export	-	-	-	M	M	M	-	-	-	-
Biological Function	-	-	-	-	-	-	-	-	-	+ 5
Wildlife Diversity/Abundance	M	M	M	-	-	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	-	L	H	H	-	-	-	-
Wildlife Diversity for Migration	-	-	-	L	L	L	-	-	-	-
Wildlife Diversity for Wintering	-	-	-	L	M	M	-	-	-	-
Aquatic Diversity/Abundance	M	M	M	M	M	M	-	-	-	-
Uniqueness/Heritage	H	H	H	-	-	-	-	-	-	-
Recreation	H	H	L	-	-	-	-	-	-	+ 4
Education	-	-	-	-	-	-	-	-	-	+18

Notes: H = high, M = moderate, L = low, U = uncertain, Mit = mitigation, Ctl = control

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -5 means that the mitigation wetland received a score 5 points lower than the control's score.

[2]function not evaluated

2. Wetland D, Iowa

Social Significance

Model results differed for only two of the functions evaluated under social significance. Wetland D's value based on its support of aquatic diversity or abundance received a moderate WET 2.0 probability rating. The original wetland received a high probability due to the presence of the grass pickerel which is a State-threatened species of extremely limited occurrence in Iowa. It is not known whether the species inhabits wetland D; therefore, a high rating for this function could not be conferred. The fact that Iowa is losing wetlands faster than the national loss rate precludes a low rating. Subjective observations suggest that these rankings may be reversed, however. Although both wetlands are somewhat isolated from productive downstream surface waters by beaver dams, wetland D is lower in elevation and therefore likely to be inundated more often by floodwaters that could carry a variety of fish species. On the other hand, the original wetland probably had better habitat than wetland D for the support of a diverse assemblage of aquatic organisms other than fish.

Hollands-Magee scored the mitigation site 19 points lower than the original control for education. This resulted primarily due to factors contributing to a lower biological function rating such as poor vegetation/water and covertype interspersion and low vegetative density. However, Hollands-Magee does not take into account the fact that wetland D is a constructed wetland which may have as much if not more educational value than a natural wetland, notwithstanding its biological value.

Effectiveness

Four of the 11 functions evaluated by WET 2.0 for effectiveness resulted in lower probabilities for the mitigation than the control, six matched the control, and one (groundwater recharge) lacked sufficient information for a definitive analysis.

Groundwater Recharge

Wetland D received an uncertain rating for groundwater recharge capability by a default process built into the model when neither high nor low criteria are met. The probability of the control wetland having recharge capability was low. The presence of a permanent outlet, but only ephemeral (surface water) inlets suggests net discharge, not recharge. The mitigation wetland's inlet and outlet are permanent. According to WET 2.0 logic, a wetland that is permanently flooded with a permanent outlet cannot have a high

Table 10. WET 2.0 and Hollands-Magee model results for the Marquette, Iowa mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0									Hollands-Magee	
	Social Significance			Effectiveness			Opportunity				
	MitD	Ct1O	Ct1B	MitD	Ct1O	Ct1B	MitD	Ct1O	Ct1B	Mit v.Ct1O	Mit v.Ct1B[1]
Groundwater Recharge	M	M	M	U	L	L	-[2]	-	-	+ 6	+ 11
Groundwater Discharge	M	M	M	M	M	M	-	-	-	-	-
Floodflow Alteration	H	H	H	H	H	H	M	H	M	- 22	- 26
Hydrologic Support	-	-	-	-	-	-	-	-	-	+ 4	+ 1
Sediment Stabilization	M	M	M	M	H	H	-	-	-	+ 4	+ 2
Sediment/Toxicant Retention	M	M	H	H	H	H	M	H	H	-	-
Nutrient Removal/Transformation	H	H	H	M	M	M	L	L	L	-	-
Production Export	-	-	-	M	M	M	-	-	-	-	-
Water Quality	-	-	-	-	-	-	-	-	-	- 21	- 23
Biological Function	-	-	-	-	-	-	-	-	-	- 23	- 22
Wildlife Diversity/Abundance	H	H	M	-	-	-	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	-	L	H	L	-	-	-	-	-
Wildlife Diversity for Migration	-	-	-	L	H	M	-	-	-	-	-
Wildlife Diversity for Wintering	-	-	-	L	L	L	-	-	-	-	-
Aquatic Diversity/Abundance	M	H	M	L	M	L	-	-	-	-	-
Uniqueness/Heritage	H	H	H	-	-	-	-	-	-	-	-
Recreation	L	L	L	-	-	-	-	-	-	+ 14	+ 11
Education	-	-	-	-	-	-	-	-	-	- 19	- 24

Notes: H = high, M = moderate, L = low, U = uncertain, Mit = mitigation, Ctl = control, MitD = mitigation wetland D, Ct1O = original control wetland, Ct1B = wetland B (secondary control)

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +6 means that the mitigation wetland received a score 6 points higher than the control's score.

[2]function not evaluated

recharge potential. The location of the Marquette wetlands at the base of a valley confirmed the likelihood of discharge over recharge.

Floodflow Alteration

Wetland D received a Hollands-Magee score 22 points lower than the control for floodflow alteration due to its low vegetation density, its permanently flooded hydrologic regime, and its location at the base of a drainageway. The control's vegetative cover slows the passage of floodwaters. Its hydrologic regime allows for additional water storage. Hollands-Magee did not take into account the importance of these wetlands' location within the floodplain of a major river (the Mississippi). Their floodflow alteration capabilities were ranked high by WET 2.0 primarily due to this juxtaposition.

Sediment Stabilization

The mitigation wetland received a slightly lower probability for providing sediment stabilization than the control. Extent of emergent vegetation was the key to the moderate versus high probability ranking. Although not considered in WET 2.0, the comparatively low density of the vegetation in wetland D was also an important factor. The lack of a broad, densely vegetated zone in wetland D reduced its ability to dissipate erosive forces. However, observations indicated that erosive forces were lacking in the control while the mitigation area had a large expanse of open water of sufficient depth and extent for the formation of waves. Open water was a factor in the WET 2.0 model for this function but the specification was that water greater than 6.6 ft (2.0 m) deep must be dominant by area. The majority of wetland D was assumed to be shallower.

Water Quality

The mitigation AA received a Hollands-Magee score 21 points lower than the original control for the water quality protection function. Predominance of open water and low vegetation density are the primary reasons for this difference. Sediment trapping was hindered and nutrient uptake was assumed to be low based on these physical characteristics.

Biological

Hollands-Magee scored wetland D 23 points lower than the original wetland complex for biological. The extensive open water and the poor vegetation-water and covertype interspersion in wetland D were the major factors to which the model responds. The model's emphasis for this function was on overall productivity and structural diversity rather than on habitat for any particular species.

Wildlife Diversity/Abundance

The probability of the mitigation AA providing breeding and migration habitat for wetland-dependent birds is rated lower than the control AA by WET 2.0. The factors responsible, poor interspersion of covertypes and of emergent and open water zones, were also the cause of many of the probability differences described above.

The recent alteration (i.e. excavation) of wetland D resulted in a low probability for breeding habitat. This is somewhat simplistic logic. Canada geese are known to nest in this newly-constructed wetland. Sheltered open water wetlands were rare in the area making wetland D actually quite valuable for this function.

Aquatic Diversity/Abundance

WET 2.0 analysis resulted in a low probability that wetland D supported a diverse and abundant community of fish or invertebrates. The control AA was rated moderate. As for the previous function, this was due to the "recent alteration" factor. If this was overlooked, the model would produce a high probability for this function. However, in the case of this particular function, the system's early stage of development may actually be the overriding factor. Invertebrates, and the fish (and other organisms) that depend on them for food, need time to colonize a newly-exposed area. Invertebrate surveys were not within the scope of this study, but would provide valuable insight into the relative values of the constructed and natural wetlands on this project. The original control AA ranked as moderate rather than high for this function because it has no permanent surface water inflow (the artesian flow is not surface water), and because there wasn't enough open water.

Recreation

The Hollands-Magee model scored the mitigation site 14 points higher than the control for recreation. This was one part of the model for which a large amount of open water had a positive effect. This illustrated that a wetland cannot usually rate high for all functions, because the same characteristic can produce different, sometimes opposite values, for different functions.

Opportunity

Two of the three functions rated for opportunity, floodflow alteration and sediment/toxicant retention, produced ratings for wetland D that were slightly lower than for the control AA. The exposed, compacted ground of the railroad yard comprised most of the control's watershed. It was therefore assumed by WET 2.0 to be a source of toxins and sediment, and to have slow infiltration rates (related to floodflow alteration). Even though this same watershed was a subset of wetland D's watershed, it was not the dominant portion and it was not in the Input Zone (within 300 ft (91.4 m) of the AA's boundary) of wetland D. Watershed infiltration rate seemed to dominate the WET 2.0 probability rating for floodflow alteration opportunity. Wetland D's location and hydrologic connections suggested, however, that the opportunity to provide this function was high.

Overview

Characteristics of the mitigation AA such as its early stage of development, lack of emergent vegetation and low covertype diversity weighed heavily in the results of the functional analysis. Of the eight functions evaluated for wetland D using the Hollands-Magee models, half scored substantially lower and half scored slightly higher than the wetland that was intended to be replaced. Using WET 2.0, probabilities of functional capability (effectiveness) for the mitigation versus the primary control were equal for six functions and lower for five.

Many of these functional shortfalls were primarily attributable to the mitigation area's early stage of development. But characteristics such as emergent fringe and shoreline shape were related to the physical morphology of the basin which were not expected to change substantially with time.

The secondary control wetland B (see table 10) most often received the same or lower model rankings than the original control. This was supported by a comparison of written and photographic records of the original wetland with direct observations of wetland B. Obvious functional impairments resulted from the filling, clearing and partitioning of the original 8.6-ac (3.4-ha) wetland. Structural diversity decreased and water quality improvement and protection capabilities were reduced by the replacement of densely-vegetated marshland with deep, sparsely-vegetated pools (wetlands A and D). Based on the mitigation goals set forth in project environmental documentation, comparison of the mitigation with the original wetland (primary control) provided a more accurate measure of success than comparison with wetland B.

3. Galesburg, Illinois

The results of the evaluation models are similar as was expected because the conceptualization of the mitigation wetland and the control wetland differed only in that the mitigation wetland included the wildlife enhancement pond. The mitigation AA and control AA also had the same watershed and service areas.

Social Significance

For 2 of the 10 functions assessed by WET 2.0 for social significance the mitigation wetland received higher ratings than the control. Hollands-Magee rated the mitigation significantly higher for only one function relating to social significance: education.

The mitigation wetland received a high and the control a medium probability that the wildlife diversity/abundance function of the wetland was socially significant. The reason for this was the > 1-ac (0.4 ha) area of open water in the wildlife enhancement ponds in the mitigation wetland vs. no open water in the control.

By virtue of the mitigation wetland being publicly owned and subject to improvements and research it is rated high by WET 2.0 for the probability its uniqueness/heritage aspects are socially significant.

The Hollands-Magee model rated the mitigation 17 points higher than the control for educational value due to the added diversity of the open water wetland habitat of the mitigation.

Effectiveness

Effectiveness probability ratings for the mitigation and control wetlands differed for 2 of the 11 functions assessed by WET 2.0: wildlife diversity/abundance for breeding and aquatic diversity/abundance. The mitigation wetland received higher scores because the ponds have limited emergent vegetation zone and open water whereas the control wetland did not.

Overview of Model Results

The functional analysis models indicated that the wetland mitigation ponds have enhanced the probability that a greater diversity and abundance of wildlife will use the wetland.

Table 11. WET 2.0 and Hollands-Magee model results for the Galesburg, Illinois mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	M	U	U	-[2]	-	0
Groundwater Discharge	M	M	M	M	-	-	-
Floodflow Alteration	M	M	H	H	H	H	0
Hydrologic Support	-	-	-	-	-	-	0
Sediment Stabilization	H	H	M	M	-	-	0
Sediment/Toxicant Retention	M	M	H	H	H	H	-
Nutrient Removal/Transformation	M	M	H	H	H	H	-
Water Quality	-	-	-	-	-	-	0
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	0
Wildlife Diversity/Abundance	H	M	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	H	L	-	-	-
Wildlife Diversity for Migration	-	-	L	L	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	M	M	M	L	-	-	-
Uniqueness/Heritage	H	M	-	-	-	-	-
Recreation	L	L	-	-	-	-	+3
Education	-	-	-	-	-	-	+17

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +7 means that the mitigation wetland received a score 7 points higher than the control's score.

[2]function not evaluated

4. Schaumburg, Illinois

There are no significant differences in the Hollands-Magee model results between the mitigation and control wetlands.

Social Significance

For 2 of the 10 functions assessed by WET 2.0 for social significance the mitigation received a higher rating than the control. These functions were sediment and toxicant retention and uniqueness/heritage. In both cases the mitigation received a high and the control a moderate probability rating that these wetland functions are socially significant at this location.

The sediment and toxicant retention received a high rating because the mitigation was perceived by WET 2.0 as protecting the retention pond immediately downstream from the wetland as a highly socially significant function. In the control wetland there was no retention pond.

The uniqueness/heritage function was deemed high for the mitigation because this wetland is now owned and maintained by the Town of Schaumburg and it is part of a wetland mitigation project. These differences model outputs are the result of the mental constructions necessary to apply WET 2.0 and do indicate qualitatively meaningful differences in the probability that functions occur.

Effectiveness

Effectiveness probability ratings for the mitigation and control wetlands differed for 5 of the 11 functions assessed by WET 2.0: floodflow alteration, sediment stabilization, sediment and toxicant retention, nutrient retention and transmission, wildlife diversity and abundance.

Floodflow Alteration was lower for the mitigation wetland because WET 2.0 perceived the exit culvert as carrying water out of the wetland faster than would be the case in the control wetland. In reality provision was made for flood protection in the placement of the culvert and retention pond. The culvert outlet is approximately 1 ft (0.3 m) above normal water level and the retention pond is designed to store the overflow volume and attenuate the release of water from the site.

Sediment stabilization is higher for the mitigation because the culvert inlet and outflow allows the wetland to process more sediment. The

Table 12. WET 2.0 and Hollands-Magee model results for the Schaumberg, Illinois mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	M	L	L	-[2]	-	+2
Groundwater Discharge	H	H	L	L	-	-	-
Floodflow Alteration	H	H	M	H	H	H	+4
Hydrologic Support	-	-	-	-	-	-	+8
Sediment Stabilization	M	M	H	L	-	-	0
Sediment/Toxicant Retention	H	M	H	M	H	H	-
Nutrient Removal/Transformation	H	H	M	H	H	H	-
Water Quality	-	-	-	-	-	-	+7
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	0
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	M	-	-	-
Wildlife Diversity for Migration	-	-	H	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	M	M	M	M	-	-	-
Uniqueness/Heritage	H	M	-	-	-	-	-
Recreation	L	L	-	-	-	-	+8
Education	-	-	-	-	-	-	+13

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +2 means that the mitigation wetland received a score 2 points higher than the control's score.

[2]function not evaluated

sediment toxicant retention is higher because the mitigation wetland has been managed for stormwater detention due to the diversion of runoff water into the wetland.

The nutrient removal and transmission function was lower for the mitigation because WET 2.0 assumes the outlet culvert removes water faster than would be the case in the control wetland, i.e., without culvert outlets water would remain longer in the wetland and would more likely function for nutrient removal and transmission.

Wildlife diversity and abundance for breeding is lower for the mitigation because of the proximity to human activity, i.e., the parking lot. The dead Cottonwoods do, however,provide additional nesting sites for birds.

Overview of Model Results

The differences in the model results stem in most cases from the mental construction necessary to apply the WET 2.0 methodology. For instance, the control wetland was envisioned before the parking lot construction, so it would indeed have less human activity than the mitigation and be more likely to function as wildlife diversity/abundance for breeding.

The culvert outlet and inlets are important to several wetland functional probabilities. The WET 2.0 questions usually ask about presence or absence. The outlet culvert is well above the normal water level in the wetland and it is questionable whether this culvert functions in removing water from the wetland and is as important to wetland functions as implied by the WET 2.0 methodology.

In any case the detailed investigations necessary to indicate how directing runoff into the wetland has changed the wetland were not addressed by these models. The results of the models imply that the same functions are performed by the wetland and after the parking lot development. The obvious exception is that this wetland would have been more likely to function for wildlife diversity/abundance for breeding if the parking facility had never been built next to it. How much, in reality, the parking facility is disturbing breeding species is beyond the rather gross probability estimates of the WET 2.0 outputs. The opening of the wetland by peripheral trees has increased the higher and more stable water level and zone/water interspersion and nesting locations for wildlife.

5. Patuxent River, Maryland

Social Significance

Six of the 10 functions evaluated by WET 2.0 for their social significance were rated lower for the mitigation than the control. Two others, floodflow alteration and uniqueness received a slightly higher probability for social significance in the mitigation than the control.

Groundwater Recharge and Discharge

The control received a moderate probability that these functions are performed at a level that is of value to society, while the mitigation ranked low. WET 2.0 makes this distinction because the control is located in an urban area and is quite large in proportion to the service area watershed.

Floodflow Alteration

According to WET 2.0 model rationale, the social significance of the control's performance of this function is imparied (low) because a municipal sewage treatment plant is located adjacent to the AA. The presence of houses within the floodplain of the mitigation area's downstream service area accounts for its higher probability rating for this function. However, the mitigation wetland's watershed is very small. This fact (not considered in the model) lowers the wetland's ability to provide this function because very little stormwater enters it except during the 10-year storm as overflow from Green Branch.(26)

Sediment Stabilization

The control received a high probability for stabilizing sediments to a socially valuable degree because it appears to act as a buffer to significant features including a shopping center, sewage treatment plant and housing. The mitigation wetland does not have these features.

Sediment/Toxicant Retention

The control and mitigation received high and moderate probabilities for this function, respectively. The occurrence of fish spawning areas downstream of both AA's that are sensitive to siltation is reason enough for WET 2.0 to confer a moderate rating.(80) The control's higher probability is due to its location in an urban area and its relatively large size.

Table 13. WET 2.0 and Hollands-Magee model results for the Patuxent River mitigation (Mit) and control (Ctl) wetlands at Bowie and Laurel, Maryland.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	L	M	L	L	-[2]	-	-43
Groundwater Discharge	L	M	H	H	-	-	-
Floodflow Alteration	M	L	M	H	M	H	-16
Hydrologic Support	-	-	-	-	-	-	+ 3
Sediment Stabilization	L	H	H	H	-	-	-28
Sediment/Toxicant Retention	M	H	H	L	H	H	-
Nutrient Removal/Transformation	M	H	H	H	L	H	-
Water Quality	-	-	-	-	-	-	-24
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	-15
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	H	H	-	-	-
Wildlife Diversity for Migration	-	-	H	L	-	-	-
Wildlife Diversity for Wintering	-	-	H	H	-	-	-
Aquatic Diversity/Abundance	L	M	M	M	-	-	-
Uniqueness/Heritage	H	M	-	-	-	-	-
Recreation	L	L	-	-	-	-	- 1
Education	-	-	-	-	-	-	- 8

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -43 means that the mitigation wetland received a score 43 points lower than the control's score.

[2]function not evaluated

Nutrient Removal/Transformation

The difference in probabilities for this function between the mitigation (moderate) and the control (high) is due again to the location and size factors described above.

Aquatic Diversity/Abundance

The control ranks a higher probability of social significance for this function than the mitigation simply because of its location in an urban area.

Uniqueness/Heritage

By virtue of its status as a managed and protected resource which has received a substantial public expenditure ($190,000), the mitigation site received a high social significance probability for this function.

Recreation

This is ranked low for both sites because of access to recreation areas and access restrictions. Although the mitigation site has good road access and was planned for recreational use it is gated and barred and general public access is limited.

Effectiveness

Three of the 11 functions eveluated by WET 2.0 in terms of performance capability differed between the mitigation and control wetlands. The mitigation area rated higher for two of these, sediment/toxicant retention and wildlife diversity, than did the control. The Hollands-Magee model ranked the mitigation substantially lower than the control for most of the functions evaluated.

Groundwater Recharge

The mitigation received a Hollands-Magee score 43 points lower than the control because the mitigation is primarily a discharge wetland as evidenced by the springs. In addition, the pond's clay liner is assumed to have low transmissivity in relation to the control wetland's substrate. The control's numerous inlets, its large size and the moderate transmissivity of its underlying soils earn it a higher rating for recharge. WET 2.0 rated both areas with low probability for this function because they have factors that suggest discharge conditions.

Floodflow Alteration

The probability that the mitigation wetland is capable of performing this function is lower than the control because of the extent of unvegetated openwater at the site. The dense vegetation in the control and its large size contribute to its high rating. The vegetation helps slow the flow of floodwaters and its size and location in the floodplain of the Patuxent River makes it more likely to be capable of performing this function.

The Hollands-Magee model scored the mitigation 16 points lower than the control for floodflow alteration due also to the predominance of open water and the low vegetative density in the mitigation area. Lack of surface water inlets and small size are additional factors leading to this difference. However, Hollands-Magee does not consider the flood storage value of the mitigation area that is designed to occur during the 10-year storm when flow from the Green Branch can enter the basin.

Sediment Stabilization

The Hollands-Magee score for sediment stabilization in the mitigation wetland was 28 points lower than the control. The Bowie site's low emergent stem density in combination with its large expanse of open water is not effective at stabilizing shoreline soils.

Sediment/Toxicant Retention

WET 2.0 predictors for evaluating this function are based more on the opportunity for erosion than the capability of a wetland to retain sediments and toxicants. For example, the control's probability is low because the banks of the Patuxent River flowing through the AA show signs of erosion due to high velocity flow during high water. Characteristics of the mitigation wetland such as the shelter provided by adjacent topography and vegetation, and the stable water levels provided by the dam are the reason for the high sediment/toxicant retention probability given by WET 2.0. Substrate and emergent zone characteristics are not of great significance in the analysis of this function by WET 2.0.

Water Quality

The mitigation received a Hollands-Magee score 24 points lower than the control mainly due to the lack of emergent vegetation suitable for filtering and retaining sediments and for taking up nutrients.

Biological Function

The biological function score for the mitigation is 15 points lower than the control. The Hollands-Magee model considers a predominantly open water wetland to have less habitat value than a forested wetland due to lack of cover. The size difference of the two AA's is also an important factor in this model in terms of habitat.

Wildlife Diversity/Abundance for Migration

WET 2.0 ranked the mitigation area high for the probability of providing favorable habitat for waterfowl in migration. The pond's irregular shape and the shelter provided by adjacent wooded hillsides make it a desirable resting spot for migrating waterfowl. The lack of open water and the regularity of the vegetative cover in the control result in a low probability being conferred by WET 2.0 for this function.

Opportunity

The opportunity for the performance of two of the three functions evaluated by WET 2.0 is lower for the mitigation than the control. Favorable infiltration rates for soils in the watershed of the mitigation area decreases the opportunity for the wetland to provide floodflow alteration services. The large proportion of impervious surfaces in the control's urbanized watershed, on the other hand, increases the opportunity for providing this service. Likewise, the potential for nutrient inputs to the control from urban runoff and sewage effluent enhances the opportunity for nutrient removal and transformation. The mitigation area's low probability for nutrient removal/transformation opportunity results due to lack of a permanent surface water inlet.

Overview

WET 2.0 analysis indicates that functional capabilities (effectiveness and opportunity) of the mitigation wetland are comparable to those of the impacted wetland (control). Many of the functional probabilities differ in terms of Social Significance; however these ratings hinge on size and location factors rather than attributes of the wetlands themselves.

Functional analysis using the Hollands-Magee models yielded almost opposite results from WET 2.0. All but one of the eight functions evaluated ranked lower in the mitigation; five of these differed substantially. Although Hollands-Magee utilizes some outside factors, it focuses primarily on physical characteristc of the wetland itself.

6. Stoll Road, Michigan

Social Significance

WET 2.0 modeling resulted in different probabilities for 3 of the 10 functions for which the mitigation and control were assessed for their value to society. In each case, the control rated higher than the mitigation. The remaining seven have identical probabilities. Both of the socially related functions evaluated using Hollands-Magee are substantially lower for the mitigation than the control.

Groundwater Discharge

According to the MDOT, there is a recent record of the occurrence of a Massasauga rattlesnake, a species proposed for the State threatened list, in the vicinity of the control AA and its service area.(81) The Massasauga rattlesnake favors wetland habitats. In addition, the State threatened marsh hawk is known to frequent Grass Lake.(29) The strong likelihood of occurrence of these species, which are at least partially wetland-dependent, places additional importance on the control AA's ability to maintain downgradient water levels. For this reason, the control's probability is high for providing socially-valuable groundwater discharge versus the mitigation's moderate probability. All applicable model inputs are identical except for the occurrence of threatened species.

Wildlife and Aquatic Diversity/Abundance

The difference between the mitigation wetland's moderate probability and the control's high probability of providing socially valuable wildlife and aquatic features also hinges on the occurrence of certain species. The sandhill crane, a U.S. Fish and Wildlife Service species of special emphasis which is declining in Michigan, occurs regularly in the Grass Lake system.(29) The Massasauga rattlesnake is of limited occurrence in the area, but records indicate it is likely to occur in the control AA or its service area. The

Table 14. WET 2.0 and Hollands-Magee model results for the Stoll Road, Michigan mitigation (Mit) Wetland and the Grass Lake control (Ctl) wetland.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	M	U	U	-[2]	-	+17
Groundwater Discharge	M	H	M	M	-	-	-
Floodflow Alteration	M	M	H	H	M	M	-18
Hydrologic Support	-	-	-	-	-	-	-41
Sediment Stabilization	M	M	M	M	-	-	-9
Sediment/Toxicant Retention	M	M	H	H	L	H	-
Nutrient Removal/Transformation	M	M	H	H	L	L	-
Water Quality	-	-	-	-	-	-	-20
Production Export	-	-	L	L	-	-	-
Biological Function	-	-	-	-	-	-	-41
Wildlife Diversity/Abundance	M	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-	-
Wildlife Diversity for Migration	-	-	L	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	M	H	L	M	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	L	L	-	-	-	-	-21
Education	-	-	-	-	-	-	-60

Notes: H = high, M = moderate, L = low, U = uncertain

[1] Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +17 means that the mitigation wetland received a score 17 points higher than the control's score.

[2] function not evaluated

mitigation is rated at moderate importance for wildlife and aquatic functions by WET 2.0 simply because it is located in a State which is losing wetlands at a relatively rapid rate.

Recreation

WET 2.0 conferred a low probability on both the mitigation and control for their social significance regarding recreation. The rating is based on their importance for recreation and the availability of other similar resources in the vicinity.

The Hollands-Magee model, however, shows a difference of 21 points between the mitigation and the control for recreation; the latter having the higher score. Biological value (higher for the control), size, and hydrologic connection are the major factors controlling this result.

Education

Evaluation of educational value by Hollands-Magee resulted in a much lower score for the mitigation than the control (-60 points). Dominant wetland class is the major factor causing this difference. Open water, the dominant class in the mitigation, is less valuable than a bog for educational purposes according to the literature-based assumptions in Hollands-Magee. Biological value, vegetation subtype diversity and species diversity are also important factors in this result.

Effectiveness

The Stoll Road mitigation site rated lower than Grass Lake for 3 of the 11 functions evaluated by WET 2.0 for effectiveness. Of the six functions evaluated by Hollands-Magee, five differed substantially between the mitigation and control.

Groundwater Recharge

The WET 2.0 model is unable to rate the recharge probability of the wetland under study due to the lack of a particular set of either favorable or unfavorable conditions for this function. Hollands-Magee, on the other hand, scored the mitigation substantially higher (+17 points) than the control for ground water recharge. The sandy outwash material underlying the Stoll Road pond is more conducive to ground water recharge than the deep peat underlying Grass Lake.

Floodflow Alteration

WET 2.0 assigned both the mitigation and control with high probability for providing flood control benefits. These results are strongly influenced by the fact that neither wetland has an outlet. Hollands-Magee, however, scored the mitigation 18 points lower than the control due to its small size, low vegetation density and predominance of open water. These factors tend to reduce a wetland's capacity to store and desynchronize flood water flow.

Hydrologic Support

Assessed by Hollands-Magee only, the Hydrologic Support model considers a wetland's contribution to maintaining high quality downstream flows over time. The mitigation scored 41 points lower than the control (out of a possible 100) for this function. Neither wetland has a surface water outlet, but Grass Lake's hydrologic character is judged more conducive to maintaining downstream flows than is the Stoll Road site. Grass Lake is a large system located adjacent to an important surface water system (Park Lake). Its densely vegetated nature and deep organic substrate suggest a highly stable system which can cleanse the water that flows through it and slowly release that water over time to adjacent systems. The dominant open water nature of the mitigation is not considered by the model to be conducive to this type of stable hydrologic support.

Water Quality

Water quality maintenance value of the mitigation scored lower based on Hollands-Magee than the control. The difference of 20 points is due to factors such as dominant cover class, percent open water, vegetative density and size. The limited emergent cover at Stoll Road is not likely to provide for water quality improvement through filtering and uptake. Organic substrate is an important component of a wetland in regard to its capability to maintain and improve water quality, although it is not an element of this model. The organic soils underlying Grass Lake make it much more effective than the mitigation at purifying the water that moves through it.

Biological Function

Variety of covertypes and wetland size are the primary differences between the mitigation and control wetlands which result in a difference in their scores of 41 points (Hollands-Magee). The mitigation is lower due, in part, to the presence of only three cover classes (including open water) versus the control's five. In addition, Stoll Road's poor interspersion of covertypes and subtypes with each other and with open water, as well as its low species density and diversity detract from its capability to support wildlife production and use. The pond's location at the center of a clearing is not particularly conducive to wildlife use.

Wildlife and Aquatic Diversity/Abundance

These functions, assessed by WET 2.0, are analogous to the biological function as assessed by Hollands-Magee. Results are similar as well. The probability that the mitigation is capable of supporting diverse and abundant wildlife during breeding and migration is low; the control's probability is high. Probability of support for diverse and abundant aquatic life is low for the mitigation and moderate for the control. The factors named under biological, above, are also applicable to these functions.

Opportunity

Only one of the three functions evaluated by WET 2.0 in regard to opportunity, sediment/toxicant retention, received a lower probability for the mitigation than the control. Each wetland received the same probability for the other two functions. The opportunity for the mitigation site to retain sediments or toxicants is low due to the absence of a source of these pollutants within its small watershed. Grass Lake, however, is flanked by an abandoned gravel pit and agricultural land. WET 2.0 therefore confers a high probability, because the potential exists for these pollutants to enter the system.

Overview

The two methods utilized for comparing the wetland functions of the Stoll Road mitigation site with the Grass Lake impact site yielded different sets of results. Relatively few differences between the mitigation and control emerged through functional analysis using WET 2.0. In each of these instances, however, the mitigation ranked lower. Seven of the eight functions evaluated using the Hollands-Magee models differed substantially between the two wetlands; all but one were lower for Stoll Road than Grass Lake.

These differences in results stem from the different approaches and emphases of the two models. The similarities between the two wetlands as analyzed by WET 2.0 result from that model's focus on location and relationship to surroundings. Although the Hollands-Magee models also consider such factors, emphasis is on the biological and physical characteristics of the wetland itself.

7. Southern Tier Expressway, New York

Social Significance

For 6 of the 10 functions assessed by WET 2.0 for social significance, the mitigation wetland received higher ratings than the control. Hollands-Magee rated the mitigation wetland significantly higher for one function relating to social significance: education.

Groundwater Recharge and Discharge

The mitigation wetland received higher probability ratings for these functions' social significance than the control wetland. The WET 2.0 logic is not clear on the recharge aspects of this model, but the reasoning appears to be as follows: if the assessment wetland is recharging a surface aquifer, that augmented aquifer will then be more capable of replenishing downstream flows via discharge. Both Birch Run and the Allegheny are subject to critically low flows during some years.[35] Therefore, they may both be serving this function, but the mitigation wetland was given a higher rating because it is closer to the upper portion of its service area (i.e., it encompasses a section of Birch Run and is immediately upstream of the service area) than any other wetland. The control wetland, on the other hand, is one of many other wetlands similarly juxtaposed to the Allegheny service area. WET 2.0 ranks the probability of social significance lower for this function if the AA is not a "one-of-a-kind" wetland. (In this case it may be an inappropriately fine distinction, but it is one which affects the ratings for several other functions as well). The social significance ratings for groundwater discharge turn on the same distinction for these wetlands.

Floodflow Alteration

Roads and buildings are present in the floodplain of the service areas of both the mitigation and control wetlands, bestowing some social value on this function in both cases. The higher rating for the mitigation wetland is due to service area juxtaposition as described above.

Table 15. WET 2.0 and Hollands-Magee model results for the New York Southern Tier Expressway mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	L	U	U	-[2]	-	+ 8
Groundwater Discharge	H	M	M	M	-	-	-
Floodflow Alteration	H	M	H	H	M	M	- 9
Hydrologic Support	-	-	-	-	-	-	+13
Sediment Stabilization	L	L	M	M	-	-	+11
Sediment/Toxicant Retention	H	M	L	H	H	L	-
Nutrient Removal/Transformation	H	M	H	H	H	L	-
Water Quality	-	-	-	-	-	-	+ 6
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	+22
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	M	M	-	-	-
Wildlife Diversity for Migration	-	-	L	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	L	L	M	M	-	-	-
Uniqueness/Heritage	H	L	-	-	-	-	-
Recreation	L	L	-	-	-	-	+ 6
Education	-	-	-	-	-	-	+33

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +8 means that the mitigation wetland received a score 8 points higher than the control's score.

[2]function not evaluated

Sediment/Toxicant Retention

Birch Run and the Allegheny River are spawning areas for many fish species that are sensitive to siltation.[35] Both the mitigation and control wetlands are thus located where they might enhance spawning habitat in those service areas. Only the juxtaposition of the mitigation wetland with Birch Run earns it a higher social significance rating than the control.

Nutrient Removal/Transformation

It was assumed for this evaluation that Birch Run is somewhat nutrient sensitive, based on observed algal blooms in early summer. The mitigation wetland is adjacent to and downstream of tilled agricultural fields. The large size of the Allegheny River and the mostly forested nature of its watershed may make the control wetland less sensitive to nutrients. There are, however, documented occurrences of elevated nitrogen levels in this stretch of the Allegheny and the large amount of agricultural land in the region suggests that it may be a recurring problem.[35] Thus, nutrient removal by either wetland is considered by WET 2.0 to have some social value. The mitigation wetland received a higher rating due to the juxtaposition distinction.

Uniqueness/Heritage

Since the mitigation wetland is held for the primary purposes of conservation and ecological enhancement, and it is part of an ongoing monitoring program, it was rated high for this function. The control wetland is not managed for similar purposes, nor does it possess any qualities particularly rare or unique in this region. It therefore received a low rating for this function.

Education

This model (Hollands-Magee) is based on such elements as wetland type, vegetation diversity and other habitat values, local scarcity of similar wetlands, and legal accessibility. The mitigation wetland's habitat values outlined above, the relative scarcity of emergent marshes in the region, and its accessibility to the public are considered by this model to make it more valuable as an education resource than the control wetland.

Effectiveness

Effectiveness probability ratings for the mitigation and control wetlands differed for only 2 of the 11 functions assessed by WET 2.0: sediment/toxicant retention and wildlife diversity/abundance for migration. For both functions, the mitigation wetland received low ratings and the control high.

The scores for the mitigation and control wetlands differed substantially (>15 points) for two of the eight functions evaluated by the Hollands-Magee models: biological and education. Biological function results will be discussed here; education was discussed in the text.

Sediment/Toxicant Retention

A high rating for this function is conferred by WET 2.0 where velocities, vegetation, and substrates create a depositional environment. The control wetland is situated where it is periodically inundated by Allegheny River floodwaters which subsequently exit via a narrow outlet, a configuration considered by WET 2.0 to be especially favorable for sediment deposition. Furthermore, the wetland is sheltered by an upland barrier from the high velocities of the river at floodstage, and it supports adequate erect vegetation to further reduce velocities. The mitigation wetland also has low velocities and a constricted outlet, but the outlet flows permanently which is assumed by the model to reduce depositional effectiveness.

Sediments and toxicants will enter the mitigation wetland four ways: (1) from Birch Run into pond 5; (2) from the Birch Run Tributary via Ponds 10, 9, and 8; (3) from the nearby agricultural fields via overland flow; and (4) from highway runoff via overland flow. The high turbidity of pond 5 is due apparently to the presence of carp who root in the mud and resuspend previously settled sediments. Much carp activity was observed during field visits for this study.

Some of the sediments entering these waters, along with toxicants adsorbed to suspended particles, are likely to drop out due to low velocities. The bands of emergent vegetation between ponds 5 and 6, and ponds 6 and 7, create sites of further deposition. Certain toxicants will be taken up by vegetation and later deposited as detritus. The abundant submerged vascular and filamentous algal vegetation in this wetland may contribute significantly to toxicant retention. Bacteria in the water and sediments can further act to break down pollutants such as hydrocarbons. Unfortunately, the carp activity may somewhat counteract the depositional environment elsewhere in the wetland. Much of the sediment stirred up by carp in pond 5 will remain in the water column and exit the wetland at pond 5's outlet.

It is expected that the sparse and narrow band of emergent vegetation at the mitigation wetland's periphery will become denser and broader over time. More emergent vegetation will create more frictional drag on these waters and improve the wetlands capability for retaining sediments. At present, the wetland probably serves this function to a moderate degree.

Wildlife Diversity/Abundance for Migration

The WET 2.0 model looks at size, vegetation type, diversity, interspersion, and juxtaposition with other wetlands, waterbodies, and agricultural lands to assess a wetland's suitability for water-dependent birds during migration. The control wetland's location on a large river, its primarily wooded character, and its large size all contribute to its high rating for this function. The low rating for the mitigation wetland was due primarily to the poor interspersion of water and vegetation, and the poor interspersion of vegetation types.

The sparcity of cover and the small size may be the main shortcomings of the mitigation wetland for migration habitat. The open water will attract migrating waterfowl in need of a temporary resting spot, but they will seek larger and more heavily vegetated areas for prolonged stopovers. Future emergent and shrub growth in this and the nearby demonstration and mitigation ponds may make the area more attractive to passing waterfowl.

Biological Function

The biological function model (Hollands-Magee) looks at general biological and physical habitat features for fish and wildlife species. The mitigation wetland received a much higher score (22 points) than did the control for this function. The pivotal elements were wetland type, class, subclass richness, and the presence of open water. A deep emergent marsh is considered by Hollands-Magee to be more valuable to a greater array of species than a wooded swamp. The presence of several classes and subclasses (open water, deep and shallow marsh, wet meadow, robust and narrow-leaved emergent) further enhance its habitat value. The control wetland is largely a monotypic forested wetland with a small area of shrub swamp. There is little open water except during flood events which are short-lived.

It is, of course, difficult to assess the relative biological value of these two wetlands. The control wetland is a mature bottomland forest on a large river serving a large watershed. Its proximity to the River makes it accessible to fish and wildlife using the river and other adjacent wetlands. Although it is characterized by a single cover type, wooded swamp, it has great internal structural diversity, including submerged vasculars, emergents, shrubs, saplings, and trees. Furthermore, it is effectively isolated from human disturbance by its location at the foot of a steep embankment for the Southern Tier Expressway. It is likely to be used by a great variety of species for nesting or hunting.

The mitigation wetland also supports some vegetative form diversity. The presence of permanent open water will make it attractive to a different group of species than the control. The sparsity of emergent vegetation, the visual exposure and proximity to the Southern Tier Expressway, and the physical accessibility to humans may limit its use by some species. The large amounts of filamentous algae observed in June may create, upon dying, low dissolved oxygen conditions, which can be detrimental to fish and other aquatic organisms. The turbidity created by carp will discourage the development of emergents and of other aquatic life. Wetlands containing open water, however, are more scarce in this region than are wooded swamps. Those with reasonably healthy biota may therefore make a more important incremental contribution to the regional biological diversity.

Opportunity

Opportunity probability ratings for the mitigation and control wetlands differed for two of the three functions assessed by WET 2.0: sediment/toxicant retention and nutrient removal. Due to its location downstream of both a gravel pit and agricultural fields, the mitigation wetland received high ratings for both functions. The control site is located downstream of the confluence of Chipmunk and Tunungwant Creeks with the Allegheny River. These creeks are bordered by developed oil fields and have been subject to hydrocarbon pollution in the past contributing to fish kills in the Allegheny.(35) There are no reports of recent occurrences. Nutrients, pH, and DO are well within State standards along this stretch of the Allegheny. Total coliform concentrations, however, substantially exceeded State standards in the summer months of 1986, the only year for which recent water quality data were available.(82)

The absence at the control site of immediate sources of nutrients, sediments or toxins somewhat reduces its opportunity to serve the sediment/toxicant retention and nutrient removal functions. Its largely forested watershed and the absence of a permanent inlet may further reduce the sediment and nutrient load entering the wetland. The control wetland received low ratings for both functions.

Overview of Model Results

Although mitigation for wetlands filled for construction of the Southern Tier Expressway was out-of-kind, differences in functional values are caused more by locational factors than by ecological differences, according to WET 2.0 results. The Hollands-Magee model places more emphasis on wetland type and ecological structure, resulting in a different set of values.

Overall, WET 2.0 results indicate there is an equal or greater probability that the mitigation wetland is performing the same functions as the control. There are two exceptions to this generalization: probabilities for performance of sediment/toxicant retention and wildlife diversity/abundance function for migration are rated lower for the mitigation than the control due to location. Size is also an important factor. Many of the higher probabilities relating to social significance result from a single model input. The model places great importance on assessment area location relative to its service area.

Hollands-Magee ranks most of the functions higher for the mitigation than the control. The emergent marsh/open water wetland type is generally favored by this model which assumes that this type affords more educational opportunities than a forested wetland, as well as better biological support.

8. West Branch French Creek, Pennsylvania

Social Significance

Neither the north mitigation, the control, nor their service area possessed any of the special features that might have earned them a high social significance rating for groundwater recharge, groundwater discharge, floodflow alteration, sediment/toxicant retention, or nutrient/removal transformation. Nor did the mitigation possess any of the four pivotal attributes necessary for a moderate rating. The control, however, met one of these criterion: its acreage represented approximately 3.6 percent of the total wetland acreage in the service area's watershed, which is much greater than the 0.35 percent annual wetland loss rate for the Atlantic flyway in general. WET 2.0 rationale for this calculation is not at all clear, but this alone resulted in the control's moderate social significance rating for all five functions listed above.

Uniqueness/Heritage

Uniqueness/Heritage is the only other social significance function for which the mitigation and control wetlands received different WET 2.0

Table 16. WET 2.0 and Hollands-Magee model results for the West Branch French Creek, Pennsylvania north mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	L	M	U	U	-[2]	-	-17
Groundwater Discharge	L	M	M	M	-	-	-
Floodflow Alteration	L	M	H	H	H	H	-3
Hydrologic Support	-	-	-	-	-	-	-11
Sediment Stabilization	L	L	M	M	-	-	-10
Sediment/Toxicant Retention	L	M	H	H	H	H	-
Nutrient Removal/Transformation	L	M	H	H	H	H	-
Water Quality	-	-	-	-	-	-	-7
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	+2
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-	-
Wildlife Diversity for Migration	-	-	H	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	L	L	L	M	-	-	-
Uniqueness/Heritage	H	M	-	-	-	-	-
Recreation	L	L	-	-	-	-	-1
Education	-	-	-	-	-	-	+3

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -17 means that the mitigation wetland received a score 17 points lower than the control's score.

[2]function not evaluated

ratings. The mitigation wetland received a high rating for this function because it is part of a long-term environmental research and monitoring program, and its creation involved substantial public expenditures. The control wetland is not part of any public or private environmental research or management project, nor is it known to contain any rare natural or historical features, so it was not eligible for a high rating. It received a moderate rating, however, because it contains a broad range of hydroperiods, from permanently flooded to intermittently flooded, so it is assumed by WET 2.0 to possess considerable habitat diversity.

Effectiveness

Groundwater Recharge

The north mitigation received a Hollands-Magee score 17 points lower than the control for the groundwater recharge function. The control's size presents a much larger surface area over which potential recharge may occur, and its many inlets suggest a larger available water supply.

Wildlife Diversity/Abundance for Breeding

The north mitigation received a low WET 2.0 rating for wetland bird breeding habitat simply because of its recent alteration. If that is overlooked it would otherwise have received a high rating. Conditions contributing to the high rating include: (1) its location near a large acreage of other accessible wetlands; (2) its favorable vegetation/water interspersion; (3) the presence of several vegetation classes and subclasses; (4) the presence of special habitat features in and around the mitigation area, such as fruit- and cone- bearing shrubs, wood duck boxes and large-diameter trees; and (5) its fine mineral substrate.

The control received a high rating for many of the same reasons: its large size, its plant form diversity; the presence of fruit- and cone-bearing trees and large-diameter trees; and substrates of organic and fine mineral soils.

Aquatic Diversity/Abundance

The north mitigation received a low WET 2.0 rating for aquatic diversity/abundance simply because of its recent alteration. It would otherwise have received a high rating due to the combination of many favorable conditions: its location near a large acreage of other accessible wetlands; the presence of permanent surface water; the presence of both emergent and open water zones; the absence of toxin sources; the absence of significantly elevated suspended solids; a fine mineral substrate; warm bottom temperatures; favorable pH; high plant form diversity; the presence of adequate fish cover in accessible wetlands; the presence of a permanent inlet and outlet; and the presence of an aquatic bed class. The control received a high rating for identical reasons, with the exception of the last.

Overview of Model Results

The north mitigation and the control wetland received differing effectiveness ratings for only three functions: groundwater recharge, wetland bird breeding habitat, and aquatic habitat. The mitigation received lower ratings than the control for each of these. For the latter two, however, were it not for the fact that the wetlands had been altered within the last three years, the mitigation wetland would have received identical ratings to those of the control. The difference in ratings for the recharge function is also somewhat artificial. It is based largely on the difference in size between the two assessments areas, which is owing more to the delineation procedures than to qualities of the wetlands themselves. Such similar scores are to be expected from two wetlands underlain by similar surficial geology, and with similar relationships to the hydrology of the West Branch. The north mitigation received high WET 2.0 effectiveness probability ratings for floodflow alteration, sediment/toxicant retention, and nutrient removal/transformation, and would have received high for wildlife migration and aquatic diversity/abundance if not for its recent disturbance during construction. These appear to be reasonable judgements for all three basins, although it is likely that the original wetland in which the north and west basins were constructed were more effective at serving the first three of these functions. The greater vegetative density in the original wetland would provide greater frictional resistance to flood waters, better depositional conditions for sediments, and greater nutrient uptake. The presence of open water areas in the mitigation wetlands, however, has probably improved the waterfowl breeding habitat and the aquatic habitat over that which existed in the original wetland.

To assess the functional values of these wetland areas, a control wetland was sought that would approximate the vegetation types and the hydrology of the filled wetlands. The WET 2.0 method, however, requires that any assessment area encompass all contiguous wetland with a high degree of hydrologic interaction. In this case, the control was therefore delineated as an area much larger than the wetland area that was actually filled for road construction. Size alone accounts for all of the differences in social significance ratings between the north mitigation and the control, except for the uniqueness/heritage function. Size and related features account for all of the substantial differences in Hollands-Magee scores for these two wetlands. The model results must therefore be interpreted with great care. Any comparison between the functional ratings of the north mitigation and the control should not be used to assess actual net gains or losses of wetland functional capability accruing from the road construction and mitigation projects, because the control was not delineated to reflect the functional capability of the filled wetlands themselves.

The mitigation project appears to have succeeded at improving local wildlife habitat. Wetlands are common in the region but most lack standing open water. The numerous farm ponds in the vicinity have limited value for wildlife: (1) most are located in view of residences and regular human activity; (2) most lack protective vegetative cover at their perimeters; and (3) most have round or rectangular configurations, uniform slopes, and they lack islands or other topographic irregularities. The mitigation wetlands, on the other hand, were designed to provide plenty of topographic and vegetative cover. The irregular shorelines and islands will act to limit sight distances, and provide topographic and vegetative cover for wildlife. Water and vegetation are well interspersed, and plant form diversity can be expected to improve as these wetlands mature. The shrub plantings are doing well; they will eventually provide cover, perching sites, and food for wildlife. The presence of many attributes favorable to aquatic habitat will promote a good food supply for fish and other aquatic organisms.

The wetland's various locations in relation to the West Branch will provide a range of flooding regimes. The north mitigation and the west basin will periodically receive nutrients and aquatic organisms from West Branch floodwaters to augment those from their regular input sources. All are adjacent to diverse wetland and upland habitats, so will be accessible to a wide variety of wildlife species and have themselves added to the local habitat diversity. The presence of open water, islands, and woodduck boxes will improve the local waterfowl habitat. Many plant food species attractive to waterfowl, songbirds, and other wildlife are present in and around these wetlands: fruit-producing shrubs, coontail, pondweed, duckweed, sedges, spikerush (*Eleocharis* spp.), burreed, cattail. Numerous wildlife species using the wetlands have been reported and observed.

9. Sweetwater River, California

Social Significance

The mitigation and control wetlands received identical WET 2.0 social significance ratings for all but the recreation function. The control received a high rating for recreation because there is evidence that it is used regularly for horseback riding. CALTRANS reports that it used seasonally by hunters, and evidence of considerable foot traffic was observed during the site visit for this study. The mitigation wetland received a low rating

Table 17. WET 2.0 and Hollands-Magee model results for the Sweetwater River, California mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	M	U	U	-[2]	-	-15
Groundwater Discharge	H	H	M	M	-	-	-
Floodflow Alteration	M	M	H	H	M	M	+9
Hydrologic Support	-	-	-	-	-	-	-8
Sediment Stabilization	M	M	L	L	-	-	0
Sediment/Toxicant Retention	H	H	L	H	H	H	-
Nutrient Removal/Transformation	H	H	H	L	H	H	-
Water Quality	-	-	-	-	-	-	+2
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	+12
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	L	-	-	-
Wildlife Diversity for Migration	-	-	L	L	-	-	-
Wildlife Diversity for Wintering	-	-	M	L	-	-	-
Aquatic Diversity/Abundance	M	M	L	L	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	L	H	-	-	-	-	-16
Education	-	-	-	-	-	-	-10

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -15 means that the mitigation wetland received a score 15 points lower than the control's score.

[2]function not evaluated

because the fence erected to exclude horses and off-road vehicles (ORV) probably discourages other uses. The mitigation also received a lower (-16 points) Hollands-Magee score for recreation than the control. This was primarily owing to its small size, its relative inaccessibility from roads, and its shrubby, as opposed to wooded, nature. Hollands-Magee considers shrub wetlands to be generally less valuable for recreation than wooded wetlands, perhaps because of their physical and visual inaccessibility.

Effectiveness

Groundwater Recharge

The control wetland received a Hollands-Magee score 15 points higher than the mitigations primarily because of the presence of several inlets and the permanent stream channel, indicating a larger water supply for recharge, and its large size. The presence of standing water in the control for much of the winter season would indeed suggest an opportunity for recharge through these sandy soils. If recharge does occur, however, it is probably restricted to the near-surface substrata, or else moves horizontally over the geologic dike that confines the underlying aquifer. Recharge from the mitigation site will be neglible because it is rarely inundated, and it is not topographically shaped to detain precipitation runoff.

Sediment/Toxicant Retention

The control received a high rating for sediment/toxicant retention because of the great breadth of the vegetated zone, and the absence of significant erosion within the wetland. The mitigation received a low rating because of its small, narrow configuration; and its lack of a constricted outlet.

The control's sandy soils with little organic matter are not well suited to retaining and stabilizing toxicants.[83] But the presence of braided channels, numerous depressions and pools, and areas of dense shrub growth are favorable for sediment deposition. The mitigation area with its terrace-like configuration only rarely receives sediment-laden floodwaters, and will not retain them for long.

Nutrient Removal/Transformation

The mitigation wetland received a high WET 2.0 rating because of the low velocity of flooding waters, the fine alluvial soils with little organic matter, the dominance of shrub vegetation, and the good vegetation class diversity. The control received a low rating because of the medium sand substrate, the poor vegetation class diversity, and the absence of surface water during the growing season, except in the channel itself.

The mitigation site's finer soils are presumably more effective than the control's medium sand at adsorbing phosphorus or at trapping nutrients in interstitial waters. Furthermore, although not recognized by the WET 2.0 model, the mitigation has considerably more herbaceous vegetation than the control, so is likely to have a greater capability for nutrient uptake. It is subject, however, to only rare flooding of short duration, so will have much less opportunity than the control to process water-borne nutrients.

Wildlife Diversity/Abundance for Wintering

The control received a low rating for wintering habitat for wetland-dependent birds because of the poor vegetation/water and vegetation class interspersion, the poor vegetation class diversity, and the absence of a significant emergent zone. The mitigation wetland received a moderate rating mainly owing to the adequate diversity and interspersion of vegetation classes.

The model may have exaggerated the mitigation site's relative value for wintering habitat. What constitutes vegetation class diversity and interspersion on this site is in many places just the patchiness resulting from failed plantings. In some areas where shrubs are absent the herbaceous growth is extremely sparse. The overall primary productivity on the site is not high. The shrub vegetation averages 6 to 10 ft (1.8 to 3.0 m) in height, and there is no protective overstory canopy. At this stage in its development it does not have either the vegetative density or the structural complexity ordinarily associated with highly productive habitats.

Overview of Model Results

The functional evaluation models were used to compare a small created shrub wetland with a large, mature wooded wetland, a portion of which was filled or degraded during bridge construction. The control assessment area is many times larger than either the area directly impacted by the bridge, or the mitigation wetland. For some functions, particularly those associated with wildlife habitat, the bridge construction is likely to have some adverse effects extending well beyond the area of direct impact. Losses of other functions, however, are probably limited to incremental losses occurring at fill sites themselves. Such functions as floodflow alteration, hydrologic support, the water quality functions, and production export fall into this latter group. For interpretation of model results, it should be remembered that the control's ratings and scores do not reflect the actual functional losses from bridge construction, but are simply probability assessments of functions provided by the whole riparian wetland.

The mitigation wetland received lower ratings than the control for groundwater recharge and sediment/toxicant retention functions. Size was a major factor in these results, so actual net losses in functional capability cannot be inferred from this comparison. Owing to its basin shape, channel complexity, and flooding frequency the control indeed seems better suited to serving these functions. Any recharge will be shallow, but not unimportant to the local and downstream environments.

The mitigation received higher model ratings than the control for nutrient removal and for wintering bird habitat, but these may be overstated. The mitigation site is poorly located and shaped for receiving and retaining nutrient-laden waters, even though its soils and vegetation may be more capable of processing nutrients than those in the control. The structural immaturity, exposure, and deficiency of vegetative cover will limit its value for wintering birds. These conditions, however, are likely to improve.

10. Lake George, Minnesota

Social Significance

Neither of the mitigation wetlands, the control, nor their service areas possessed any of the special features that might have earned them a high social significance rating for groundwater recharge, groundwater discharge, floodflow alteration; sediment/toxicant retention or nutrient removal/transformation. Nor did the mitigation sites possess any of the four pivotal attributes necessary for a moderate rating. The control, however, met one of these latter criteria: it represents 2.2 percent of the total wetland acreage in its service area's watershed, which is greater than the annual wetland loss rate of 0.67 percent for the Central Flyway region. (A rationale for this calculation is not offered in the WET 2.0 manual.) Therefore, the control received a moderate rating for the five functions listed above, and the mitigation wetlands received low ratings.

The mitigation and control ratings differed for only one other WET 2.0 social significance function, uniqueness/heritage. The mitigation wetlands received a high rating because they are part of an ongoing research and environmental monitoring program. The control received only a moderate rating because it is not part of any public or private environmental research or management project, nor is it known to contain any rare natural or histori-

Table 18. WET 2.0 and Hollands-Magee model results for the Lake George, Minnesota pond 3A, Schoolcraft River, and control wetlands.

	WET 2.0									Hollands-Magee	
	Social Significance			Effectiveness			Opportunity			PD3A	SCH.R
	PD3A[2]	SCH.R[3]	Ctl[4]	PD3A	SCH.R	Ctl	PD3A	SCH.R	Ctl	V. Ctl	V. Ctl[1]
Groundwater Recharge	L	L	M	L	L	L	-[5]	-	-	+25	+32
Groundwater Discharge	L	L	M	H	H	M	-	-	-	-	-
Floodflow Alteration	L	L	M	H	H	H	M	M	M	-18	-5
Hydrologic Support	-	-	-	-	-	-	-	-	-	-1	-43
Sediment Stabilization	M	M	M	M	M	M	H	H	L	+2	+10
Sediment/Toxicant Retention	L	L	M	M	H	H	L	L	L	-	-
Nutrient Removal/Transformation	L	L	M	H	H	L	-	-	-	-	-
Water Quality	-	-	-	M	L	M	-	-	-	-	-5
Production Export	-	-	-	-	-	-	-	-	-	-26	-
Biological Function	-	-	-	-	-	-	-	-	-	-14	+10
Wildlife Diversity/Abundance	M	M	M	-	-	-	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	-	M	M	M	-	-	-	-	-
Wildlife Diversity for Migration	-	-	-	L	H	L	-	-	-	-	-
Wildlife Diversity for Wintering	-	-	-	H	H	H	-	-	-	-	-
Aquatic Diversity/Abundance	M	M	M	M	M	M	-	-	-	-	-
Uniqueness/Heritage	H	H	M	-	-	-	-	-	-	-	-
Recreation	L	L	L	-	-	-	-	-	-	+12	0
Education	-	-	-	-	-	-	-	-	-	-8	+16

Notes: H = high, M = moderate, L = low, U = uncertain

[1] Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +25 means that the mitigation wetland received a score 25 points higher than the control's score.

[2] PD 3A = mitigation Pond 3A

[3] SCH.R = Schoolcraft mitigation wetland

[4] Ctl = control wetland

[5] function not evaluated

cal features. Since it represents, however, a significant proportion of the wetland acreage in its service area's watershed, it did not receive a low rating.

The Schoolcraft River wetland received a Hollands-Magee score 16 points higher than the control for the education function simply because the model considers a shallow marsh to be more valuable for educational purposes than a shrub swamp. This is due to the greater possibility for visual or physical accessibility. Pond 3A is also, in fact, a shallow marsh, but due to a quirk in the Hollands-Magee classification system, it is not designated as such. The estimated proportional composition of pond 3A is as follows: 40 percent open water, 30 percent robust shallow marsh, and 30 percent wet meadow. Even though the vegetated classes constitute the greatest proportion of the wetland, open water is still the largest single class, and is therefore considered dominant for purposes of Hollands-Magee evaluation.

Effectiveness

Groundwater Recharge

Pond 3A and the Schoolcraft River mitigation wetland received Hollands-Magee scores 25 and 32 points higher, respectively, than the control's score, primarily due to differences in surficial geology. According to the 1930 Hubbard County Soil Survey, the mitigation sites are underlain by glacial outwash, suggesting a highly transmissive aquifer. The control is underlain by glacial till which may act as a barrier to groundwater movement.

Groundwater Discharge

Pond 3A and the Schoolcraft River wetland each received a high rating for groundwater discharge. In this dry region, the presence of permanent standing water in these wetlands in spite of their small watersheds and lack of inlets suggests either active discharge from springs, or an intersection with the water table. The control received only a moderate rating because it is only intermittently flooded, and it has intermittent inlets and outlets. The local topography, however, favors discharge so it did not receive a low rating.

Pond 3A received higher ratings than the control for groundwater discharge and nutrient removal/transformation, and a lower rating for sediment/toxicant retention.

The WET 2.0 model for groundwater discharge assesses only the likelihood that discharge exceeds recharge at these sites on a net annual basis. It does not attempt to predict the volume of discharge, nor can any relative volumes be inferred from the results. The elements considered by the model indeed show strong evidence of discharges occurring here. Furthermore, the springs observed in pond 3A, and the "pumping up" phenomenon encountered by the equipment operator during excavation are symptoms of active discharge. It is impossible to know whether the absence of surface outflow in spite of inflow from small springs during the field visit was due to the occurrence of shallow recharge or simply to evapotranspiration. The borrow area as a whole, however, located as it is on an outwash plain with only a discontinuous clay lense, may be the site of as much recharge as discharge, particularly during extended dry periods when the water table is depressed. If the control wetland is in fact situated over glacial till, it is likely that net annual discharge will exceed recharge.

Floodflow Alteration

Pond 3A received a Hollands-Magee score 18 points lower than the control wetland primarily because of the large proportion of open water, the lower vegetation density, and its small size.

Hydrologic Support

The Schoolcraft River mitigation wetland received a Hollands-Magee score 43 points lower than the control primarily because it has no outlet. The model does not consider the support function provided by through-ground exchange.

Sediment/Toxicant Retention

The Schoolcraft River wetland received a high rating because it has no surface water outlet. Any sediments or toxicants entering the wetland will remain there or will percolate into the groundwater. The model does not consider export of toxicants via groundwater. The control wetland received a high rating because it is densely vegetated throughout, and it has a constricted outlet. These features will prolong the residence time for water passing through and create a depositional environment.

Pond 3A received only a moderate rating mainly because of the narrowness (<500 ft [152.4 m]) of the vegetated zone. It did not receive a low rating, however, mainly because of the low water velocity, and the substantial emergent and submergent zones.

Nutrient Removal/Transformation

Pond 3A received a high rating for this function because of the low water velocity, the clay substrate,and the dominance of persistent emergent vegetation. The Schoolcraft River wetland received a high rating simply because it has no outlet. Any nutrients entering the wetland will not be exported via surface waters.

The control wetland received a low rating for nutrient removal/transformation because of the lack of nutrient source, the organic surface soils, and the lack of a permanent surface water throughout most of the wetland. The model gives no weight to the importance of organic soils to nitrogen retention and to the dentrification process.

Production Export

The Schoolcraft River wetland received a low rating for production export because it has no outlet. Any wetland with a surface water outlet will receive at lease a moderate rating. Pond 3A therefore received a moderate but not a high rating because there is no appreciable surface water flow; thus, little flushing of plant material will occur.

The control wetland received only a moderate rating because it has a small watershed (<1 mi^2 [2.6 km^2]), and the dominant vegetation class is shrub swamp. The model would, however, grant a high rating to a similar wetland dominated by aquatic bed or emergent vegetation. The control has quite a dense ground cover of sedges, cattails, and other species, but that is overlooked by the model, which only considers the dominant class.

Water Quality

Pond 3A received a Hollands-Magee score 26 points lower than the control's score primarily because of its small size, the absence of a surface water inlet, the moderate vegetation density, and the dominance of the open water class. If the model instead recognized the dominance of herbaceous vegetation, the difference between pond 3A's and the control's scores would be reduced by 7 to 11 points.

Wildlife Diversity/Abundance for Migration

Both pond 3A and the control wetland received a low rating for migrating wetland bird habitat due to their poor vegetation class interspersion, poor vegetation/water interspersion and their low vegetation class diversity. The Schoolcraft River wetland received a high rating due to the favorable vegetation/water proportions and interspersion, the good vegetation class interspersion (aquatic bed and persistent emergent), the abundance of waterfowl food species (*Potamogeton, Carex, Juncus, Lemna, Eleocharis*), the proximity of other large wetlands, and the absence of regular human disturbance.

Opportunity

Sediment Stabilization

The two mitigation wetlands received a high rating for sediment stabilization opportunity because their disturbed, poorly vegetated watersheds constitute a potential sediment source. The control wetland received a low rating because of its forested watershed with a large acreage of upslope wetlands, the absence of erosive conditions, the absence of potential sediment sources, and the absence of a permanent inlet.

Overview of Model Results

The functional evaluation models were used to compare created emergent marshes with a mature, natural shrub swamp. A shrub swamp was chosen for the control because it is the most ubiquitous wetland type in the region, and therefore the most likely to be affected by future road projects. Differences in habitat values and hydrologic functions are to be expected in such a comparison. Differences and similarities in model results should be used, however, not to judge the success or failure of the mitigation ponds, but rather as a starting point for considering the probable functional losses incurred from wetland filling for road construction. Each of the mitigation wetlands received ratings differing from the control for 3 of the 10 functions evaluated by WET for effectiveness. Pond 3A received higher ratings than the control for groundwater discharge, and nutrient removal/transformation; and a lower rating for sediment/toxicant retention. The Schoolcraft River wetland received higher ratings than the control for nutrient removal/transformation, and wildlife-migration, and a lower rating for production export.

Pond 3A - Groundwater Exchange

Pond 3A received higher WET 2.0 rating that did the control for groundwater discharge, but also a higher Hollands-Magee score for groundwater recharge. For these functions, WET 2.0 mainly considers general topography, surface hydrology and surface soil conditions, while Hollands-Magee gives greater weight to surficial geology. The actual nature of net annual groundwater exchange cannot be predicted at either of these sites without more information.

Pond 3A - Water Quality

Pond 3A received a higher WET 2.0 rating than the control for nutrient retention/transformation; a lower rating for sediment/toxicant retention, and a lower Hollands-Magee score for overall water quality maintenance. Although the WET 2.0 models ostensibly look for features contributing to a depositional environment when assessing water quality functions, in this instance the model's logic sequence permitted the small size of pond 3A to be the pivotal feature for its sediment/ toxicant retention rating. The WET 2.0 nutrient model attributes great significance to the P-removal potential of a clay substrate, but overlooks the N-removal potential of an organic substrate. Furthermore, it recognized the dominance of persistent emergent vegetation in pond 3A but overlooks the high density of herbaceous vegetation in the control, simply because the wetland is classified as a shrub swamp. The Hollands-Magee water quality model considers pond 3A's small size, its lack of inlets (and thus lack of nutrient and toxicant sources) and its moderate vegetation density, but gives inordinate weight to the open water area as described earlier. These treatments illustrate some of the potential shortcomings of broad brush modeling approaches to complex interactions in natural systems.

There are many indications that the control would be highly effective at retaining sediments, toxicants, and nutrients. The hummocks and tussocks, and the dense woody and herbaceous vegetation would effectively dampen flows, trap and stabilize sediments, and take-up nutrients. There is sufficient organic matter to support decompositional activity necessary for denitrification.

Pond 3A with its ephemeral outlet has considerable retention capability. The vegetation density is likely to increase, and will provide significant nutrient uptake capability. The clay substrate may act to stabilize phosphorus. Its location, however, in what will eventually be protected lands will reduce the likelihood that it will ever receive significant nutrient or toxic inputs. Thus, any nutrient and toxicant retention values of a wetland filled for road construction would not in fact be replaced by a wetland such as pond 3A due to its location.

Pond 3A - Floodflow Alteration

Pond 3A received a Hollands-Magee score lower than the control's for floodflow alteration owing to the high proportion of open water, the moderate vegetation density and its small size. This is probably a reasonable assessment even though it possesses some flood storage capability. Furthermore, its small watershed reduces its opportunity to serve this function. The cumulative impact of many such small headwater wetlands, however, is probably significant.

Schoolcraft River mitigation - Groundwater Exchange

The Schoolcraft River mitigation wetland, like pond 3A, received a higher WET 2.0 rating than the control's for groundwater discharge, but also a higher Hollands-Magee score for groundwater exchange. As for pond 3A, the actual nature of net annual groundwater exchange cannot be predicted without more hydrographic and geological information.

Schoolcraft River - Hydrologic Support

Since it has no surface water outlet, the Schoolcraft River mitigation wetland was deemed substantially incapable of providing hydrological support to downstream systems. The high degree of through-ground exchange, however, suggests that this wetland acts like a detention basin and indeed may help maintain base flows in the Schoolcraft River.

Nutrient Removal/Transformation and Production Export

Also owing to the lack of an outlet, the Schoolcraft River wetland received a higher score than the control for nutrient removal, and a lower score for production export. Except during extreme floods, there will indeed be no organic matter discharged from this wetland. The WET 2.0 model ignores the possibility of nutrients percolating to the groundwater from a closed basin. Nonetheless, this wetland appears to have sufficient water retention capability and vegetation density to serve the nutrient removal function to some degree.

Migrating Bird Habitat

It was primarily the exceptional interspersion of open water with vegetation that earned the Schoolcraft River wetland a high WET 2.0 rating for this function. In spite of its small size and limited structural diversity, this may be a reasonable assessment, particularly since there are other nearby wetlands to provide both space and habitat diversity.

Education

The Hollands-Magee education model is based on very simple assessments of such elements as habitat richness, physical accessibility and local scarcity. It is not capable of detecting the educational opportunities inherent in the ecological complexities of a mature natural wetland, as opposed to the relatively simple interactions in a newly created wetland. Nonetheless, the Schoolcraft River wetland is both visually and physically accessible, and is an interesting example of a created wetland in an early successional stage.

The functional evaluation scores are very similar because the mitigation wetlands and the natural marsh are hydrologically connected and have the same vegetation type, species and wetland hydrology. These wetlands would likely be providing the same functions.

11. Rancocas Creek, New Jersey

Effectiveness

Results of the WET 2.0 functional assessment are identical for the mitigation and control wetlands with the exception of one rating under effectiveness. Nutrient removal/transformation is rated medium for the natural marsh because the model assumes that the presence of an outlet reduces retention time, thereby reducing effectiveness for this function. The mitigation has all the same features as the control that pertain to nutrient removal effectiveness. However, since the mitigation is a recently altered system (i.e., recently constructed), the model rates its probability of effectiveness at performing this function as low. Vegetation density in the mitigation is not yet on par with the natural marsh.

The Hollands-Magee wetland function evaluation models were developed for glaciated inland wetlands and have not to our knowledge been used for tidal wetlands. The results of these models for tidal wetlands should therefore be considered tentative. The lower Hollands-Magee scores for the Mitigation wetland reflect the lack of provision for the hydrology of tidal channels in these models compared to the mitigation as a small wetland, low in the watershed along a small stream (the tidal channel) which would have less chance of performing the functions of sediment stabilization and hydrological support. The control is previewed by the models as an extensive emergent wetland adjacent to the open water of the river. The differences in scores in this case do not indicate a real difference in wetland function.

Table 19. WET 2.0 and Hollands-Magee model results for the Rancocas Creek, New Jersey mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit V. Ctl[1]
Groundwater Recharge	M	M	L	L	-[2]	-	-11
Groundwater Discharge	M	M	M	M	-	-	-
Floodflow Alteration	M	M	L	L	L	L	+1
Hydrologic Support	-	-	-	-	-	-	-25
Sediment Stabilization	M	M	H	H	-	-	-21
Sediment/Toxicant Retention	H	H	H	H	H	H	-
Nutrient Removal/Transformation	H	H	L	M	H	H	-
Water Quality	-	-	-	-	-	-	+7
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	-4
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	L	-	-	-
Wildlife Diversity for Migration	-	-	H	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	M	M	M	M	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	L	L	-	-	-	-	+6
Education	-	-	-	-	-	-	+6

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -11 means that the mitigation wetland received a score 11 points lower than the control's score.

[2]function not evaluated

Overview of Model Results

The four differences in model results appear to be due more to the artificial conceptualizations required by WET 2.0 and the lack of provision for tidal hydrology in the Hollands-Magee models, than to differences in fact. The mitigation IA is in reality part of the control AA wetland, share the same watershed and service area, and have similar wetland vegetation hydrology. Because the control AA is the larger wetland it encompasses more wetland vegetation type and diversity. However, the same functions likely occur in both wetlands.

12. Wilmington, North Carolina

Social Significance

The probability ratings for the mitigation and control wetlands differed for 3 of the 10 functions assessed by WET 2.0 for social significance: floodflow alteration, sediment stabilization, and uniqueness/ heritage.

Floodflow Alteration

The probability that the mitigation is of value to society for altering floodflow is rated high while the control is rated low by WET 2.0. The model produces a low score if a pollution source or buildings are located such that they may be inundated by flooding of the AA. A package wastewater treatment plant is located in a residential area adjacent to the control as are recently developed residential areas.[84] The mitigation is rated high because it does not have any such features and because it is located in an urban area. WET 2.0 does not consider the fact that the mitigation area is located so high in the local watershed that it probably has very little opportunity to perform this function. The social significance models focus more on potential.

Sediment Stabilization

The control wetland received a high rating for this function largely because of the presence of residential settlements within the 100-year floodplain adjacent to the control. The wetland may act to buffer such areas from the erosive force of Smith Creek floodwaters. The mitigation site is not located where it could act as a buffer to socially valuable features, but its location in an urban area is enough to earn a moderate rating from WET 2.0 for social significance.

Table 20. WET 2.0 and Hollands-Magee model results for the UNC-Wilmington, North Carolina mitigation (Mit) wetland and the Smith Creek control (Ctl) wetland.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	M	M	L	U	-[2]	-	+2
Groundwater Discharge	M	M	H	L	-	-	-
Floodflow Alteration	H	L	M	H	M	H	-14
Hydrologic Support	-	-	-	-	-	-	-12
Sediment Stabilization	M	H	H	H	-	-	-21
Sediment/Toxicant Retention	M	M	L	L	H	H	-
Nutrient Removal/Transformation	M	M	L	L	L	M	-
Water Quality	-	-	-	-	-	-	-27
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	-5
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-	-
Wildlife Diversity for Migration	-	-	L	L	-	-	-
Wildlife Diversity for Wintering	-	-	H	M	-	-	-
Aquatic Diversity/Abundance	M	M	L	M	-	-	-
Uniqueness/Heritage	H	M	-	-	-	-	-
Recreation	L	L	-	-	-	-	+11
Education	-	-	-	-	-	-	-3

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee results are in the form of the raw score point difference between the mitigation and control wetlands (range 0-100). +2 means that the mitigation site received a score 2 points higher than the control for that function.

[2]function not evaluated

Uniqueness/Heritage

The mitigation wetland received a high rating for this function because it is owned and managed by a public institution for the purposes of ecological enhancement, research, and education. The control wetland was given a moderate rating because its location in an urban area is considered by WET 2.0 to give it some social value.

Effectiveness

The effectiveness probability ratings for the mitigation and control wetlands differed for 5 of the 11 functions assessed by WET 2.0: groundwater discharge, groundwater recharge, floodflow alteration, wildlife-breeding, and aquatic diversity/abundance. The mitigation wetland received a lower rating than the control for the latter four functions.

The Hollands-Magee results differed substantially (>15 points) between the mitigation and control wetlands for two of eight functions evaluated: sediment stabilization and water quality. The mitigation site received lower scores than the control for both functions. In addition, the mitigation scored 14 points lower for floodflow alteration than the control.

Groundwater Recharge

The mitigation wetland received a low rating by WET 2.0 for this function because it is spring fed, and therefore assumed by WET 2.0 to be the site of greater net annual discharge than recharge. The mitigation site, however, is underlain by fine sand over Castle Hayne Limestone and Peedee Sandstone aquifers, which constitute the primary and secondary recharge systems in this region.[85] It is likely that considerable recharge and discharge occur at this site.

In the absence of such obvious indicators of discharge, and in the absence of obvious impediments to recharge, such as an impermeable substratum, WET 2.0 gives most wetlands an uncertain rating unless a level 3 assessment is performed. The control wetland was therefore rated uncertain. It too, though, is underlain by sandy soil over the same limestone and sandstone aquifers, so probably serves a significant recharge function.

Groundwater Discharge

The mitigation wetland received a high rating by WET 2.0 for groundwater discharge because it is fed almost entirely by springs. The control wetland received a low rating because there was no evidence of springs, and the local topography did not suggest the presence of a low elevation head or low pressure head that might favor discharge. Furthermore, the appearance of Smith Creek, with its deeply entrenched bed, suggests highly unstable flows controlled by precipitation events.

Floodflow Alteration

The control wetland's large size, constricted outlet, and broad floodplain which is unsaturated under normal conditions, are the primary contributors to its high rating by WET 2.0 for this function. WET 2.0 considers wetlands that are permanently flooded to be less valuable for floodwater storage; hence the mitigation wetland's moderate rating. The model, however, does not take into account the large capacity of this deeply excavated, steep-sided pit with a constricted outlet. The mitigation site may, in fact, be very effective at detaining floodwaters, but the small watershed will provide little floodwater runoff.

The Hollands-Magee model also rated the mitigation wetland less valuable than the control for floodwater storage. This model looks at such elements as wetland type, size, vegetative density, topographic position, surficial geologic material, and status of inlets and outlets. The sparse vegetation, high proportion of open water, lack of surface water inlets, and smaller size account for the mitigation site's lower score.

Sediment Stabilization

The sediment stabilization model (Hollands-Magee) considers vegetative density, wetland type, surficial geologic material, fetch and water depth. The mitigation wetland received a much lower score than the control because of the sparseness of the vegetation at the periphery, and the large expanse of deep open water, capable of generating erosive waves. Signs of erosion are common in the mitigation pond.

The control wetland is forested, with a moderately dense understory and ground layer. Such conditions will tend to bind soil and protect it somewhat from the erosive force of the flowing stream. Smith Creek, however, flows in a deeply entrenched streambed whose cut-away banks show that significant erosion indeed occurs there.

Water Quality

The water quality model (Hollands-Magee) looks at features affecting the residence time for water, and the uptake, deposition, adsorption, or degradation of pollutants. Such features include wetland type, vegetative density, hydrologic complexity, topographic configuration, status of inlets and outlets, and size. The mitigation wetland received a much lower rating (-27 points) than the control for this function because of the large expanse of unvegetated water, with only sparse peripheral vegetation, and the absence of surface water inlets. The control site, on the other hand, is almost entirely forested, has two perennial inlets, and is considerably larger than the mitigation site. During average flows, the unvegetated streambed will do little to enhance the water quality of Smith Creek. During flood events, however, the moderately dense vegetation throughout the floodplain will aid in the filtration and settlement of suspended solids and debris, and may take up nutrients to some extent.

Wildlife Diversity/Abundance for Breeding

WET 2.0 considers bottomland hardwoods and other floodplain wetlands to be particularly valuable for breeding birds. The control wetland received a high rating for this function because it is a large bottomland hardwood forest with many mast-, cone- and fruit-bearing species. The mitigation site received a low rating because of the recent disturbance of the site during excavation and grading. If the disturbance is overlooked, it would receive a higher rating because of its large size and its location in an area containing many other wetlands. The model does not in all cases take into account specific attributes of the wetland. The lack of vegetative cover in and around the mitigation site will greatly limit its habitat value for breeding birds.

Aquatic Diversity/Abundance

The mitigation wetland received a low rating for this function due to the recent disturbance during construction. If that disturbance is overlooked, it would receive a moderate rating for aquatic diversity and abundance, as did the control site.

The mitigation area would receive a moderate rating simply because it is a large, permanently flooded area with good water quality that remains unfrozen for most of the winter. Many other attributes, however, reduce its value for fish habitat. The sand substrate is very low in organic content and will be slow to establish an emergent zone. The upslope watershed is only 50 ac (20.3 ha), and will contribute little in the way of nutrients and organic material. The existing emergent zone is too narrow and too sparsely vegetated to constitute adequate fish cover. With no permanent surface water inlet or outlet, there is no regular access for fish and other aquatic life.

Opportunity

Opportunity probability ratings for the mitigation and control wetlands differed for two of the three functions assessed by WET 2.0: floodflow alteration and nutrient removal/transformation. The mitigation site rated lower than the control for both functions.

Floodflow Alteration

The mitigation wetland is not likely to receive large volumes of water during runoff periods because of its very small watershed, the highly permeable surficial material of the watershed, and the largely forested cover. The control wetland, however, is small in proportion to its watershed acreage, and much of the watershed is underlain by somewhat poorly to very poorly drained soils. The slow infiltration rate could lead to large runoff volumes from the watershed during heavy precipitation.

Nutrient Removal/Transformation

There is no apparent source of significant nutrient runoff into these wetlands. The small and forested watershed, and the absence of a permanent surface water inlet account for the low opportunity rating given the mitigation wetland for removal and transformation of nutrients. The control wetland was presumed to have some likelihood of nutrient inputs because of its two permanent inlets and its relatively large watershed. It received a moderate opportunity rating.

Overview

WET 2.0 is a "broad brush" model which tends to focus on wetland location, and gross watershed and site characteristics rather than site details. Results of these models therefore tend to oversimplify wetland systems. On the other hand, WET 2.0 is quite useful for providing an objective comparison of the gross characteristics of two very different systems such as Smith Creek and the University of North Carolina - Wilmington (UNC-W) mitigation area. The Hollands-Magee models focus mainly on site characteristics and somewhat less on a wetland's place in the landscape.

Only 3 of the 11 functions rated by WET 2.0 for effectiveness (i.e. functional capability) were lower for the mitigation than the control. Two of these are habitat related and result from differences in wetland type and cover. Six out of eight mitigation area functions were rated lower than the control by the Hollands-Magee models; although only two were substantially lower.

Both the mitigation and control received a high probability for sediment stabilization capability. WET 2.0's evaluative criteria for this function are as much related to opportunity as they are capability, however. For example, potential erosive forces and unsheltered areas dictate a high rating for this function. A protective characteristic must also be present. In the case of the UNC-W mitigation pond the "sand bar" located at the pond's east end is considered by WET 2.0 to be enough of a protective feature to warrant a high sediment stabilization rating. This ignores the erosion-prone nature of the bar itself and the remaining unstabilized shoreline. The Hollands-Magee sediment stabilization model is based on shoreline protection by means of dense, well-established shoreline vegetation. It scored the mitigation lower than the control.

13. Nehalem Bay, Oregon

Social Significance

Neither the mitigation, the control, nor the control's service area possessed any of the special features that might have earned them a high social significance rating for groundwater recharge, floodflow alteration, sediment/toxicant retention, or nutrient removal/transformation. Nor did they possess any of the four pivotal attributes necessary for a moderate rating, so they both received low ratings for those four functions.

Groundwater Discharge

An overriding feature in the WET 2.0 groundwater discharge model is the occurrence of critically limiting low water levels in the service area during dry periods. Although the mitigation wetland was assigned no service area, its own low water levels and those of other wetlands on the spit are limiting to wildlife, so the discharge function of this wetland was deemed quite valuable. Since the mitigation wetland, however, possessed none of the four pivotal attributes for social significance, it received only a moderate rating for groundwater discharge.

Table 21. WET 2.0 and Hollands-Magee model results for the Nehalem Bay, Oregon mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit v. Ctl[1]
Groundwater Recharge	U	U	U	L	-[2]	-	+8
Groundwater Discharge	M	L	L	M	-	-	-
Floodflow Alteration	L	L	H	H	M	H	+4
Hydrologic Support	-	-	-	-	-	-	-64
Sediment Stabilization	L	H	M	H	-	-	-25
Sediment/Toxicant Retention	L	L	H	L	H	H	-
Nutrient Removal/Transformation	L	L	H	M	H	H	-
Water Quality	-	-	-	-	-	-	-17
Production Export	-	-	L	M	-	-	-
Biological Function	-	-	-	-	-	-	-22
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-	-
Wildlife Diversity for Migration	-	-	L	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	M	-	-	-
Aquatic Diversity/Abundance	L	H	L	L	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	M	L	-	-	-	-	-29
Education	-	-	-	-	-	-	-33

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, +8 means that the mitigation wetland received a score 8 points higher than the control's score.

[2]function not evaluated

Sediment Stabilization

The control wetland received a high WET 2.0 rating for sediment stabilization because it acts as a buffer to roads and agricultural lands in an erosion-prone area. The mitigation wetland is not located where it might buffer economically or socially valuable features from water-caused erosion; nor is it part of a scarce wetland system, or located in an urban area. Hence it received a low social significance rating for sediment stabilization.

Aquatic Diversity/Abundance

The control wetland received a high rating for this function because it is believed to be rearing grounds for salmonids, including Chinook salmon, which appears on the U.S. Fish and Wildlife Service's National Species of Special Emphasis List. The mitigation wetland received a low rating because: (1) it is not known to provide habitat for any rare species or Species of Special Emphasis; (2) it is not part of a scarce wetland system; and (3) it is not located in an urban area.

Recreation

The control wetland received a low WET 2.0 rating because it is not regularly used for recreational activities and it is not part of a scarce wetland system. The mitigation wetland received a moderate rating because it is located within the Nehalem Bay State Park which is regularly used for recreation. Since it is not a regionally scarce wetland type, however, it did not receive a high rating.

The control received a Hollands-Magee score 29 points higher than the mitigation for recreational values because of its surface water connection to the Bay, its accessibility by road, its larger size, and its higher biological value as assessed by the Hollands-Magee model.

Education

The control received a Hollands-Magee score 33 points higher than the mitigation because of its accessibility by road, its vegetation species and subclass diversity, and its overall biological value as assessed by the Hollands-Magee model.

Effectiveness

Groundwater Recharge

The WET 2.0 model gives a low probability rating for groundwater recharge to all tidal riverine, marine, or estuarine wetlands because of the low elevation head at sea level. The control wetland therefore received a low rating.

Unless a level 3 WET 2.0 assessment is performed, most other wetlands receive an uncertain rating for this function except where there are known barriers to recharge (such as a pan, or soils with slow infiltration) or clear evidence of discharge (such as springs, or an outlet but no inlet). The mitigation wetland received an uncertain rating because no such conditions were present.

Groundwater Discharge

The mitigation wetland received a low probability rating for groundwater discharge because: (1) the water level extremes are not indicative of a spring-fed system; (2) the dune substratum is more favorable to recharge than to discharge; and (3) the absence of an outlet indicates the lack of a constant water inflow.

The control received a moderate rating because the local topography favors discharge over recharge; it is located at sea level near the base of a steep regional slope. There were, however, no other obvious indicators of discharge.

Hydrologic Support

The mitigation wetland received a Hollands-Magee score 64 points lower than the control's primarily because it has no surface water outlet. This model assesses a wetland's ability to retain water and discharge it to downstream systems during dry periods. The presence of an outlet is critical to such a function, hence the mitigation's low score.

Sediment Stabilization

The control wetland received a high WET 2.0 rating for sediment stabilization because the flow in slough channels and ditches creates erosive conditions that are mitigated by the adjacent zones of dense vegetation.

The mitigation wetland received a moderate rating because there are no flowing surface waters, and no significantly elevated suspended solids. The emergent vegetation throughout the basin would nonetheless serve some stabilization function. The WET 2.0 model does not look for erosive conditions, per se, but only for the presence of significantly elevated suspended solids. This appears to be an error in the model design. The coarse sand on the steep banks of the mitigation wetland, though highly erodable, will settle quickly from the water column, but such erosive conditions are invisible to this model.

The Hollands-Magee sediment stabilization model focuses on stabilization of shorelines bordering open water areas. Only wetlands situated to receive the erosive forces of currents or wind-driven waves will be given appreciable scores. The mitigation wetland received a score of zero because of the absence of unvegetated open water. The control received a somewhat higher score owing to the presence of open water sloughs bordered by densely vegetated wetlands.

Sediment/Toxicant Retention

The mitigation wetland received a high WET rating for sediment/toxicant retention simply because it has no surface water outlet. Any sediments or toxicants entering the wetland will remain there, or will percolate into the groundwater, but will not be exported to other surface water systems. The control wetland received a low rating because it is a tidal palustrine wetland with a vegetation zone narrower than 500 ft (152.4 m) and a submergent zone smaller than its open water zone. The verbal rationale in the WET 2.0 manual, however, states that only a 20-ft (6.1-m) wide zone of erect vegetation is required to obtain a high rating. The 500-ft (152.4-m) minimum specified in the model and the interpretive key may be an error.

Nutrient Removal/Transformation

The mitigation wetland received a high probability rating simply because it has no surface water outlet. Any nutrients entering the basin will remain there, or percolate into the groundwater, but will not be exported to other surface water systems. The control wetland received only a moderate rating because it possesses an outlet and the vegetated zone is narrower than 500 ft (152.4 m).

Water Quality Maintenance

The mitigation wetland received a Hollands-Magee score 17 points lower than the control's because of the only moderate vegetation density, its small size, and its lack of surface water inlets suggesting little opportunity to process polluted waters.

Production Export

The mitigation wetland received a low probability rating because the absence of an outlet prevents any surface water export. The control received a moderate rating because, even though it has a permanent outlet, the wetland comprises less than 20 percent of its watershed acreage. Thus its production contribution is assumed to be proportionately small.

Biological Function

The mitigation wetland received a Hollands-Magee score 22 points lower than the control's owing to its poor vegetation class diversity and interspersion, its low species diversity, its only moderate vegetation density, its lacks of open water, and its small size.

Wildlife Diversity/Abundance for Breeding

The mitigation wetland received a low probability rating for wetland bird breeding habitat because of (1) its recent disturbance during construction; (2) the poor interspersion of vegetation and open water; (3) the low plant form diversity; and (4) the absence of open water during much of the breeding season.

The control received a high probability rating because of (1) adequate interspersion of vegetation classes and of vegetation and water; (2) good plant form diversity; (3) its location near a large acreage of other accessible wetlands; and (4) the presence of special habitat features such as fruit-bearing shrubs (twinberry, blackberry, elder), cone-bearing trees (alder), and mudflats.

Wildlife Diversity/Abundance for Migration

The mitigation wetland received a low probability rating for habitat for migrating wetland birds for reasons similar to those listed above for breeding habitat, including poor interspersion, low plant form diversity, and lack of open water. The model, however, assesses the presence of open water only under average conditions, while, in fact, there is probably adequate standing water here during spring and late fall when the migration occurs.

The control wetland received a high probability rating because it is part of a large cluster of accessible wetlands; it is tidal; and it contains adjoining mudflat and emergent zones.

Wildlife Diversity/Abundance for Wintering

The mitigation wetland received a low probability rating for reasons similar to those listed above for waterfowl breeding and migration habitat. Here, also, the model assesses only average hydrologic conditions, while in fact there is probably adequate standing water for waterfowl use during the wet winter season.

The control received a moderate rating for wintering habitat primarily because of its adjacency and accessibility to a large wetland acreage, its adequate interspersion of vegetation types and of vegetation and open water, and its good plant form diversity.

Opportunity

Floodflow alteration was lower for the mitigation wetland than the control because of the isolated nature of the mitigation.

Overview of Model Results

The mitigation wetland received higher effectiveness ratings than the control for sediment/toxicant retention and nutrient removal/transformation, and lower ratings for groundwater discharge, hydrologic support, sediment stabilization, production export and the wildlife habitat/biological functions. The absence of an outlet is the sole reason for its higher sediment/toxicant and nutrient ratings because those models are concerned more with a wetland's contribution to downstream surface water quality than with conditions within the wetland itself or in the underlying aquifer. Although the mitigation wetland will surely retain any sediments that wash in from its banks, its vegetation and soils are not well suited to processing nutrients or toxicants, which may then be passed into the groundwater.

The mitigation's lower ratings for hydrologic support and production export are also owing to the absence of a surface water outlet. The hydrologic support model does not consider the potential support value of through-ground exchange. In a recharge wetland such as the mitigation this recharge may be significant since it is located in a land formation where fresh water is limiting. It was given low ratings for sediment stabilization by both WET 2.0 and Hollands-Magee.

These are reasonable ratings even though neither of the models was in fact assessing the wetland's capability for stabilizing sediments. Both ratings were based on opportunity-related features (i.e., presence of suspended solids and open water), but not effectiveness-related features such as vegetation density. The mitigation wetland's low groundwater discharge rating is owing to conditions suggesting that net annual discharge does not exceed recharge at this site. While this is probably true, its importance as a site of passive discharge (that is, a water table wetland) is great. It is in that capacity that it is so valuable as a drinking water source for wildlife on Nehalem Spit. The mitigation wetland's low ratings for habitat-related functions are owing to the poor structural and species diversity, the poor vegetation and water interspersion, and the absence of open water. While these shortcomings will greatly limit its habitat value, its importance as a watering hole is nonetheless notable.

The above functional analysis and discussion is based on a comparison of model results for the mitigation and control wetlands. For several reasons however, such a comparison should not be used to assess actual net gains or losses of wetland functions accruing from the road construction and mitigation projects.

The road-widening project resulted in the filling of a narrow wetland strip along the existing road embankment. To assess the functional value of this strip, a control area was sought that would approximate the vegetation types and the hydrology of the wetland area that was filled. The WET 2.0 method, however, requires that any assessment area encompass all contiguous wetland with a high degree of hydrologic interaction. Consequently, the area delineated as the control encompasses an area much larger and with somewhat different features than the filled wetland area. Many of the differences in the WET 2.0 results are due more to the control delineation requirements than to actual functional differences between the mitigation wetland and the wetland area that was filled. Certainly many functional differences exist between the mitigation and the impacted area, because their settings, their hydrology, and their vegetation types are so dissimilar; but in this case, WET 2.0 was ill-suited to discover their differences.

Actual Differences

The discussion below will focus on actual differences between the mitigation site and the impacted area. All references below to the "impacted wetland" refer to the 2.4-ac (0.9-ha) natural wetland area that was filled for road construction.

Groundwater Recharge. The water level in the mitigation wetland is a function of the local water table. Any precipitation occurring when the water table is low is likely to percolate to the groundwater through the highly pervious dune substrate. Such recharge may be important to the Nehalem Spit's groundwater supply, but is not likely to be any greater than recharge occurring from surrounding upland dune sites. The impacted wetland, on the other hand, was underlain by slowly permeable alluvial silt loam over marine clays, and thus not likely to serve a significant recharge function.

Floodflow Alteration. Both the mitigation and control wetland received high WET 2.0 probability ratings for floodflow alteration effectiveness, but these ratings may be exaggerated. The control assessment area will serve some flood alteration functions benefitting the adjacent drier pastures and the Route 53 roadway during normal flood events. The impacted wetland area would have contributed to this. The dominant flood alteration feature in the immediate area, however, is certainly the Route 101 road embankment itself. It will prevent all but the largest storm and tidal surges from the bay from entering the control wetland. On the other hand, when overbank flooding from the Nehalem River upstream inundates the control and other areas within the oxbow, the Route 101 roadway will act to retard drainage of floodwaters and prolong the period of inundation of these agricultural lands. The presence or absence of wetlands here during such an event may be of little consequence.

The mitigation wetland is located on a barrier peninsula that shields Nehalem Bay from ocean-borne winds, tides, and currents. The wetland area itself, however, is not necessarily more capable than the surrounding upland dune of buffering adjacent areas from tidal storm waters.

Nutrient Removal/Transformation. Particularly during the dry season the mitigation will receive high nutrient inputs from the feces of deer, elk, and other wildlife who use it as a waterhole. The wetland appears to have limited capability for denitrification and nutrient uptake due to the lack of organic material in the substrate and the limited vegetation density. Both of these parameters are expected to increase, however, as the wetland matures. For the time being, the basin may act as a conduit for passing nutrients into the groundwater. The impacted wetland, on the other hand, was characterized by dense herbaceous vegetation and plenty of organics in the surface substrate. It probably had substantial capability for nutrient removal and transformation.

Wildlife Habitat. Drinking water is limiting to wildlife on the Spit during the late summer and fall until the winter rains begin. The mitigation wetland is apparently an important drinking water source for wildlife on Nehalem Spit. Due to the depth of the excavation, it retains surface water after other wet depressions on the Spit have dried up. The presence of this wetland may permit deer, elk, and other species to remain there throughout the year if they choose. It offers, however, poor waterfowl habitat due to the low plant species and structural diversity, and the poor vegetation/water interspersion. It may provide resting habitat for a few migrating waterfowl, but it is not suited to long-term use for breeding or wintering.

The impacted area may have also been unsuitable for waterfowl habitat, due to the absence of open water; but its species and structural diversity, its vegetation density, and its proximity to a variety of tidal and freshwater wetland types indicate that it provided high quality habitat for a variety of wildlife, including hunting and foraging grounds for large and small mammals and breeding and feeding habitat for songbirds.

Recreation and Education. The mitigation wetland is located within the Nehalem Bay State Park. It is accessible to the public for non-consumptive recreational and educational usage. Its long distance from any road may make it less accessible to some potential users, but will render it more valuable to those who can get there. Opportunities for wildlife observation and natural science studies in general will be enhanced by its remoteness from human activities and disturbance. The control wetland and the impacted area were privately owned and therefore inaccessible to the public, in spite of their proximity to roads. Furthermore, the disturbance of road traffic, and the flat, open landscape may make the area unattractive to certain wildlife species who are intolerant of human activity.

Brackish water wetland. Sand and debris were removed from the inland end of an embayment to enlarge the embayment and increase tidal flushing of an adjacent wetland. This was accomplished, but it may have been a futile exercise. Sand movement is more or less continuous in coastal areas. It is a function of winds, currents, and their complex interaction with upcurrent and upwind geologic and oceanic features. Sand deposition in this embayment will continue to occur unless conditions change elsewhere to alter its movement patterns. The sand and debris that was removed will probably soon be replaced by natural forces. Furthermore, expansion of the embayment by sand removal, though it has enlarged the open water area, is not equivalent to wetland creation. Wetlands are defined by and derive much of their value from the presence of vegetation.

14. Noti-Veneta, Oregon

Social Significance

To be eligible for a high or in some cases a moderate probability rating for five of the WET 2.0 social significance functions--groundwater recharge, groundwater discharge, floodflow alteration, sediment/toxicant retention; and nutrient removal/transformation--a wetland must possess, in addition to other features, at least one of four attributes: (1) it must be part of a scarce wetland system (e.g., estuarine) in the region; (2) it must be the closest wetland to the service area; (3) it must be located in an urban area; or (4) its acreage must represent a significant proportion of the total wetland acreage in the service area's watershed (i.e., a proportion greater than the State's or region's annual wetland loss rate). The mitigation pond 4 and the control wetlands met none of these criteria, so neither received high ratings for any of the functions listed above. For several functions, however, the control possessed other features that earned it a moderate rating.

Groundwater Discharge

Mitigation pond 4 received a low probability rating for this function due to the absence of a surface water outlet. The WET 2.0 model assumes that groundwater discharge is valuable only to downstream areas. Its importance to the immediate environs is not considered.

The control wetland received a moderate rating due to the presence of rare wetland-dependent species in its service area, Fern Ridge Lake: Bradshaw's lomatium and bald eagle. Any discharge from the control will help maintain the wetland habitats that support those species.

Sediment/Toxicant Retention

The mitigation wetland received a low probability rating because it has no surface water outlet. Although it will retain any sediments or toxicants that it receives, this will not effect offsite surface waters. The model does not consider its possible value to the water quality of underlying aquifers.

The control wetland received a moderate rating for sediment/toxicant retention because cutthroat trout and other fish species sensitive to siltation occupy Fern Ridge Lake, the control's service area. All wetlands in the lake's siltation-prone watershed will presumably help to reduce turbidity and siltation in the lake.

Table 22. WET 2.0 and Hollands-Magee model results for the Noti-Veneta, Oregon pond 4 mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit V.Ctl[1]
Groundwater Recharge	L	L	U	U	-[2]	-	-2
Groundwater Discharge	L	M	H	M	-	-	-
Floodflow Alteration	L	L	H	H	M	M	-17
Hydrologic Support	-	-	-	-	-	-	-37
Sediment Stabilization	L	L	M	M	-	-	+17
Sediment/Toxicant Retention	L	M	H	H	H	L	-
Nutrient Removal/Transformation	L	M	H	M	L	L	-
Water Quality	-	-	-	-	-	-	-15
Production Export	-	-	L	M	-	-	-
Biological Function	-	-	-	-	-	-	10
Wildlife Diversity/Abundance	L	L	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	L	-	-	-
Wildlife Diversity for Migration	-	-	L	L	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	L	L	L	L	-	-	-
Uniqueness/Heritage	H	L	-	-	-	-	-
Recreation	L	L	-	-	-	-	+11
Education	-	-	-	-	-	-	+10

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -2 means that the mitigation wetland received a score 2 points lower than the control's score.

[2]function not evaluated

Nutrient Removal Transformation

The mitigation received a low social significance rating because it has no surface water outlet. The control wetland received a moderate rating because of the presence of swimming areas in Fern Ridge Lake that would benefit from reduced nutrient levels.

Uniqueness/Heritage

The mitigation wetland received a high social significance rating for uniqueness/heritage because it is now a publicly owned conservation area that is part of an ongoing monitoring program, and substantial public expenditures have been made for ecological management. The control wetland received a low rating because it is not under public ownership, management, or protection, nor is it known to possess any unique natural archaeological or historical features.

Effectiveness

Groundwater Discharge

Water levels in mitigation pond 4 are maintained by the local water table and there is little evidence that much, if any, groundwater recharge ccurs from the basin. The silt clay soils will somewhat impede water infiltration. It received a high probability rating for groundwater discharge because it is permanently flooded; its tiny watershed indicates little surface water input; and its position near the base of the coast range foothills suggests favorable conditions for discharge.

The control received only a moderate rating because it has a larger watershed; it is only seasonally flooded; and it is subject to unstable flows, high water level fluctuation, and expansive flooding. All of these attributes suggest that surface water levels in the wetland are a function of precipitation and surface runoff instead of groundwater discharge. The soils and local topography, however, are more conducive to discharge than to recharge.

Floodflow Alteration

The control wetland received a Hollands-Magee score 17 points higher than the mitigation primarily because of its stream connection, its larger size, its forested nature, and its moderately dense vegetation. Wetland vegetation can reduce the energy of inflowing storm waters, and remove some water by evapotranspiration. A pond such as pond 4, with much open water and little vegetation, will act as a catchment basin, but will otherwise do little to retard floodwaters. With its small watershed, pond 4 will only receive high-energy floods during the largest (50-year or greater) storms, when the Long Tom River overtops its banks. During ordinary storms it will serve as a low-capacity flood retention area, with small incremental value; but the cumulative value of many such small wetlands may in fact be significant over a large general watershed.

Hydrologic Support

The control wetland received a Hollands-Magee score 37 points higher than the mitigation primarily because of its stream connection. This model assesses a wetland's ability to retain water and discharge it slowly to downstream systems during dry periods. The presence of an outlet is critical to such a function, hence the mitigation wetland's low score.

Sediment Stabilization

The Hollands-Magee sediment stabilization model focuses on stabilization of shorelines bordering open water areas. Only wetlands situated to receive the erosive forces of currents or wind-driven waves will be given appreciable ratings. The control wetland received a score of zero because it contains no open water. The mitigation wetland received a somewhat higher score because of its unobstructed open water areas. The sparse vegetation, however, will do little to hold sediments.

Nutrient Removal/Transformation

The mitigation wetland received a high WET 2.0 rating for nutrient removal/transformation simply because it has no outlet. Any nutrients entering the basin will presumably remain there. The model does not consider the wetland's effectiveness at transforming or removing nutrients from resident waters, or from waters percolating to underlying aquifer. The sparse vegetation will offer little capability for nutrient uptake. The lack of organic matter in the sediments may limit denitrification processes.(86) The apparently low levels of biological activity will limit the production of organic colloids suitable for phosphorus adsorption. On the other hand, the fine silty clay soils may be quite effective at trapping nutrients.(87) The actual capability of pond 4 to stabilize, transform, or remove nutrients from the water column cannot be inferred from the information at hand, but it will presumably improve as vegetation densities and robustness improve.

The control wetland received only a moderate rating because (1) it has an outlet so it may export nutrients to downstream waters; (2) there is little surface water during the average and dry conditions, (3) there are no significant nutrient sources, so it has little opportunity to process nutrient-laden waters; and (4) there is little vegetation class diversity. (The rationale for including the last criterion is unclear).

Water Quality Renovation

The mitigation wetland received a Hollands-Magee score 15 points lower than the control primarily because (1) it is small, with a large area of predominantly open water and sparse vegetation, and thus little apparent capability for nutrient uptake; (2) its only surface water inputs are from a small roadside ditch and overland flow from a tiny watershed, so it will have little opportunity to process polluted waters; and (3) it has no stream connection, so its presence will not enhance downstream water quality.

The control wetland, on the other hand, is larger, predominantly forested with moderately dense herbaceous and shrubby vegetation, and it possesses a downstream connection.

Production Export

The mitigation wetland received a low rating for production export because it has no outlet. Any wetland with a surface water outlet will receive at least a moderate rating. The control therefore received a moderate but not a high rating because it is not subject to high water velocities or wave action that might dislodge organic material, nor are there large areas of aquatic bed or inundated emergent vegetation.

Opportunity

The WET 2.0 opportunity models focus on characteristics of the watershed in general and of the immediate input zones to determine whether the wetland will have the opportunity to perform a function. The mitigation and control wetlands received differing scores for only one of these models.

Sediment/Toxicant Retention

The mitigation wetland received a high probability rating for sediment/toxicant retention because the disturbed, poorly vegetated banks and islands are steep in many areas, and are dominated by alluvial silts and clays. The high turbidity of the pond attests to the presence of a highly erosive substrate. The control received a low rating because (1) such erosive conditions are absent; (2) the watershed is largely forested; and (3) there are no known significant sources of sediments or toxins.

Overview of Model Results

The functional evaluation models were used to compare a small, created open water and emergent wetland, pond 4, with a large, mature wooded wetland, the control, representing wetlands that were filled during road construction. For several reasons these assessment areas cannot accurately illustrate either gains or losses of wetland functions ensuing from the road construction and mitigation projects. Firstly, the mitigation project involved the creation of three wetland basins, each having similar design and development features, but each with a different type of hydrologic connection. Choosing any one pond to represent all three will necessarily underrate the size of the total wetland acreage created, and will underrate or exaggerate their functional capability. Owing to the design of this study, however, and the constraints of the model technique, only one of the ponds was used for functional comparison with the control.

Secondly the control wetland is predominantly wooded swamp with only small areas of shrub swamp and wet meadow; but it is used in the comparison to represent the impacted wetlands, which included large areas of shrub swamp and emergent marsh. (The search for a local wetland with a more comparable mix of wetland types was unsuccessful). Furthermore, the control is many times larger than pond 4, and twice as large as the total area of wetland filled for road construction. For those models that rely heavily on size-related features, the results will reflect the choice of assessment areas rather than the probable functional capabilities of the impacted and mitigation wetlands themselves. Lastly, placement of road fill in wetlands along the Route 126 alignment would result in small, incremental losses to some wetland functions, and substantial losses to others, some of which are addressed neither by these modeling systems, nor by most mitigation plans.

In any case, functional probability ratings for the control assessment area cannot accurately be interpreted as a reflection of functions actually served by the preconstruction wetlands; nor is a simple comparison of probability ratings for pond 4 and the control sufficient to evaluate the likelihood of actual gains and losses. At best, the model results can be used, after careful consideration of their derivation, as a basis for assessing possible functions served by wetlands similar to pond 4 and the control in type, size, location, and hydrologic regime.

The mitigation wetland received higher ratings than the control for groundwater discharge, sediment stabilization and nutrient removal/ transformation. The Hollands-Magee sediment stabilization model focuses on features indicative of erosive forces more than on those contributing to effectiveness. Pond 4 has large expanses of open water, but little vegetation to buffer shorelines from wave erosion. Until vegetation becomes better established, bank erosion and high turbidity will be continuing problems in all the mitigation wetlands. The WET 2.0 nutrient model in this instance considers only the fact that nutrients will not be exported from pond 4. It does not treat the issue of nutrient processing within the wetland. Except for some possible nutrient retention capability of the fine sediments, pond 4 possesses few features associated with nutrient removal or transformation.

Pond 4 received lower ratings than the control for water quality maintenance, floodflow alteration, hydrologic support and production export functions. Ratings for the latter two were owing solely to the lack of a downstream surface water connection. The hydrologic support model does not consider the support value of through-ground exchange. The Hollands-Magee water quality maintenance model, unlike the WET 2.0 nutrient model, gives greater weight to the wetland features related to nutrient dynamics than to the presence or absence of downstream connections. It thus recognized the apparent lower capability of this wetland than the control for processing nutrients. Pond 4's floodflow alteration capability will be simply a function of its basin capacity. Vegetation and soil conditions will not contribute to a flood storage or desynchronization.

Among the most important wetland impacts resulting from construction of Route 126 on its new alignment between Noti and Veneta are (1) degradation and loss of wildlife habitat; (2) alteration of hydrologic regimes; (3) hydrologic isolation of existing wetland parcels; and (4) introduction of roadway runoff to wetlands. Other impacts include incremental losses of groundwater discharge, hydrologic support, production export, and water quality maintenance functions.

Wildlife Habitat

WET 2.0 only assesses wetland-dependent bird habitat, but wetlands provide essential habitat to numerous wildlife groups including large and small mammals, reptiles, amphibians, raptors, passerines and other bird groups for some or all of their life requirements. Road building results not only in direct loss of wetland acreage, but also fragmentation of wetland and upland tracts that may have been important territorial and hunting grounds, as well as travel corridors for wildlife. The effects on wildlife of fragmentation of large tracts, and the enhanced human accessibility to previously inaccessible, undeveloped lands are consequences of road building that are difficult to quantify and may be impossible to address via mitigation.

For much of its length between Noti and Veneta, the new Route 126 alignment runs 150 to 400 ft (45.7 to 121.9 m) from, and parallel to, the Southern Pacific railroad tracks. The road thus isolates a long, narrow strip of land, including wetlands and uplands, between itself and the tracks; imposes a physical barrier to the free movement of wildlife between an undeveloped and roadless 5500+ ac (2172.5+ ha) tract to the south, and the forested and open land to the north of the road; and increases the likelihood of human incursions into these lands via foot travel and possible future development. These impacts were not addressed by the mitigation plan.

The mitigation design called for undulating shorelines and irregularly shaped islands as a means of providing topographic and vegetative cover for nesting and feeding wildlife. Instead, the shorelines and islands were constructed with straight, regular edges. The islands have very steep sides, possibly too steep for easy access by the nesting birds for which they were designed. The steepness has exacerbated the erosive tendencies of these soils, and the zone within which the water levels fluctuate remains almost devoid of vegetation. The slopes below the water line, however, are somewhat variable, and therefore may eventually support irregular bands of vegetation that will serve to limit sight distances for waterfowl and other wildlife using these wetlands. Had the shorelines themselves been irregular, this effect would be greatly enhanced.

Hydrologic Alteration and Isolation

Most of the Noti-Veneta stretch of Route 126 lies within the 50-year floodplain of the Long Tom River. The roadway crosses numerous wetland areas, and a high water table and occasional flooding are characteristic of even the upland soils. The placement of roadway fill creates a hydrologic barrier to surface waters and isolates wet-land areas that formerly had significant hydrologic interchange with adjacent areas, permitting exchange of nutrients, aquatic organisms, and plant propagules. As a consequence of road construction, some areas will become wetter, others drier, and others may not be substantially altered. Any long-term hydrologic changes will eventually alter the vegetation species and structure and hence the wildlife habitat attributes in these areas that were not filled but were merely adjacent to the roadway. Such hydrologic changes may be ultimately harmful or beneficial to wildlife or to human interests, but are generally neglected in the calculation of total wetland impacts.

Roadway Runoff

Construction of a new roadway in an undeveloped area such as this will result in the introduction of roadway runoff to swales, wetlands, and surface waters previously uncontaminated by such substances. The common constituents of roadway runoff are oil and grease, lead, cadmium, and zinc from auto exhaust, asbestos and rubber from auto debris, pesticides from roadside maintenance, salt and other deicing compounds.(88) Quantities of pollutants found in at least one study in Florida have been found not to be excessive.(89) Wetlands may be effective at retaining such contaminants and preventing them from passing to downstream waters, but the wetland ecology can be damaged by their presence in limited cases. Hydrocarbons may be broken down to some degree by bacterial degradation. Heavy metals and certain other toxicants are generally absorbed to soil particles, volatilized, stabilized under anaerobic conditions and stored in wetland sediments.(83) They are thus removed from the water column, but they can be reintroduced by any disturbance that results in oxidation. Pesticides can similarly become immobilized in the sediments, but until their degradation is complete they remain a hazard to aquatic and benthic organisms and all species higher on the food chain. Road salts can act to change the plant species composition in wetlands to salt-tolerant species that are less valuable to wildlife. Other deicers such as CMA can deplete the dissolved oxygen content of surface waters. The new Route 126 may introduce any or all of these contaminants to the adjacent natural wetlands, and thus degrade them in ways unaddressed by the mitigation project.

Other Functions

Construction of Route 126 resulted in the filling of portions of wooded swamps, shrub swamps, shallow marshes and wet meadows that were well vegetated, according to Oregon DOT preconstruction field notes. They are likely to have contributed to the groundwater recharge and discharge, hydrologic support, production export and water quality maintenance functions performed by the larger wetlands of which they were a part. Since the mitigation ponds are themselves sites of passive groundwater discharge, and the underlying soils are not particularly conducive to recharge, there has probably been a net gain in the discharge function resulting from the mitigation project. The mitigation ponds will probably do little to control the quantity or quality of water passing to downstream systems or underlying aquifiers. With the absence of organic soils, and near absence of vegetation throughout most of the ponded area, they will act only as detention basins for floodwaters. Until vegetation becomes well established and organic materials accumulate in the surface substrate they will do little to renovate water quality; indeed the eroding soils in ponds 2 and 3 will contribute to the turbidity of Long Tom River.

In summary, the Route 126 road construction resulted in impacts to adjacent unfilled wetlands that were unaddressed by the mitigation project: degradation and fragmentation of wildlife habitats; hydrologic alteration and isolation of existing wetlands; and introduction of roadway contaminants. The actual filling of wetland areas resulted in direct and indirect losses of wildlife habitat and incremental losses of goundwater discharge, hydrologic support, water quality maintenance and other functions.

15. Sharptown, Maryland

Social Significance

Since the control and mitigation wetlands have the same watershed and service area the social significance of the wetland functions are expected to be similar. The only difference was for the sediment stabilization function. The control received a high rating because it will act as a buffer to Route 313, a feature of social and economic importance. The mitigation wetland does not act as a buffer because of its location (approximate 1000 ft [304.8 m] from Route 313) and small size, so it recieved a low rating.

Effectiveness

The control (AA) is a large and diverse wetland system along the Nanticoke River. The mitigation wetland was evaluated as an impacted area within the larger control and was the strip of restored wetland where the old roadbed was removed. The source of the several differences in effectiveness ratings between the two are owing to differences in size, location, substrate, hydrologic and vegetation differences.

Groundwater Recharge

The mitigation wetland received a Hollands-Magee score 15 points lower than the control for groundwater recharge primarily owing to its small size, the lack of surface organics, and only a single inlet. The actual magnitude of recharge, if any, from these wetlands is, of course, impossible to predict. It is most likely, however, that the compacted road bed substrate will permit little or no percolation.

Table 23. WET 2.0 and Hollands-Magee model results for Sharptown, Maryland mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit V.Ctl[1]
Groundwater Recharge	L	L	L	L	-[2]	-	-15
Groundwater Discharge	L	L	M	M	-	-	-
Floodflow Alteration	L	L	H	H	H	H	-17
Hydrologic Support	-	-	-	-	-	-	-38
Sediment Stabilization	L	H	M	H	-	-	-55
Sediment/Toxicant Retention	L	L	L	H	H	H	-
Nutrient Removal/Transformation	L	L	L	M	H	H	-
Water Quality	-	-	-	-	-	-	-14
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	-12
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-	-
Wildlife Diversity for Migration	-	-	L	L	-	-	-
Wildlife Diversity for Wintering	-	-	M	H	-	-	-
Aquatic Diversity/Abundance	H	H	L	M	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	L	L	-	-	-	-	-
Education	-	-	-	-	-	-	-5

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -15 means that the mitigation wetland received a score 15 points lower than the control's score.

[2]function not evaluated

Hydrologic Support

The mitigation wetland received a Hollands-Magee score 38 points lower than the control for hydrologic support mainly because of its small size, its single outlet, and the absence of an open water edge.

Sediment Stabilization

The control received a high rating for this function because of the wide vegetated wetland zone exposed to river currents and waves. The mitigation wetland received a moderate rating because it is protected from the river by an upland berm and riprap at the river's edge. For the same reason the Hollands-Magee model rated the control wetland 55 points higher than the mitigation site for sediment stabilization.

Sediment/Toxicant Retention

The control received a high rating for sediment/toxicant retention because of the wide emergent vegetation zone in those areas that have periodic standing water, and the absence of evidence of long-term erosion. The mitigation received a low rating because of its recent alteration (restoration) and its small size.

Nutrient Removal/Transformation

The mitigation wetland received a low rating because of the recent alteration (restoration) otherwise it would have received the same score as the control.

Wildlife Diversity Abundance - Breeding

The mitigation wetland received a low rating for wetland bird breeding habitat because of the recent alteration (restoration) otherwise it would have received the same score as the control.

Wildlife Diversity Abundance - Wintering

The mitigation received a moderate rating largely because it contains no open water. The Nanticoke is not considered a part of this wetland due to the previously mentioned conceptualization necessary to apply the models. The presence of open water, the greater vegetation diversity and size of the control wetland contributed to its high rating for this function.

Opportunity

Because the control and mitigation wetlands share the same watershed the opportunity for wetland function performance would be similar. There were no differences in the opportunity probability results from the WET 2.0 analyses.

Hollands-Magee

The Hollands-Magee wetland function evaluation models were developed for glaciated inland wetlands and have not been adapted for use in tidal wetlands. The results of this analysis for tidal wetlands should therefore be considered tentative. The mitigation site's lower scores for groundwater recharge, sediment stabilization and Hydrologic Support than the control reflects the models' perception of the mitigation areas as a small wetland, removed from open waters, whereas the control is perceived as a large diverse wetland adjacent to the Nanticoke River.

Overview of Model Results

The mitigation wetland received equivalent or lower scores for all functions evaluated by the WET 2.0 and Hollands-Magee models. The mitigation wetland's small size and its lack of open water account for most of the differences. Since size-related features drive many of these models, other internal wetland characteristics are not adequately assessed. The mitigation wetland's small, linear configuration, its compacted substrate, its raised crown, and its early successional vegetation all suggest that its functional effectiveness will differ greatly from that of the control. The model results, however, do not reflect these features.

16. Willapa Bay, Washington

Social Significance

Neither the mitigation, the control, nor their service areas possessed any of the special features that might have earned them a high social significance rating for groundwater recharge, floodflow alteration, sediment/ toxicant retention or nutrient removal/transformation. Nor did the mitigation possess any of the four pivotal attributes necessary for a moderate rating.

Table 24. WET 2.0 model results for the Willapa Bay, Washington mitigation (Mit) wetland and the Hoquiam control (Ctl) wetland.

	WET 2.0					
	Social Significance		Effectiveness		Opportunity	
	Mit	Ctl	Mit	Ctl	Mit	Ctl
Groundwater Recharge	L	M	L	L	-[1]	-
Groundwater Discharge	L	H	M	M	-	-
Floodflow Alteration	L	M	L	H	L	M
Sediment Stabilization	L	L	H	H	-	-
Sediment/Toxicant Retention	L	M	L	H	H	H
Nutrient Removal/Transformation	L	M	L	L	M	M
Production Export	-	-	M	M	-	-
Wildlife Diversity/Abundance	H	H	-	-	-	-
Wildlife Diversity for Breeding	-	-	L	H	-	-
Wildlife Diversity for Migration	-	-	L	H	-	-
Wildlife Diversity for Wintering	-	-	M	H	-	-
Aquatic Diversity/Abundance	H	H	H	M	-	-
Uniqueness/Heritage	H	H	-	-	-	-
Recreation	L	L	-	-	-	-

Notes: H = high, M = moderate, L = low, U = uncertain

[1]function not evaluated

The control, however, met two of these latter criteria: it was considered to be the closest wetland to the Olympic mudminnow's habitat, since it straddles the Little Hoquiam River; and its acreage is estimated to be approximately 0.29 percent of the total wetland acreage in the Hoquiam River's watershed, exceeding Washington's annual wetland loss rate of 0.10 percent.[90] (The rationale for the use of this calculation and its importance in these models is not explained in the WET 2.0 documentation). The mitigation wetland therefore received low ratings for all of the above functions, and the control received moderate ratings.

For the groundwater discharge function, the control received a high social significance rating because of the likely presence of the Olympic mudminnow in the service area, and the control's close proximity to the mudminnow's habitat. A discharge wetland is important for the maintenance of downstream baseflows.

For the remainder of the social significance functions, the mitigation and control wetlands received equivalent ratings.

Effectiveness

Floodflow Alteration

The mitigation wetland received a low rating for floodflow alteration because it is estuarine tidal. WET 2.0 rates all riverine tidal, estuarine, and marine wetlands low for this function because they tend to be lower in the watershed than most floodable properties, and they are assumed to act as significant buffers only during mild storm surges at low tide.

The control wetland received a high rating because of its large size, its constricted outlet, and its large area lacking standing surface water. These conditions suggest a high floodflow retention capability.

Sediment/Toxicant Retention

The mitigation wetland received a low rating for this function simply because of its recent disturbance during construction. Otherwise it would have received a moderate rating because of the substantial submergent growth in the channel. The control received a high rating for sediment/toxicant retention because of its very broad vegetated zone, and the absence of long-term erosion.

Wildlife Diversity/Abundance for Breeding

The mitigation wetland received a low rating for waterfowl breeding habitat owing to its recent disturbance during construction, and its gravel substrate. The control received a high rating because of its large size, its irregular upland edge (prior to road construction), and the presence of numerous special habitat features: large trees, snags, fruit-bearing shrubs (elder, crabapple, huckleberry, blackberry, salmonberry, gooseberry), and cone-bearing trees (alder, spruce, hemlock).

Wildlife Diversity/Abundance for Migration

The mitigation wetland received a low rating for migrating wetland bird habitat because of its poor vegetation/water interspersion, and its poor interspersion and diversity of vegetation classes. The control received a high rating because of its adequate vegetation class interspersion, and its proximity to tidal and estuarine wetlands.

Wildlife Diversity/Abundance for Wintering

The control wetland received a high rating for waterfowl wintering habitat because of its large size and accessibility to estuarine wetlands, its permanent outlet, its unfrozen winter condition, the presence of both emergent and open water zones in the flooded areas, the presence of a forested area and a forested watershed, and the absence of daily human disturbance. The mitigation wetland received only a moderate rating because of its smaller size and the absence of large nearby wetlands, its lack of a forested area, its low plant form diversity, its gravel substrate, and its regular disturbance from Route 101 pull-over traffic.

Aquatic Diversity/Abundance for Wintering

The mitigation wetland received a high rating for this function due to the absence of toxin sources, its forested watershed, its accessibility by fish to other wetlands, its regular tidal flushing, the presence of substantial wetland acreage in the watershed, and the presence of good vegetation/water interspersion in the channel.

The control wetland received a moderate rating for aquatic habitat, but this is due to an error either in the software or in the interpretive keys. According to the keys the control should have received a high rating for this function owing primarily to its large size and accessibility to other wetlands, its permanent inlets and outlet, the presence of both open water and emergent zones in the flooded portions, the favorable pH, the presence of permanent surface water, its unfrozen winter condition, its fine mineral substrate, and the presence of fish cover in upstream wetlands.

Opportunity

The mitigation and control wetlands received different opportunity ratings for only one function: floodflow alteration. The mitigation received a low rating because it is lower in the watershed than most floodable properties. The control received a moderate rating because it and upslope wetlands comprise only a small proportion of its watershed acreage. It did not receive a high opportunity rating, however, because the predominant soils in the watershed have moderate-to-rapid infiltration rates.

Overview

Using the WET 2.0 method as the basis for (a) delineation of assessment areas, and (b) comparison of the wetland functions lost to road construction with those gained through mitigation measures, can produce misleading results. The WET 2.0 method requires that any assessment area encompass all contiguous wetland having a high degree of hydrologic interactions. Such a stipulation is aimed at considering the highly interactive nature of whole wetland systems. An alteration at one location within a wetland can cause changes elsewhere in the wetland due to hydrologic and biological interdependence. The Hoquiam control was delineated according to WET 2.0 instructions as a 170-acre (67-ha) wetland on the floodplain of the Little Hoquiam River. Although it was chosen to represent the wetland area filled for road construction, it was in fact 33 times larger and possessed numerous features not contained within the strip of filled wetland. Yet the design of this study together with the limitations of the WET 2.0 method offer this as the only formal basis for establishing the functional capability of the lost wetlands.

Several caveats are offered here for the interpretation and comparison of WET 2.0 results for the Hoquiam and Willapa Bay wetlands. The Hoquiam control is contiguous with but many times larger than the impacted wetland. It should not be assumed that the filling of a strip of wetland for road construction will result in the destruction of all functions served by contiguous wetland areas. It is likely to have resulted in huge losses to some functions, such as wildlife habitat, and only incremental losses to others, such as groundwater discharge and nutrient retention. Therefore, a simple comparison of probability ratings is not sufficient to evaluate the probability of actual gains and losses.

Construction of the Hoquiam by-pass probably resulted in incremental losses (proportional to the actual area filled) of the following functions: groundwater discharge, floodflow alteration, sediment stabilization, nutrient removal/transformation, and production export. Each of these was probably served to a moderate or high degree by the wetland as a whole. Impacts to wildlife habitat, however, were substantial. The road creates for wildlife a barrier to free movement between the extensive undeveloped area to the north and the riparian wetland. The game crossings will be used by some animals, but avoided by others for whom the wetland and the river will thus be rendered inaccessible. The road traffic has also introduced an element of disturbance to this hither to roadless and isolated area.

The Willapa Bay mitigation wetland is probably serving the following functions to some degree: sediment stabilization; sediment/toxicant retention, nutrient retention, wildlife habitat, aquatic habitat, recreation. The sparse vegetation and large amounts of bare substrate will limit its effectiveness at serving most of these functions in the near term. It is 50 percent smaller than the Hoquiam impacted wetland, so its capacity for replacing certain of the lost functions is further limited. Until the vegetation becomes better established, the wetland will be a net importer of plant production. Its groundwater discharge and floodflow alteration functions appear to be negligible due primarily to its topographic position. The wetland is very well situated for nonconsumptive recreational use, particularly birdwatching. Willapa Bay is used by large populations of migrating waterfowl and shorebirds. The mitigation wetland is accessible from a pull-over area on Route 101, and the location offers a view of the diverse habitats of mudflats, saltmarshes, and the mitigation lagoon itself.

In summary, the road construction and the mitigation project resulted in a loss of 5.1 ac (2.0 ha) of clearcut but densely vegetated riparian wetland, and a gain of approximately 2 ac (0.8 ha) of saltmarsh. There appears to have been a net loss of groundwater discharge, floodflow alteration, sediment stabilization, nutrient retention, production export, and wildlife habitat functions, and a net gain of aquatic habitat and recreational functions. As the mitigation wetland matures, its capability for many of these functions will improve.

17. South beltline, Wisconsin

Social Significance

Probability differed between the mitigation and control for only one function in the social significance category: sediment stabilization. The extensive Upper Mud Lake control acts as a buffer to many features of social or economic value such as a sewage treatment plant, an industrial park and a

Table 25. WET 2.0 and Hollands-Magee model results for the south beltline, Wisconsin mitigation (Mit) and control (Ctl) wetlands.

	WET 2.0						Hollands-Magee
	Social Significance		Effectiveness		Opportunity		
	Mit	Ctl	Mit	Ctl	Mit	Ctl	Mit V.Ctl[1]
Groundwater Recharge	H	H	U	L	-[2]	-	-10
Groundwater Discharge	H	H	H	H	-	-	-
Floodflow Alteration	L	L	H	M	M	M	+2
Hydrologic Support	-	-	-	-	-	-	-7
Sediment Stabilization	M	H	H	H	-	-	-18
Sediment/Toxicant Retention	M	M	H	H	H	H	-
Nutrient Removal/Transformation	H	H	M	H	H	H	-
Water Quality	-	-	-	-	-	-	-6
Production Export	-	-	M	M	-	-	-
Biological Function	-	-	-	-	-	-	-12
Wildlife Diversity/Abundance	H	H	-	-	-	-	-
Wildlife Diversity for Breeding	-	-	M	H	-	-	-
Wildlife Diversity for Migration	-	-	L	H	-	-	-
Wildlife Diversity for Wintering	-	-	L	L	-	-	-
Aquatic Diversity/Abundance	M	M	L	L	-	-	-
Uniqueness/Heritage	H	H	-	-	-	-	-
Recreation	L	L	-	-	-	-	-8
Education	-	-	-	-	-	-	-5

Notes: H = high, M = moderate, L = low, U = uncertain

[1]Hollands-Magee model results are in the form of the raw score point difference between the mitigation and control wetlands (range 0 - 100). For example, -10 means that the mitigation wetland received a score 10 points lower than the control's score.

[2]function not evaluated

fuel storage facility. Therefore, WET 2.0 ranks its sediment stabilization high versus moderate for the mitigation IA. Although not a decisive factor in WET 2.0, the Yahara River channel which runs through the AA is a substantial erosive force. Dense vegetation in the adjacent wetlands provides a good deal of protection and erosion control for the system as a whole.

Effectiveness

Probability ratings of the mitigation and control wetlands differed for 5 of the 11 functions evaluated by WET 2.0 in terms of performance capability. Only one function evaluated by Hollands-Magee differed substantially between the mitigation and control.

Groundwater Recharge

WET 2.0 assumes low probability for recharge if one of the following is present: (a) easily observable evidence of groundwater discharge, e.g. springs, or an outlet but no inlet; (b) significant barriers to recharge, e.g. low permeability of underlying strata; or (c) obvious conditions unfavorable to recharge, e.g. an upslope impoundment or ditches within the wetland. The control received a low probability for recharge based on the presence of ditches and an upstream impoundment. Since none of these conditions is present in the IA and because a level 3 analysis was not part of the methods for this study, the model gave the mitigation IA an "uncertain" rating. In fact, geological studies that have been conducted in the Yahara River valley indicate that the Upper Mud Lake system is primarily a groundwater discharge system.

Floodflow Alteration

WET 2.0 ranked the probability of the mitigation wetlands higher than the control for floodflow alteration due to the predictor concerning the presence of ditches. Although the control has ditches and the mitigation does not, this is a very minor distinction. Observations of key characteristics of the two evaluation areas such as vegetation density and surface water connections suggest that floodflow alteration capabilities are quite similar.

Sediment Stabilization

The mitigation wetlands ranked 18 points lower than the control for this function based on Hollands-Magee analysis. The great shoreline length and long fetch of Upper Mud Lake make the control's shoreline more susceptible to erosion. Therefore, the control is considered to have greater value for this function.

Nutrient Removal/Transformation

The probability of the nutrient removal/transformation function occurring was high in the control and moderate in the mitigation wetlands. This difference was due primarily to the smaller emergent zone in the area of standing water and the lower vegetation class diversity in the mitigation wetlands. The much larger natural marsh had several vegetation classes including shrub and forested wetland in the periphery of the wetland system. The natural marsh also has a large persistent emergent zone in the area of standing water. Given the large area of dense wetland emergent vegetation and organic soil in contact with low velocity water flow it is likely that nutrient removal and transformation occurs in the natural marsh. Several of the wetland mitigation areas are not connected to surface water channels and may well be somewhat less likely to be providing a nutrient removal/ transformation function.

Wildlife Diversity/Abundance

The effectiveness of wildlife diversity/abundance for breeding and for migration were rated higher for the control than for the mitigation wetland. These differences were due primarily to the larger size and greater wetland class diversity of the natural marsh system. The control encompasses woody covertypes which do not exist within the restored wetlands. The mitigation wetlands, however, replicated successfully the dense emergent vegetation and areas of open water on a smaller scale.

Opportunity

According to the WET 2.0 analysis, the mitigation and control wetlands have similar opportunities to perform the three functions evaluated under this category. This is presumably due to the fact that they are located within the same basin and are subject to similar outside influences and hydrologic regime.

Overview

Probability levels for performance effectiveness of five wetland functions very somewhat between the restored and natural wetlands according to results produced by WET 2.0 modeling. For two of these functions (groundwater recharge and floodflow alteration), the difference in predicted probability is due to presumed lack of information or minor wetland features that have an overriding effect on model outcome. The other three functional differences (nutrient removal/transformation and wildlife diversity/abundance for breeding and migration) are the result of size differences between the mitigation and control wetlands. Social significance functional probabilities are identical for the two assessment areas except for sediment/toxicant retention; opportunity probabilities are identical. These results reflect the fact that the mitigation areas represent a subset of the control AA. Therefore, they are both subject to very similar outside influences and are more likely to have the opportunity to provide the same services.

An attempt was made to reduce the size discrepancy in the analysis by focusing on the 22-ac (8.7-ha) area directly impacted by the construction. However, WET 2.0 impact area (IA) assessment is not sensitive enough to detect substantial differences between the control AA and the highway IA. The highway IA is a cross-section of all the covertypes included in the AA and when evaluated in the context of the AA (which is what the model does), functional differences are masked. Therefore, the entire AA was considered to be a better control for comparison with the mitigation IA, although this scenario also has flaws.

The Hollands-Magee model results vary only slightly for the restored and natural wetlands. Sediment stabilization is the only function for which the restored wetlands rank substantially lower than the control. This difference is due entirely to characteristics of the control wetland that occur outside the area impacted by the highway. Overall functional similarities are due to the hydrologic and vegetational similarities between the restored and natural wetlands.

APPENDIX B:

WET 2.0 QUESTIONS[1]

3.0 SOCIAL SIGNIFICANCE EVALUATION

Social significance assess a wetland in terms of its special designations, potential economic value, and strategic location. The evaluation consists of two levels of assessment. The first level consists of 31 questions designed to determine if the wetland has specific characteristics that indirectly indicate it may be performing functions and values beneficial to society. Responses to these questions are analyzed in a series of interpretation keys that assign probability ratings of HIGH, MODERATE, or LOW to ten wetland functions and values for social significance. A Level 1 assessment can be completed in 1-2 hours using the information resources described in Task 1.

Read the instructions for Form B (page B-4) before starting the social significance evaluation. Record your answers to the following questions in the appropriate section of Form B.

3.1 Social Significance Evaluation - Level 1 Assessment

3.1.1 "Red Flags"

1. Are any Federal or State endangered or threatened species (including officially designated "candidate" species) known to use the AA regularly? (uniqueness/heritage)**

2. Is the AA/IA part of an area owned by an organized conservation group or public agency for the primary purpose of preservation, ecological enhancement, or low-intensity recreation? For example, a park, refuge, scenic route, water bank or conservation easement, historic site, marine or estuarine sanctuary, wilderness or primitive area, landmark area, public recreation area, or research natural area. (uniqueness/heritage)

3. Is the AA/IA included in a statewide listing of historical or archaeological sites? (uniqueness/heritage)

4. Is the AA/IA known to have ecological or geological features consistently considered by regional scientists to be unusual or rare for wetlands in the region? (Answer "N" if the type is merely sensitive or threatened, answer "Y" <u>only</u> if the AA is indeed rare among regional wetland types.) Examples include:

   (a) Peat bogs in southern New England.
   (b) Fens in some parts of the Midwest.
   (c) Cypress swamps in northern states.
   (d) Spring communities in various regions.
   (e) Wild rice producing wetlands in the north-central U.S.
   (uniqueness/heritage)

* The AA/IA designation indicates the question should be answered for the AA or IA whichever is appropriate for the evaluation. See page 22 for discussion and delineation of the IA.

** The parenthetical phrase following each question indicates which function or value the question addresses.

[1] The following information has been taken verbatim from the WET 2.0 Manual, and is intended to provide background on the WET 2.0 model methodology and terminology. Figure, Table, and page numbers have been altered to conform to the numbering sequence throughout. For further information, the reader is referred to P.R. Adamus, E.J. Clairain, Jr., R.D. Smith, and R.E. Young. <u>Wetland Evaluation Technique (WET)</u>: Volume II; Methodology. Operational Draft, Waterways Experiment Station, Vicksburg, Mississippi, 1987. [Changes have been made to Questions 3.2, 37 and 38.2 to correct typographical errors and errors in context.]

5. Does the AA/IA represent most or all of this wetland system (e.g., estuarine, palustrine, lacustrine, etc.) in this locality? (all functions)

6. Have substantial public or private expenditures been made to create, restore, protect, or ecologically manage the AA/IA? Examples include, costs to resource agencies for conservation purchase, seeding, fencing, maintenance, water quality improvements, installation of fishways or impoundments, and improved accessibility. (uniqueness/heritage)

3.1.2 On-Site Wetland Social Significance

7. (Answer "I" if the AA is tidal.) Are there biological communities in the AA that are stressed by saline springs or abnormally high salinities, <u>or</u> are there wetlands contiguous with the AA where this situation exists? (ground water discharge)

8. (Answer "I" if AA is tidal.) Are there potential point sources of pollution (e.g., hazardous waste sites) or other features of social or economic value (e.g., buildings in incorporated areas, industrial developments, etc.) adjacent to the AA that would be inundated by a 100 year flood? (floodflow alteration)

3.1.3 Off-Site Wetland Social Significance

For Questions 9-14, consider the "area specified" to be the same downstream area used during the identification of service areas (see page 24).

9. (Answer "I" if tidal.) Are there features of social or economic value within the 100 year floodplain of the area specified <u>or</u> has a dam, with the primary purpose of flood control, been proposed within 5 miles upstream or downstream of the AA? (floodflow alteration)

10. Are <u>any</u> of the following features present within the area specified?

    (a) Harbors, channels, stormwater detention ponds, or reservoirs that are dredged or cleaned regularly.
    (b) Artificial recharge pits.
    (c) Fish spawning areas that are known to be sensitive to siltation.
    (d) Commercial shellfish beds.
    (e) Areas known to be in violation of Section 401 of the Clean Water Act water quality standards due to suspended solid or toxicant levels. (sediment/toxicant retention)

11. Are there bodies of water, within the area specified, that have been targeted by government agencies as "priority areas" for construction of wastewater treatment facilities or other water quality improvement projects because they violate official water quality standards (e.g., Section 401) for metals, organics, suspended solids, nitrogen, or phosphorous? (nutrient removal/transformation, sediment/toxicant retention)

12. Is there surface water within the AA or the area specified that is a major source of drinking water? (nutrient removal/transformation, sediment/toxicant retention)

13. Are either of the following conditions present in the area specified?

(a) Bodies of water known to be especially nutrient-sensitive or subject to regular blooms of algae, aquatic fungi, or oxygen-related fish kills.
(b) Bodies of water known to be in violation of Section 401 water quality standards due to nutrient levels (e.g., nitrogen, phosphorous). (nutrient removal/transformation)

14. Are there swimming/bathing areas that are used frequently in the area specified? (nutrient removal/transformation)

If any of Questions 9-14 were answered "Y," refine your answers using the following procedure:[1]

(a) Determine if condition (1) or (2) below is true. If either of these conditions is true, do not change the original "Y" answer(s) in Questions 9-14 and continue with Question 15. If neither condition (1) or (2) below is true go to (b).

(1) The land cover of the watershed of the service area closest to the AA is covered by more than 10% impervious surface.

(2) Wetlands and open water (excluding the AA) comprise less than 7% of the watershed of the service area closest to the AA.

(b) Determine if either of the conditions (1) or (2) above is true for the remaining service areas that were identified. If <u>either</u> of the conditions is true for <u>any</u> of the remaining service areas, do not change the original "Y" answer(s) to Questions 9-14 and continue with Question 15. If <u>neither</u> of the conditions is true for <u>any</u> of the remaining service areas, change all original "Y" answers in Questions 9-14 to "N", then continue with Question 15.

<u>Guidelines</u>:

1 The rational for this refinement is as follows. Wetlands within a service area watershed with extensive areas of impervious surface, and/or few wetland/deepwater areas, are of greater relative importance in terms of providing functions and values than wetlands within a service area watershed with an insignificant area of impervious surface, and/or extensive wetland/deepwater areas

For Questions 15-18, consider the "area specified" to be the area within 2 miles of the AA's perimeter <u>and</u> within the same watershed.

15. (Answer "I" if tidal.) Does a threatened or endangered species that is **wetland-dependent** regularly inhabit the area specified? (ground water discharge)

16. (Answer "I" if tidal.) Are any of the following features present in the area specified?

(a) Sites designated by US Environmental Protection Agency (USEPA) as Sole Source Aquifers or Class II (Special) Ground Waters.

(b) Wells that serve at least 2,500 people (people using the well may be living outside the area specified).

(c) Actively used wells with yields that are greater than the yields shown for this region on the map in Figure 31.

(d) Wells that are within a major alluvial valley (i.e., watershed area of at least 100 square miles) and have yields exceeding 2,500 gallons per minute. (ground water recharge, ground water discharge)

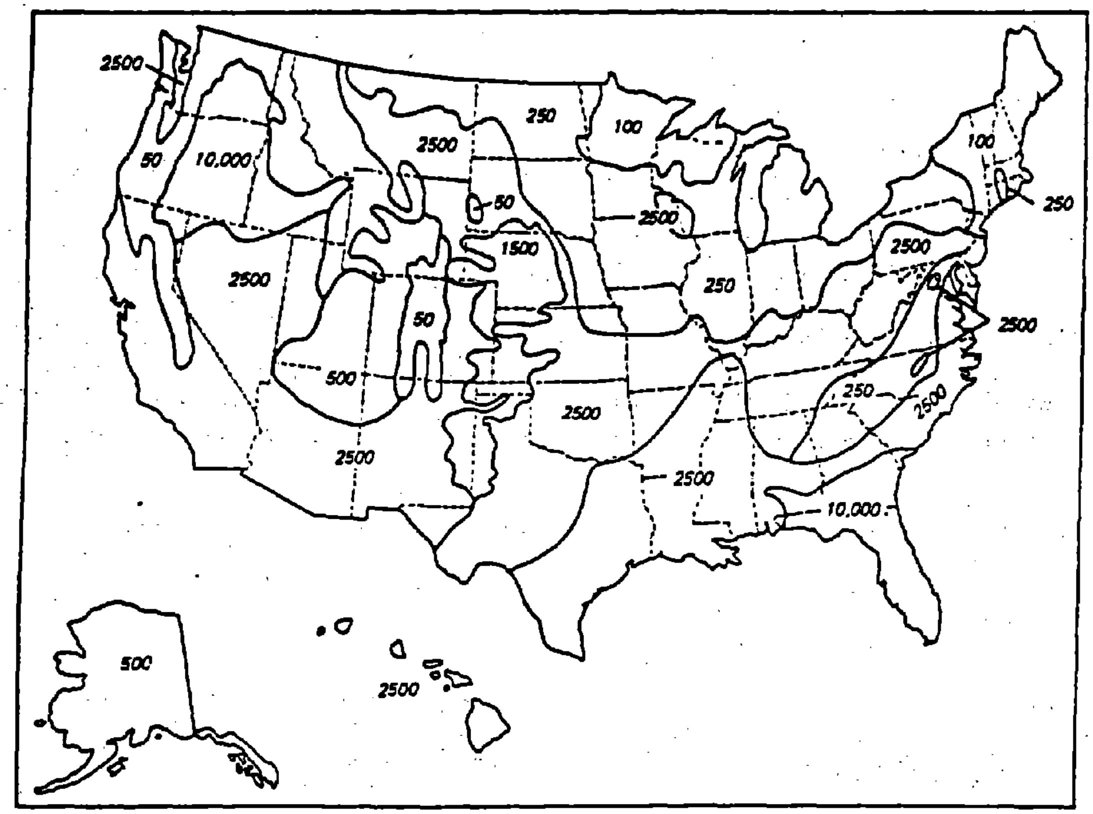


Figure 31. Ground water regions of the United States with exceptional well yields[in gallons per min (USGS, 1970)]

17. (Answer "I" if tidal.) Do well yields in the area specified surpass the criteria described in Question 16(c) or does the AA empty into an area (within 2 miles) where fish or wildlife use has been critically limited by excessively low water flow or low water level during dry years? (ground water recharge, ground water discharge)

18. (Answer "I" if none of Questions 9-17 were answered "Y.") Is either of the following conditions true for any of Questions 9-17 that were answered yes?

(a) The AA is the only wetland in the watershed of the closest service area.

(b) The AA is closer to the service area where the service identified in the question is delivered, than any other AA (that could be delineated if desired) in the watershed of the closest downstream service area. For example, in Question 12, the AA is closer to the service area to which drinking water is being supplied than any other AA in the watershed of the closest service area. (all functions)

19. Does the AA/IA act as a buffer to features of social or economic value that are situated in erosion-prone or wave-vulnerable areas? (sediment stabilization)

20. Is any of the following true?

(a) The AA/IA supports at least one fish species that is on USFWS National Species of Special Emphasis List (Table 26) and is rare or declining in the region.

(b) The AA/IA has a State or Federal special designation relating to its recognized fishery value.

(c) There is commercial fishing or shellfishing with the AA/IA. (aquatic diversity/abundance)

21. Is any of the following true?

(a) The AA/IA supports at least one wildlife species that is on USFWS National Species of Special Emphasis List (Table 26) and is rare or declining in the region.

(b) The AA/IA has a State or Federal special designation relating to its recognized wildlife value.

(c) A fee is charged at the AA/IA for consumptive (hunting) or nonconsumptive (observation) use of wildlife. (wildlife diversity/abundance)

22. (Answer "I" if less than 1 acre of open water is present in the AA.) Is the AA in a waterfowl use region of major concern as defined by FWS (Figure 32) or has it received a priority rating in state waterfowl concept plans? (wildlife diversity/abundance)

Table 26. National Species of Special Emphasis (Source: USFWS, unpubl. data)

MAMMALS:
- Grizzly Bear
- Polar Bear
- Black-Footed Ferret
- Sea Otter:
  - Southern
  - Alaskan Population
- Gray Wolf:
  - Eastern
  - Rocky Mountain
  - Mexican
- Pacific Walrus
- West Indian Manatee

BIRDS:
- Brown Pelican:
  - Eastern
  - California
- Tundra Swan:
  - Eastern Population
  - Western Population
- Trumpeter Swan:
  - Interior Population
  - Pacific Coast Population
  - Rocky Mountain Population
- Greater White-Fronted Goose:
  - Eastern Mid-Continent Population
  - Western Mid-Continent Population
  - Tule
  - Pacific Flyway Population
- Snow Goose:
  - Greater,
    - Atlantic Flyway Population
  - Lesser,
    - Mid-Continent
  - Western Central Flyway Population
  - Western Canadian Arctic Population
  - Wrangel Island Population
- Brant:
  - Atlantic Population
  - Pacific Population
- Canada Goose:
  - Atlantic Flyway Population
  - Tennessee Valley Population
  - Mississippi Valley Population
  - Eastern Prairie Population
  - Great Plains Population
  - Tall Grass Prairie Population
  - Hi-Line Population
  - Short Grass Prairie Population
  - Western Prairie Population
  - Rocky Mountain Population
  - Pacific Population
- Canada Goose (cont.)
  - Lesser (Pacific Flyway Population)
    - Vancouver
    - Dusky
    - Cackling
    - Aleutian
- Northern Pintail
- Wood Duck
- Black Duck
- Mallard
- Canvasback:
  - Eastern Population
  - Western Population
- Ring-Necked Duck
- Redhead
- California Condor
- Osprey
- Bald Eagle:
  - Southeastern Population
  - Chesapeake Bay Population
  - Northern Population
  - Southwestern Population
  - Pacific State Population
  - Alaskan Population
- Golden Eagle:
  - Western Population
- Peregrine Falcon:
  - Eastern Population
  - Rocky Mountain Population
  - Southwestern Population
  - Pacific Coast Population
  - Alaskan Population (Arctic, American and Peal's)
- Attwater's Greater Prairie Chicken
- Masked Bobwhite
- Clapper Rail:
  - Yuma
  - Light-Footed
- Sandhill Crane:
  - Eastern Population-Greater
  - Mid-Continent Population-Lesser
  - Canadian-Greater
  - Rocky Mountain Population-Greater
  - Lower Colorado Population-Greater
  - Central Valley Population-greater
  - Pacific Flyway Population-Greater
- Whooping Crane
- American Woodcock
- Piping Plover

(Continued)

Table 26. National Species of Special Emphasis (continued).

BIRDS
- Least Tern:
  - Interior
  - Eastern
  - California
- Roseate Tern
- White-Winged Dove
- Spotted Owl (Northern)
- Red-Cockaded Woodpecker
- Kirtland's Warbler

REPTILES AND AMPHIBIANS:
- American Alligator

FISH:
- Sockeye Salmon (Alaskan)
- Coho Salmon:
  - Non-Alaskan U.S. Stock
  - Alaskan Stock
- Chinook Salmon
- Cutthroat Trout (Western United States)
- Steelhead Trout
- Atlantic Salmon
- Lake Trout (Great Lakes)
- Striped Bass
- Cui-ui

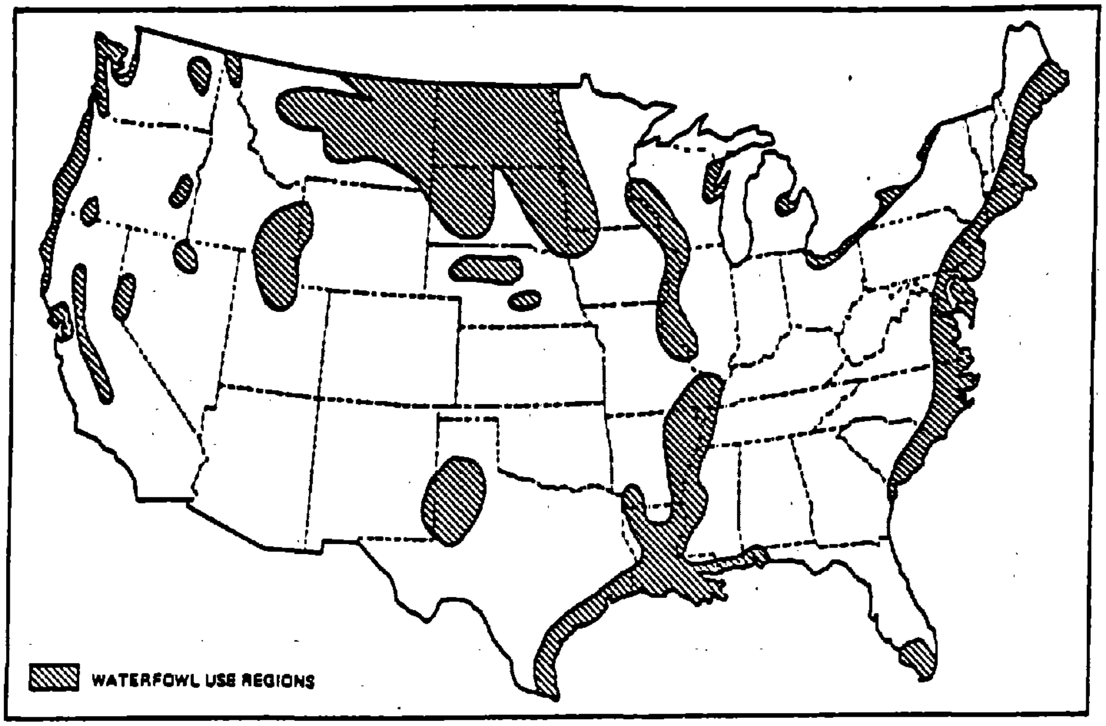


Figure 32. Waterfowl use regions of major concern (Source: USFWS, unpubl. data)

23. Does this AA/IA support plant or animal species with exceptionally narrow habitat requirements or of extremely limited occurrence in this region (e.g., desert pupfish)?[1] (wildlife diversity/abundance, aquatic diversity/abundance, uniqueness/heritage)

Guidelines:

[1] Species for which less than 1% of the other wetlands in the same class (e.g., emergent, forested, scrub/scrub) provide acceptable habitat.

24. (Answer "N" if the AA is less than 5 acres in size.) Is the AA/IA the closest wetland to any nature center, school, camp, college, or similar educational facility, and is it within 2,000 ft of a public road where parking is allowed? (uniqueness/heritage)

25. Is the AA/IA part of, and essential to, an ongoing, long-term environmental research or monitoring program? (uniqueness/heritage)

26. Is the AA and its watershed a "pristine" natural area, in the sense of having no lasting, direct or indirect, human alteration? (uniqueness/heritage)

27. Is the AA/IA used regularly for recreational or consumptive activities, for which opportunities are otherwise locally deficient as recognized by a local or state recreational plan (e.g., SCORP)? (recreation)

28. Is the AA/IA a major public access point to a recreational waterway? (recreation)

29. Is the AA located in an urban area? (all functions)

For Questions 30 and 31, if data for a more restricted region or geographic area are available, substitute it for the state data shown in Table 27.

30. Is the AA located in a state that is losing wetlands at a rate greater than, or equal to, the national annual average of 0.42%/year (Table 27)? (all functions)

31. Is the AA's wetland acreage (expressed as a percent of the acreage of wetlands in the watershed of the closest service area) greater than the annual percentage loss rate of wetlands for the state (Table 27)? For example, if the watershed of the closest service area has 200 acres of wetland and the AA comprises 20 of these acres, then 20/200 = 0.1 and 0.1 x 100 = 10%. The corresponding statewide loss rate (for Alabama) from Table 27 is 0.67%. Therefore, the answer to Question 31 for this example is "Y" since the calculated loss rate is greater than the state loss rate shown in Table 27.[1] (all functions)

Guidelines:

[1] The rational for Question 31 is as follows. This question serves a weighting mechanism in several of the social significance keys. If the wetlands in the AA represent an amount equal to, or lower than, the average state wetland loss per acre then Question 31 has no effect in the social significance keys. However, if the wetlands in the AA represent an amount greater than the average state wetland loss per acre the probability ratings for several functions are elevated.

This completes the first assessment level of the social significance evaluation. Interpret the responses to these questions using the interpretation keys in Section 3.2, or, alternatively, interpret the responses using the computer program described in Appendix E.

When the interpretation is completed three options are possible:

(1) Continue with the second assessment level of the social significance evaluation (page 41), or

(2) Begin the first assessment level of the effectiveness and opportunity evaluation in Section 4.0.

(3) Stop the evaluation at this point and complete Form D: Evaluation Summary.

Table 27. Acreage Criteria for Oases (OA) and Clusters (CL) for Emergent (EM), Scrub-Shrub (SS), and Forested (FO) Vegetation Classes, and Wetland Loss Rates. (Source: USFWS unpubl. data.)

STATE	PALUSTRINE (acres/mile^2)				ESTUARINE (acres/mile shoreline)				LOSS RATE (%/year)
	EM		SS/FO		EM		SS/FO		
	OA	CL	OA	CL	OA	CL	OA	CL	
AL	0.4	2.3	11.1	66.5	7.6	45.6	ND		0.67**
AZ	0.2	1.3	1.2	7.0	------------				0.42***
AR	0.9	5.6	9.1	54.6	------------				1.80
CA	0.3	1.6	0.2	1.0	6.1	36.8	ND		0.42***
CO	0.6	3.7	0.5	2.7	------------				0.42***
CT	0.5	2.9	7.8	47.0	5.9	35.3	1	1	0.35**
DE	0.6	3.8	9.6	57.7	47.1	282.7	1	1	0.81
FL	11.3	67.8	21.7	129.9	27.8	166.5	13	78	0.57
GA	0.7	4.2	15.6	93.6	29.3	175.7	1	1	0.35**
ID	0.2	1.4	0.6	3.8	------------				0.42***
IL	0.2	1.1	2.2	13.0	------------				0.84
IN	0.4	2.6	0.8	5.0	------------				0.67**
IA	1.3	7.6	1.6	9.7	------------				0.67**
KS	0.3	1.9	0.2	0.9	------------				0.42***
KY	0.2	1.1	0.4	2.3	------------				0.67**
LA	5.3	31.8	21.4	128.6	48.8	292.9	ND		0.84
ME	1.6	9.9	8.6	51.7	4.6	27.6	ND		0.35**
MD	0.3	2.0	3.8	22.6	10.3	62.0	1	1	0.35**
MA	1.5	9.1	10.8	64.5	3.0	18.2	1	1	0.35**
MI	3.2	19.2	9.7	58.1	------------				0.67**
MN	8.8	53.0	9.9	59.6	------------				0.67**
MS	1.3	7.9	14.7	88.3	4.8	28.7	ND		1.48
MO	0.2	1.4	1.3	7.7	------------				0.67**
MT	0.8	4.6	0.4	2.3	------------				0.42***
NE	3.5	21.1	1.0	5.9	------------				0.42***
NV	0.2	1.0*	0.1	0.1*	------------				0.42***
NH	0.6	3.6	3.0	17.8	4.3	25.6			0.35**
NJ	0.7	4.1	13.6	81.8	------------				0.35**
NM	0.6	3.7	0.1*	0.1*	------------				0.42***
NY	1.1	6.7	2.7	16.0	6.6	39.9	ND		0.35**
NC	1.7	10.2	19.0	113.9	10.4	62.5	ND		0.65
ND	7.1	42.7	0.5	3.1	------------				0.42***
OH	0.7	4.4	1.2	6.9	------------				0.67**
OK	0.4	2.6	2.5	15.1	------------				0.42***
OR	1.6	9.7	0.8	4.6	8.7	51.9	ND		0.42***
PA	0.3	1.8	1.6	9.4	------------				0.35**
RI	0.5	3.0	7.9	47.1	16.5	99.3	ND		0.35**
SC	1.3	7.8	25.1	150.8	32.4	194.3	1	1	0.35**
SD	3.2	18.9	0.2	1.1	------------				0.42***
TN	0.4	2.3	2.9	17.4	------------				0.67**
TX	1.1	6.4	1.0	6.1	32.9	197.6	ND		0.42***
UT	0.9	5.6	0.4	2.3	------------				0.42***
VT	0.7	4.2	4.1	24.5	------------				0.35**
VA	0.3	1.8	3.3	19.6	14.25	85.5	ND		0.35**

(Continued)

Table 27. Acreage Criteria for Oases (OA) and Clusters (CL) for Emergent (EM), Scrub-Shrub (SS), and Forested (FO) Vegetation Classes, and Wetland Loss Rates (continued).

STATE	PALUSTRINE (acres/mile²)				ESTUARINE (acres/mile shoreline)				LOSS RATE (%/year)
	EM		SS/FO		EM		SS/FO		
	OA	CL	OA	CL	OA	CL	OA	CL	
WA	1.6	9.7	0.8	4.6	1.8	10.7			0.42***
WV	9.2	1.0	0.5	3.2	ND		ND		0.35**
WI	3.2	19.2	9.9	59.3	--------------------				0.67**
WY	0.7	4.2	0.4	2.3	--------------------				0.42***

* Wetland acreage estimates were not available for this state, so data from nearby states were used. More detailed or accurate data on wetland densities from state or local agencies may be substituted if available. The following formula should be applied to improve the definition of clusters and oases: Oasis = 0.2x; Cluster = x + 0.2x (where x = mean statewide density of wetlands in acres per square mile).

** State data were statistically insignificant, and figures represent regional (flyway) data. Substitute more detailed or accurate data if available.

*** State data were statistically insignificant, and figures represent the national loss rate (0.42%). Substitute more detailed or accurate data if available.

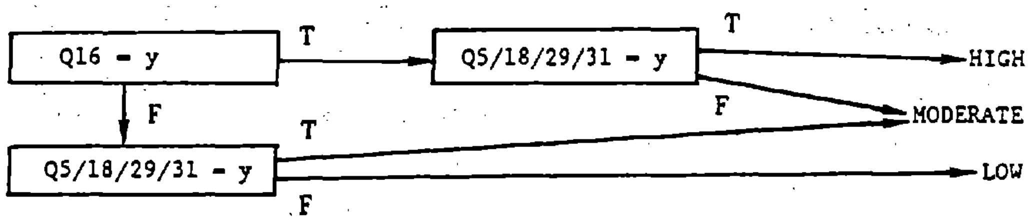
3.2 Social Significance Evaluation - Level 1 Interpretation

This section outlines the procedure for interpreting the responses to questions in the first level of the social significance evaluation and assigning probability ratings of HIGH, MODERATE, or LOW to functions and values in terms of social significance.

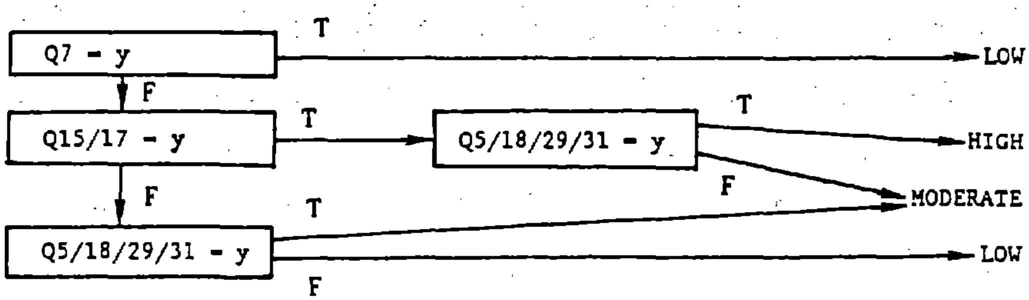
Place Form B and the Social Significance Keys in front of you. Note that there is an separate key for each of the functions and values to be evaluated. Each key consists of a series of boxes. Within each box are coded references to a single question, or group of questions from the Level 1 assessment. Each coded reference is followed by a specified answer of "y" (yes) or "n" (no). Within the boxes, "/" should be read as "or". For example, in the ground water recharge key the ~~first~~ [second] box contains the statement ~~"Q16/17~~ [Q5/18/29/31] - y." This translates into, "Were Questions ~~16 or 17~~ [5, 18, 29 or 31] answered yes?" A true (T) and false (F) arrow emerges from each box. Follow the true arrow if the conditions specified are met, and follow the false arrow if the conditions specified are not met. Proceed through the key from box to box until a HIGH, MODERATE, LOW, or UNCERTAIN probability rating is specified. Then proceed to next key until all function and values have been assigned a probability rating for social significance. Record the probability ratings for each of the functions and values in the Social Significance column of Form D.

Social Significance Keys

Ground Water Recharge

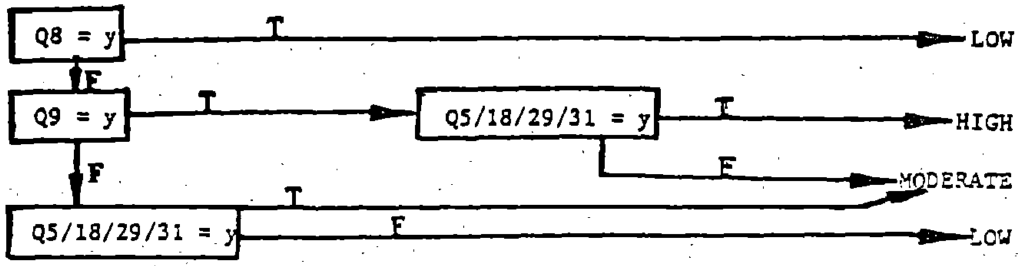


Ground Water Discharge

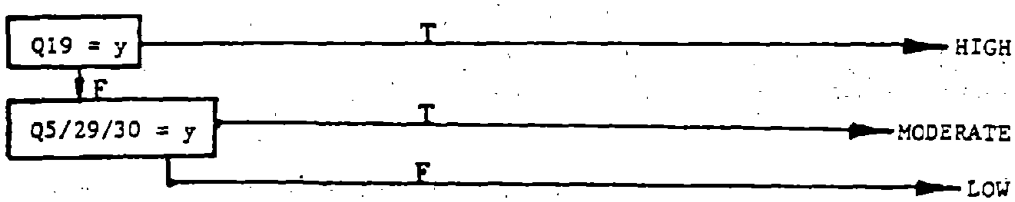


Social Significance Keys (Cont.)

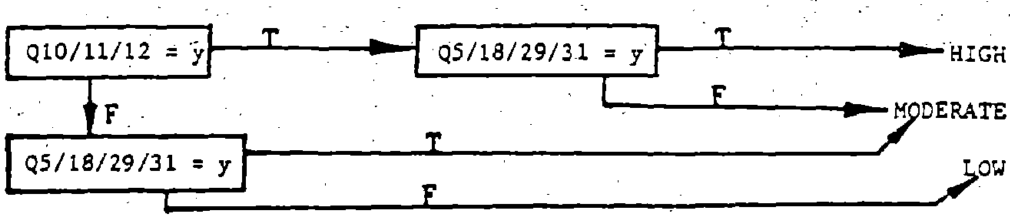
Floodflow Alteration



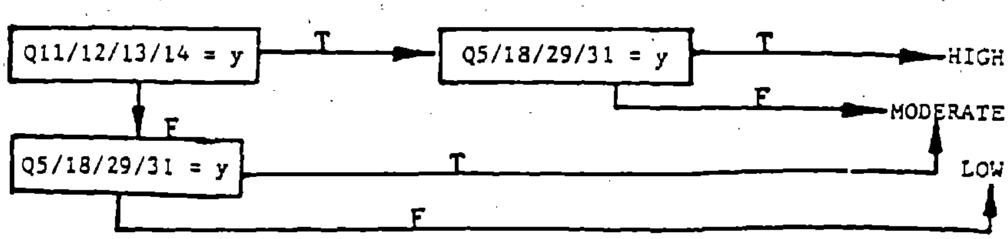
Sediment Stabilization



Sediment/Toxic Retention

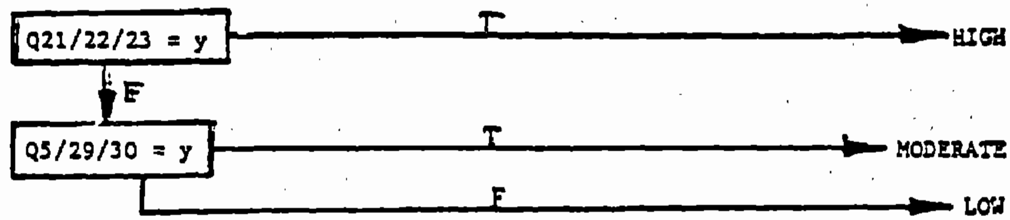


Nutrient Removal/Transformation

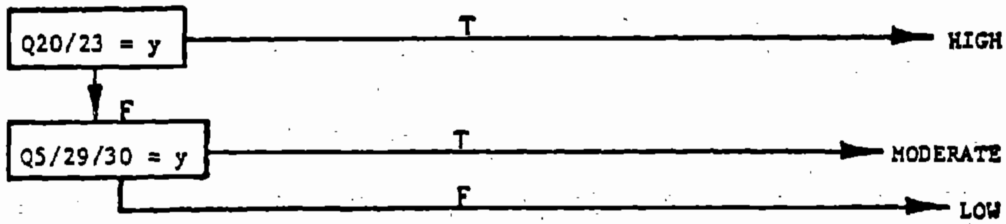


Social Significance Keys (Cont.)

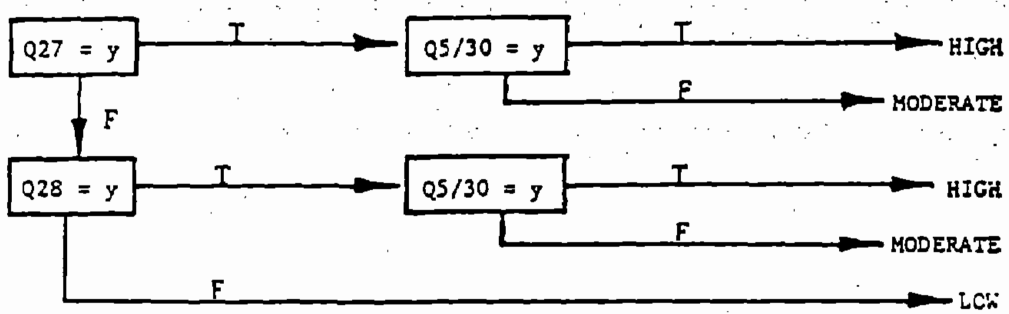
Wildlife Diversity/Abundance



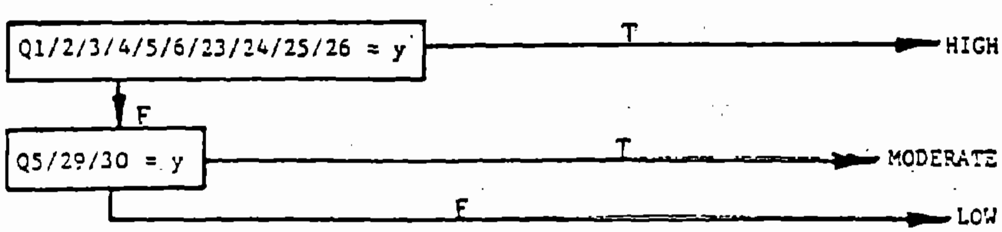
Aquatic Diversity/Abundance



Recreation



Uniqueness/Heritage



3.3 Social Significance Evaluation - Level 2 Assessment

Social significance level 2 assessment is an optional step to refine the probability rating for uniqueness/heritage. The probability rating for uniqueness/heritage assigned during Level 1 assessment is refined by considering how other wetlands in a selected area (context region) are related to the wetland being evaluated. The ideal approach for accomplishing this goal would be to assess uniqueness/heritage for all wetlands in the context region and then scale the probability rating for uniqueness/heritage for the wetland of interest accordingly. In the more realistic approach (in terms of effort) that follows, single-characteristic assessments are tallied for all wetlands in the context region to improve the uniqueness/heritage estimate.

3.3.1 Selection of Context Region

There are several options for choosing a context region. Select the context region that coincides with available manpower and project objectives. The smallest area you may wish to use as a context region is locality. A disadvantage in using locality is that difficult to compare wetland uniqueness/heritage in localities of greatly different size. Larger localities are more likely to have a greater number of wetlands, and thus more wetland types. Although this increases the probability of there being an especially rare or unique type, the relative value of each wetland may seem smaller.

Another option for the context region is to use a standard density circle (SDC). A standard density circle is a circle drawn to include a predetermined number of wetlands (typically 30). Within any two SDC's, the probability of encountering a rare type of wetland is greater. Thus, wetland comparisons based on scarcity and uniqueness have a statistical basis. A third option is to use the watershed of a service area or USGS hydrologic unit as the context region. Although such an option has little political relevance and makes comparisons statistically less reliable, it accounts for the potential interactions among wetlands and uniqueness/heritage values. Other options include evaluating wetlands in terms of their uniqueness/heritage in an ecoregion (see Bailey 1978) or within a local, state, or jurisdictional district. These options may require extensive effort to examine and classify wetlands. The result, however, would be a more realistic perspective on uniqueness/heritage of a particular wetland.

3.3.2 Assessment Procedure

Assess the uniqueness/heritage of the AA using the following steps:

(1) Select the context region.
(2) Obtain NWI wetland classification maps for the context region. If NWI maps are not available and no regional wetland classification maps are available, a classification of the wetlands within the context region must first be completed using aerial photography, field visits, etc.
(3) From the wetland classification map tally the number, and if convenient, the acreage of all wetlands according to wetland system and class, and if possible subclass and hydroperiod.
(4) Calculate percentages for the categories tallied in Step 3.

(5) Answer the four following questions.

(a) Is the wetland's class the rarest or next-to-rarest wetland class in the context region by number or acreage?
(b) Is the wetland's subclass the rarest or next-to-rarest wetland subclass in the context region by number or acreage?
(c) Is the wetland's hydroperiod the rarest or next-to-rarest wetland hydroperiod in the context region by number or acreage?
(d) Of all the wetland hydroperiods or subclasses that are present in this context region, does this wetland possess more than 80%?

3.4 Social Significance Evaluation - Level 2 Interpretation

If none of the four questions above (a-d) was answered "Y" enter a LOW in the uniqueness/heritage row of the social significance column of Form D. If only one of the four questions above (a-d) was answered "Y," enter a MODERATE on Form D in the uniqueness/heritage row of the social significance column. If more than one of the four questions above (a-d) were answered "Y," place a rating of HIGH in the uniqueness/heritage row of the social significance column of Form D. If a higher probability rating has already been assigned to uniqueness/heritage as a result of the Level 1 assessment, do not replace it with a lower probability rating. Enter the appropriate code next to the uniqueness/heritage probability rating to indicate the type of Level 2 assessment that was done. For example:

Context Region	Wetlands Classification	Code
SDC	Hydroperiod	SDC-HP
Locality	Class, subclass	L-C,SC
Hydrounit	Class, hydroperiod	HU-C,HP

This completes the second level assessment of the social significance evaluation. Two options are now possible:

(1) Continue with the effectiveness and opportunity evaluation in Section 4.0.

(2) Stop the assessment at this point and complete the evaluation by filling in the appropriate portions of Form D.

4.0 EFFECTIVENESS AND OPPORTUNITY EVALUATION

The effectiveness and opportunity evaluation assesses the capability and opportunity of a wetland to perform functions. The evaluation consists of a series of questions designed to characterize the wetland and the surrounding area in terms of its physical, chemical and biological attributes. The evaluation has three levels of assessment. Each successive level of assessement adds to the information gathered during previous levels to build a more detailed characterization of the wetland and the surrounding area. Corresponding with the more detailed characterization of the wetland is an increased confidence in the probability ratings resulting from the assessment. The level of assessment chosen will depend upon time and information available, as well as the confidence desired. Experience has shown that the second level of assessment provides a reasonable balance between these three factors for most evaluation situations.

The first level of assessment can be conducted in the office using the information resources described in Task 1 and will take approximately 1 hour to complete. The second level of assessment requires visiting the wetland site for observation and data collection. This level will take approximately 1-3 hours to complete. The third level of assessment requires requires detailed (and in some cases long term) physical, chemical, and biological monitoring data from the wetland site. The time required for this level varies depending on the size and complexity of the wetland being evaluated.

An interpretation key specific to each function assigns probability ratings of HIGH, MODERATE, or LOW to eleven wetland functions in terms of effectiveness, and three wetland functions in terms of opportunity. The interpretation keys that assign probability ratings for effectiveness and opportunity were constructed with the assumption that responses from the questions in the first and second level of the effectiveness and opportunity evaluation would be available for interpretation. The only provision made for partially completed data sets (i.e., unknown answers) is in the case of a Level 3 assessment (Questions 51-64). If all Level 1 and 2 questions are not answered (unless specified in the question itself), the validity of the probability ratings is uncertain. Therefore, it is recommended that effectiveness and opportunity evaluations be conducted at Level 2 or 3.

4.1 Effectiveness and Opportunity Evaluation - Level 1 Assessment

1. CLIMATE

1.1 Is the AA located in one of the precipitation deficit region shown in Figure 33 <u>or</u> does local data indicate that on-site evaporation exceeds precipitation on an annual basis?

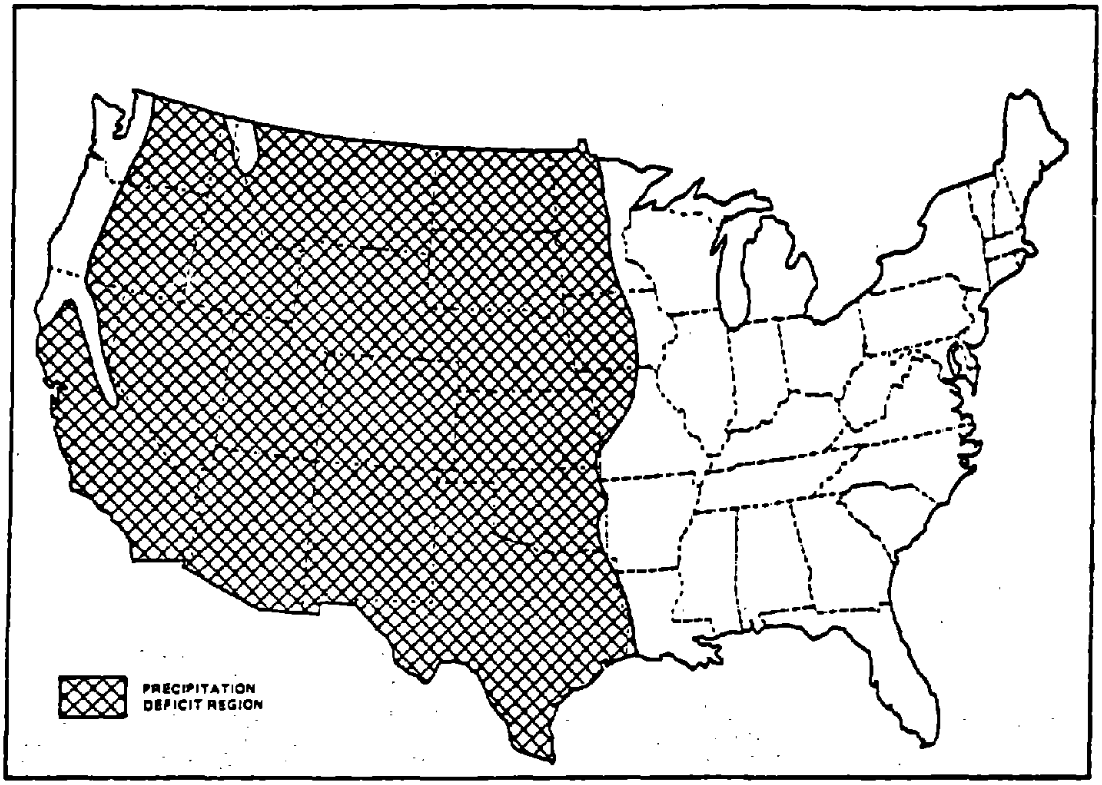


Figure 33. Precipitation deficit regions of the United States (Source: USGS 1970) (Note: Use local data if available, especially in the mountainous regions of the western United States.)

1.2 Is either of the following conditions true?

(a) The AA is located in one of the intense storm regions shown in Figure 34.

(b) The rainfall erosivity factor for the area is greater than 300[1]?

Guidelines:

[1] This value is available from your local Soil Conservation Service office.

1.3 Does the entire AA freeze over for more than 1 month during most winters? (If unknown, estimate based on climate, salinity, flow, depth, size, and presence of springs.)

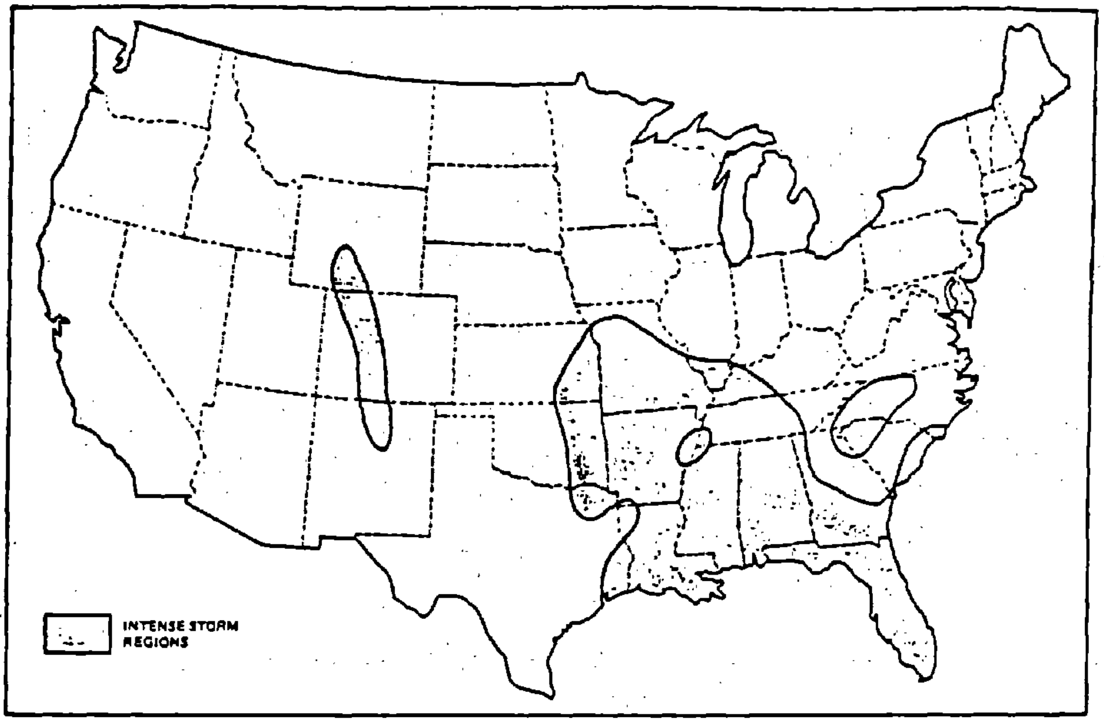


Figure 34. Intense storm regions of the United States

2. ACREAGE

2.1 Is the surface area of the AA/IA and any accessible[1] wetlands within 1 mile of the AA/IA:

2.1.1 Less than 5 acres?
2.1.2 Greater than 40 acres?
2.1.3 Greater than 200 acres?

Guidelines:

1 Throughout this document, accessible refers to accessibility of an area to the same population of fish. See the Glossary for greater detail.

2.2 (Answer "I" if the AA/IA has no forest.) Is the forested area within the AA/IA and up to 1 mile away from the AA/IA:[1]

2.2.1 Less than 5 acres?
2.2.2 Greater than 40 acres?

Guidelines:

1 Include all forested within 1 mile of the AA/IA connected by an unbroken, forested corridor of at least 150 ft in width (Figure 35).

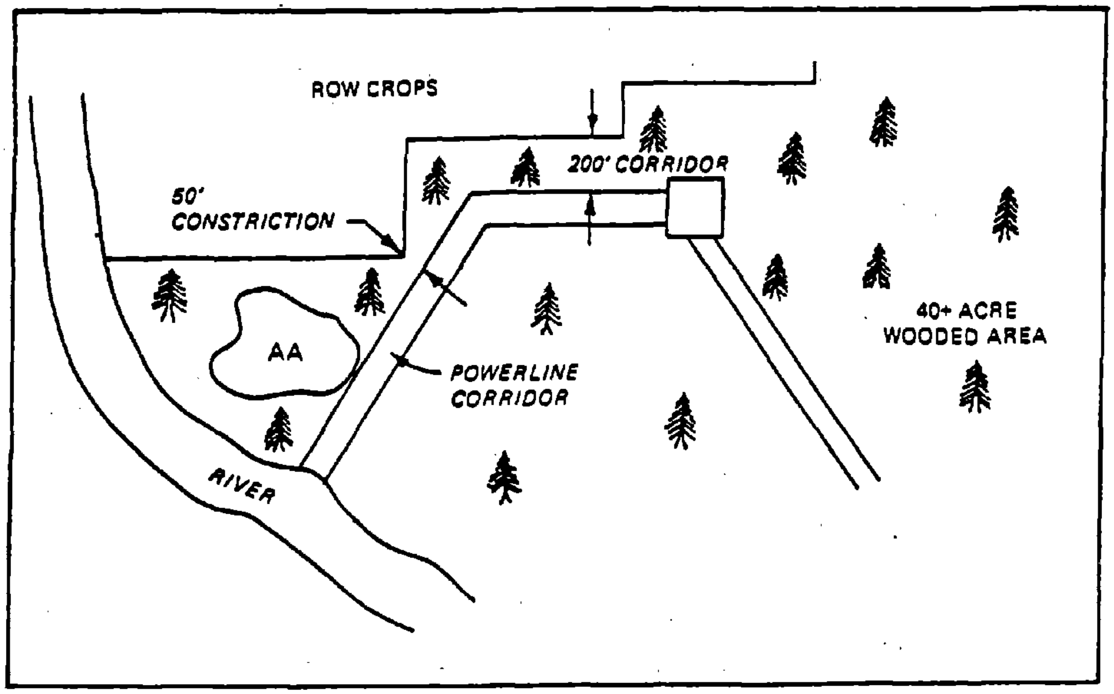


Figure 35. Example of a forested corridor connecting the AA/IA to adjacent forested areas (Note: In the figure, a 10-acre forested AA/IA is connected by a forested corridor to a 40-acre forest within 1 mile. However, the corridor has a constriction of less than 150 ft, therefore, Questions 2.2.1 and 2.2.2 would be answered "N.")

3. COMPLEX, CLUSTER, OASIS

3.1 Are there other wetlands within 1 mile of the AA?

3.2 Within 1,000 yd of the AA's center (or within 1 mile along the shoreline if the AA is tidal), is the acreage of emergent or scrub-shrub/forested wetland classes[1] greater than the criteria acreage shown for the corresponding type in the "cluster" columns of Table 27?

3.3 Within 1,000 yd of the AA's center (or within 1 mile along the shoreline if the AA is tidal), is the acreage of emergent or scrub-shrub/forested wetland classes[2] less than the criteria acreage shown for the corresponding type in the "oasis" columns of Table 27?

Guidelines:

[1] For Question 3.2 if both emergent and scrub-shrub/forested classes are present, use the class with the greater acreage.

[2] For Question 3.3 if both emergent and scrub-shrub/forested classes are present use the class with the lesser acreage.

4. LOCATION AND SIZE

4.1 Is the AA within 5 miles of tidal waters, the Great Lakes, or a river of at least 100 miles length?

4.2 The watershed of the AA is:

- **4.2A** Less than 1 square mile?
- **4.2B** 1-100 square miles?
- **4.2C** 100-2,500 square miles?
- **4.2D** greater than 2,500 square miles?

5. ASSESSMENT AREA/WATERSHED RATIO

5.1 What percentage of the AA watershed acreage[1] does the AA comprise?[2]

- **5.1.1** Less than 5% or less than 10% if region is dry.
- **5.1.2** More than 20% or more than 15% if region is dry.

Guidelines:

[1] If the AA is a subsample of a larger hydrologically interdependent AA (see page 22), use the acreage of the larger AA to answer this question.
[2] Using the acreages from Form A, Part 2, perform the following calculation: AA acreage/AA watershed acreage x 100.

5.2 Do upslope AA's comprise more than 5% of the total acreage of this AA watershed (Figure 36) or more than 3% if region is dry?

Guidelines:

[1] Determine acreage of all upslope AA's in watershed of AA and using the watershed acreage from Form A, Part 2, perform following calculation: upslope AA acreage/AA watershed acreage x 100.

6. LOCAL TOPOGRAPHY

6.1 Are any of the following conditions present?

(a) The AA is a playa.
(b) The drop in elevation from the downslope end of the AA to a point 2 miles downslope (or to the bottom of a valley, whichever comes first) is greater than the rise in elevation from the upslope end of the AA to a point 2 miles upslope (or to the top of a ridge, whichever comes first) (Figure 37).
(c) The AA is located within 2 miles of a topographic divide that separates two major watersheds[1] and is not at the toe of a slope of greater than 20% (Figure 38).

Guidelines:

[1] A major watershed contains a river channel of at least 100 ft width from bank to bank.

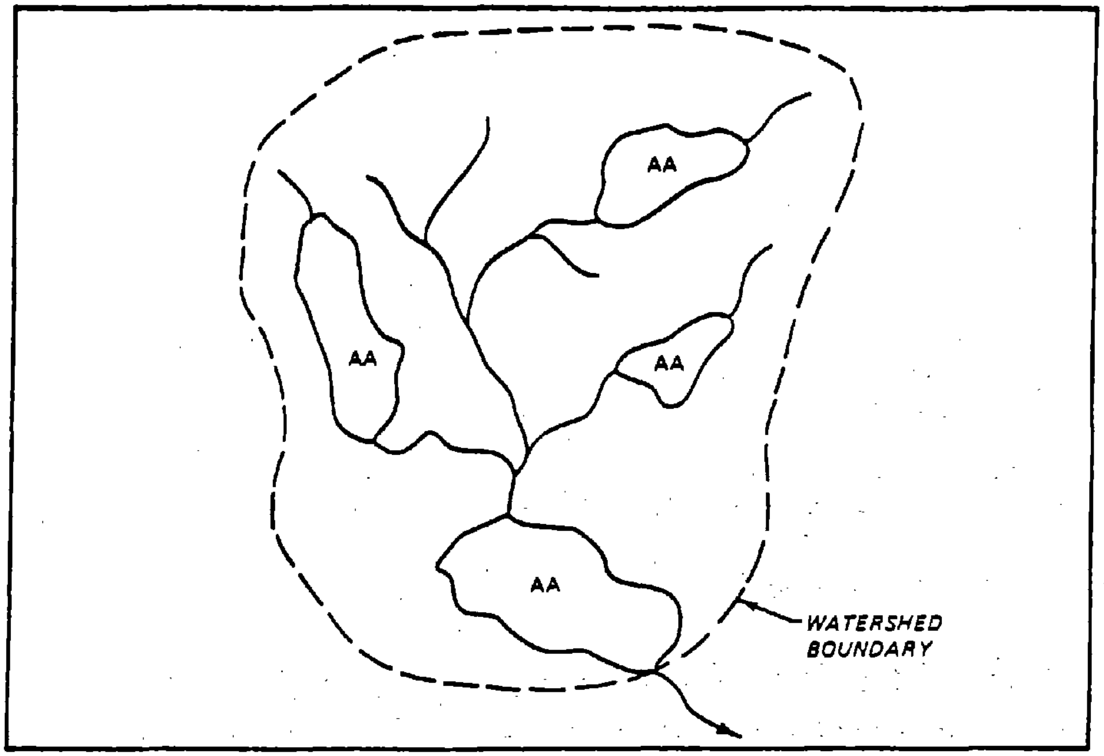


Figure 36. Upslope AA's in relation to the watershed (Note: In the figure, upslope AA's comprise more than 5 percent of the watershed area excluding the AA, therefore, Question 5.2 = "Y.")

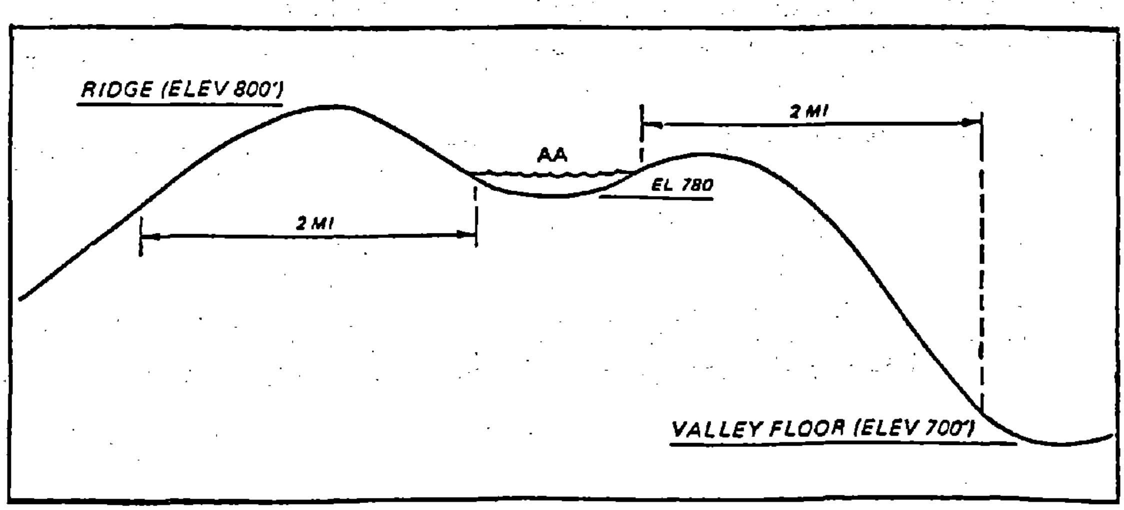


Figure 37. Elevational change upslope and downslope of the AA (Note: In the figure, the downslope elevational change of 80 ft is greater than the upslope elevational change of 20 ft; therefore, Question 6.1 would be answered "Y.")

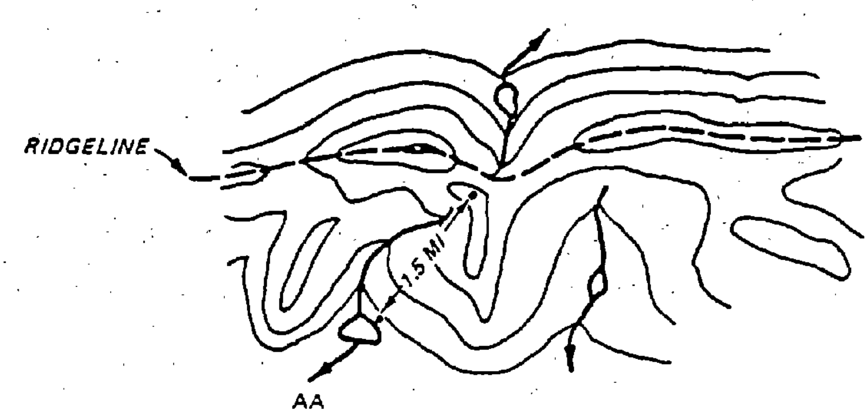


Figure 38. Example of a topographic feature dividing watersheds (Note: In the figure, a ridge line, within 2 miles, divides two watersheds; therefore, Question 6.1 would be answered "Y.")

6.2 Do soil maps, geologic maps, or field inspection indicate that any of the following is true?

(a) A geologic fault, oriented perpendicular to surface flow, is present within the AA.

(b) Within the AA's watershed the permeability of the soils decreases in a downslope direction toward the AA. If unknown, assume that decreased permeability[1] is represented by increased prevalence of marine clays or fine particled soils, shallower depth to bedrock, or decreased prevalence of talus or coarse alluvial sediments (such as occur at the mouths of canyons in glacial moraine areas or at the base of avalanche paths).

(c) The AA is at the base of a relatively steep regional slope.

Guidelines:

1 Permeability can be thought of as the ease with which soil pores permit the movement of water. It is most directly related to soil structure and texture.

7. GRADIENT

(Answer "I" if Question 41 can and will be answered <u>or</u> if the AA/IA is tidal.) Is either of the following true?

- (a) The AA/IA does not have a channel <u>or</u> the annual floodplain is wider than the channel.
- (b) The channel gradient of the AA/IA is less than the corresponding gradient value shown in Table 28.[1]

<u>Guidelines</u>:

[1] Determine the AA/IA's gradient (see Figure 39) and compare the calculated gradient value to the gradient value shown in Table 28 for the selected roughness coefficient (columns) and depth (rows).

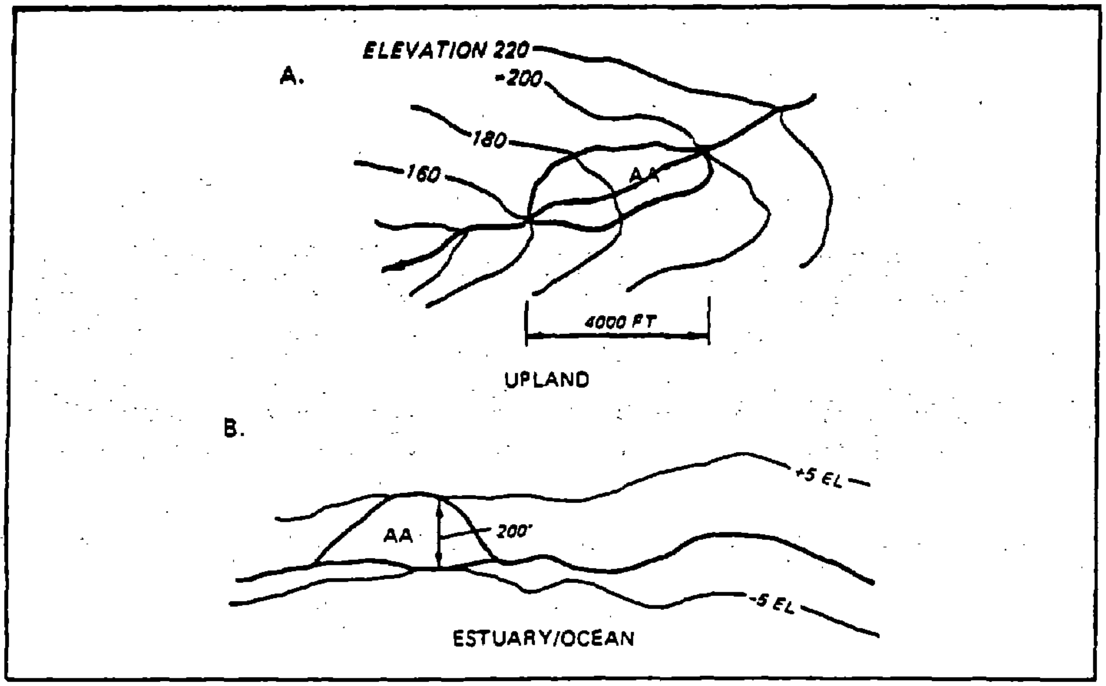


Figure 39. Determining gradient of the AA/IA using topographic maps (Note: In Part A. the gradient of the AA/IA is 0.01 (200 minus 160 divided by 4000). In Part B. the gradient of the AA is 0.05 (+5minus -5 divided by 200).)

Table 28. Gradient Necessary to Create Depositional Velocity Conditions. (Interpreted from SCS curves for channel flow.)

Mean Depth (ft)	$N \geq 0.125$[1]	$N = 0.080$[2]	$N = 0.050$[3]	$N \leq 0.035$[4]
< 0.5	< 0.0250	< 0.0100	< 0.0038	< 0.0018
0.5-1	< 0.0150	< 0.0060	< 0.0023	< 0.0012
1-2	-----	< 0.0030	< 0.0012	< 0.0006
2-3	-----	< 0.0017	< 0.0006	< 0.0003
3-4[5]	-----	< 0.0013	< 0.0005	< 0.0002
4-6[5]	-----	< 0.0008	< 0.0003	< 0.0001
6-8[5]	-----	< 0.0006	< 0.0002	< 0.0001
8-10[5]	-----	< 0.0004	< 0.0002	-----
10-12[5]	-----	< 0.0003	< 0.0001	-----

1 Densely wooded floodplains ("N" is Manning's roughness coefficient).
2 Densely vegetated emergent wetlands not totally submerged by floodflow.
3 Moderately vegetated or totally submerged (by floodwater) emergent wetlands, or with boulders.
4 Unobstructed channels.
5 Assumes width, perpendicular to flow is <8 ft. If channel is 8-20 ft wide, the value in the row immediately below the value identified should be used. If channel is wider than 20 ft, answer "I."

8. INLETS, OUTLETS

Does surface water enter and/or exit the AA through an:[1]

8.1 Inlet with permanent flow?
8.2 Inlet with intermittent flow?
8.3 Outlet with permanent flow?
8.4 Outlet with intermittent flow?

Guidelines:

1
(a) Do not consider precipitation or sheetflow to be surface water.
(b) Consider fringe wetlands to have both a permanent inlet and outlet.
(c) Inlets and outlets regularly flooded by the tide are permanent.

9. CONSTRICTION

9.1 Is any of the following true?

(a) Channel flow is present, and the width of the AA/IA's outlet(s), at annual high water, is less than one-third the average width of the AA/IA perpendicular to flow (Figure 40A).
(b) Channel flow is present, and the cross-sectional area of the AA/IA's outlet(s) is less than the cross-sectional area of the inlet(s) (Figure 40A).
(c) Channel flow is not present (i.e., AA/IA has no gradient or is tidal), and the total width of the AA/IA's outlet(s) is less than one-tenth the average width of the AA/IA (Figure 40B).

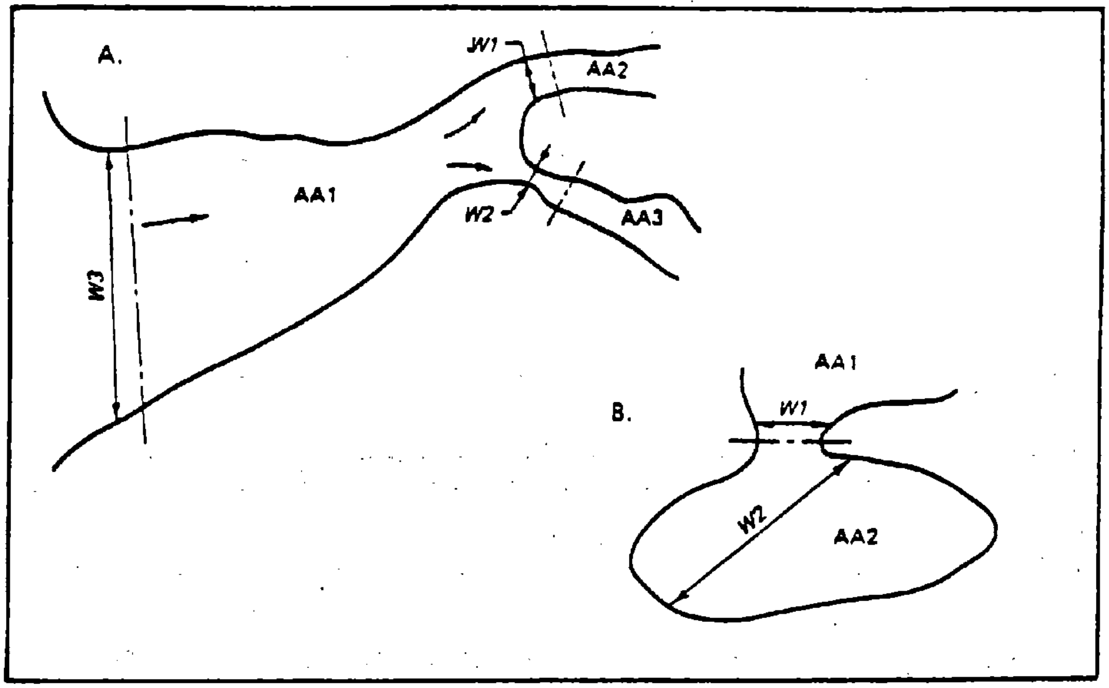


Figure 40. Examples of constricted outlets (Note: In Part A, the width and/or cross-sectional area of the outlets (W1 and W2) is less than 1/3 of the inlet (W3). In Part B, there is no channel flow, and the outlet (W1) is less than 1/10 the average width of the AA1 (not shown). In both cases the outlet is constricted.)

9.2 (Answer "I" if tidal.) Does sheetflow from a contiguous body of water inundate wetlands in the AA/IA at least once a year, and subsequently exit the wetland through a constricted outlet(s) or not exit the AA/IA wetland at all (Figure 41)?

9.3 (Answer "I" if the AA/IA has no outlet.) Does outflow (if any) from the AA/IA originate mostly from precipitation or snowmelt occurring within the AA/IA (i.e., AA/IA has little or no watershed)?

10. WETLAND SYSTEM

Which wetland system covers the greatest area in the AA/IA?

- **10.A** Lacustrine (no woody or persistent emergent vegetation)
- **10.B** Palustrine
- **10.C** Riverine nontidal (no woody or persistent emergent vegetation)
- **10.D** Riverine tidal (no woody or persistent emergent vegetation)
- **10.E** Estuarine
- **10.F** Marine (no erect vegetation)

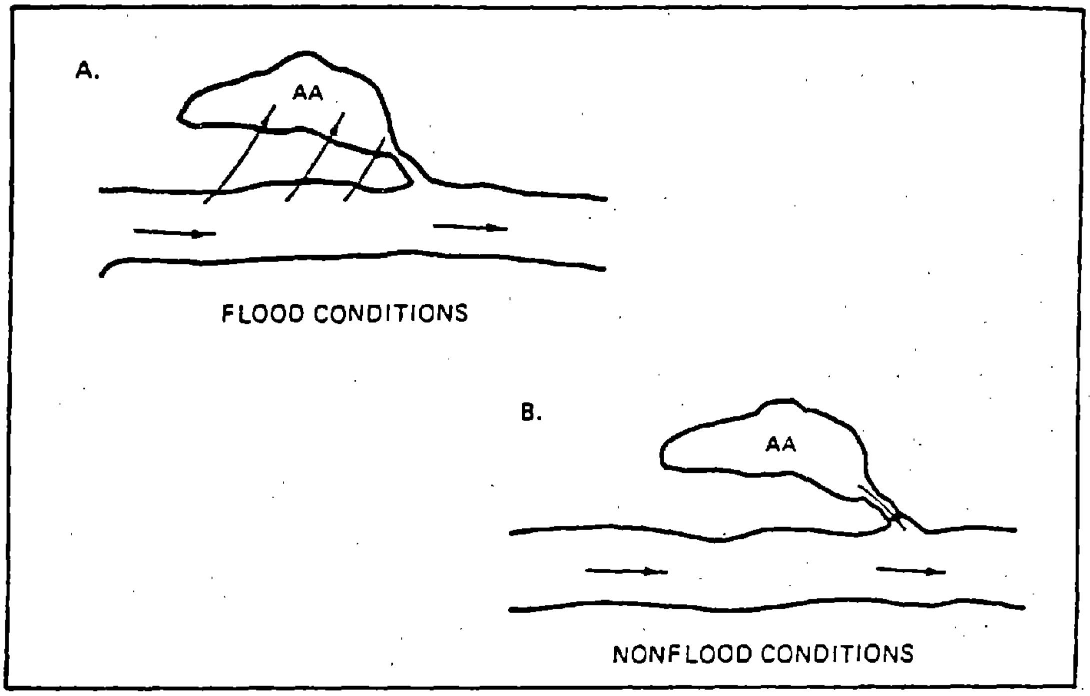


Figure 41. Example of a seasonally constricted outlet

11. FRINGE WETLAND OR ISLAND

Is the AA/IA part of a fringe wetland or an island or does the AA/IA comprise all, or most of, a fringe wetland or island?

12. VEGETATION CLASS/SUBCLASS (PRIMARY)

Select from the list below, the vegetation class[1] (e.g., forested, emergent, etc.) and subclass (e.g., needle-leaved evergreen, broad-leaved deciduous, etc.) that is:

(a) Dominant[1] in the AA/IA?

(b) Dominant at the edge of open water of Zones B and C (Figure 42). (Exclude the subclass rooted vascular, "12Cc".)

(c) In contact with water over the largest area of the AA/IA (i.e., roots and stems inundated).

Circle "Y" on the answer sheet for the classes and subclasses that were selected. Circle "N" for the classes and subclasses not selected.

12.A Forested?
- **Aa and dead?**
- **Ab and needle-leaved evergreen?**
- **Ac and broad-leaved evergreen?**
- **Ad and needle-leaved deciduous?**
- **Ae and broad-leaved deciduous?**

12.B Scrub-shrub?
- **Ba and dead?**
- **Bb and needle-leaved evergreen?**
- **Bc and broad-leaved evergreen?**
- **Bd and needle-leaved deciduous?**
- **Be and broad-leaved deciduous?**

12.C Aquatic bed?
- **Ca and algal?**
- **Cb and floating vascular?**
- **Cc and rooted vascular?**
- **Cd and aquatic bryophyte (moss or liverwort)?**

12.D Emergent?
- Da and persistent?
- Db and nonpersistent?

12.E Moss-lichen?

Guidelines:

1 "Dominant" in this question means the class or subclass that covers the greatest area. However, if 12.A (forested) and 12.B (scrub/shrub) together or 12.C (aquatic bed) and 12.D (emergent) together cover a greater area than any other single class, answer "Y" to the larger of the two classes. Apply this procedure on a subclass level by grouping evergreens (all 4), deciduous (all 4), or dead (both). For example, if the four evergreen subclasses together cover a greater area than any other single subclass, answer "Y" to the largest of the four subclasses.

13. VEGETATION CLASS/SUBCLASS (SECONDARY)

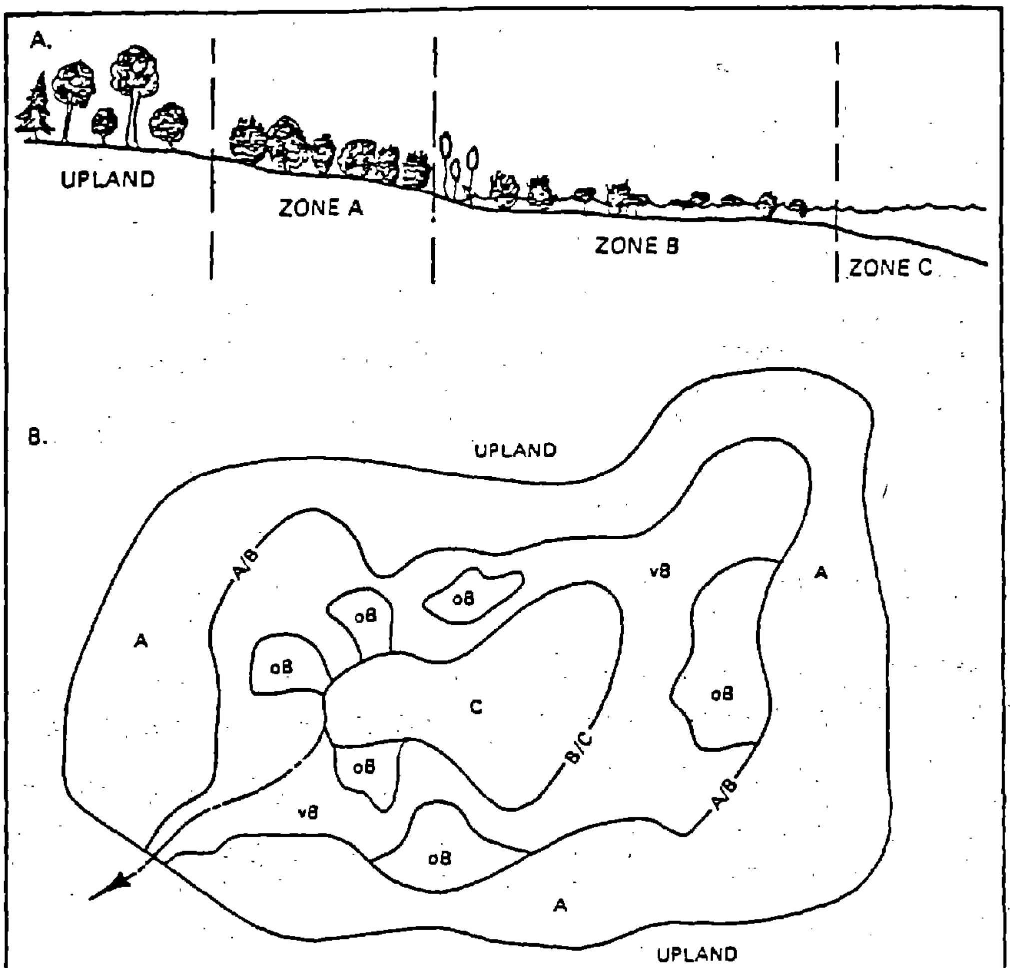
Select from the vegetation classes and subclasses listed in Question 12 those that comprise 10% of the AA/IA <u>or</u> at least 1 acre of the AA/IA?

14. ISLANDS

Is the AA/IA an island or does it contain part, or all, of an island that is:

14.1 At least 25 sq ft in size <u>and</u> at least 50 ft from the shoreline?

14.2 At least 2 acres in size, separated from the mainland by permanent water at least 30 in. deep, <u>and</u> at least 2 miles offshore if the wetland system is marine or 0.5 mile offshore if the wetland system is not marine?



ZONE A IS:

(1) VARIABLY SATURATED, BUT SURFACE WATER IS NOT PERMANENT
(2) MORE LIKELY TO BE VEGETATED WITH FACULTATIVE SPECIES

ZONE B IS:

(1) SURFACE WATER IS PRESENT AT THE SPECIFIED SEASON OR TIDE
(2) MORE LIKELY TO BE VEGETATED WITH OBLIGATE SPECIES
(3) MADE OF THE FOLLOWING SUBZONES:

(oB) OPEN WATER
(vB) VEGETATED
(eB) ERECT VEGETATION
(rB) ROBUST VEGETATION
(sB) SUBMERGED VEGETATION

ZONE C IS:

(1) OPEN WATER WITH A DEPTH OF AT LEAST 6.6 FT (2M)

Figure 42. Wetland zones

15. VEGETATION/WATER INTERSPERSION

(Answer "I" to all of 15.1 if the wetland system is riverine. Answer "Y" to 15.1A if surface water is absent.) Does the horizontal pattern of erect vegetation in Zone B (Figure 42) consist of:

15.1A Relatively few, continuous areas supporting vegetation with little or no interspersion with channels, pools, or flats (Figure 43)?

15.1B A condition intermediate between 15.1A and 15.1C?

15.1C A mosaic of relatively small patches of vegetation (i.e., none smaller in diameter than two times the height of the prevailing vegetation) interspersed with pools, channels, or flats (Figure 43)?

15.2 (Answer "I" if channel or tidal flow never occurs in the AA/IA.) Is either of the following conditions present in that portion of the AA/IA having measurable flow?

(a) In channel situations, vegetation in Zone B consists mainly of persistent emergent distributed in the mosaic pattern described in 15.1C.

(b) Under average flow conditions, water enters the AA/IA in a channel and then spreads out over a wide area.

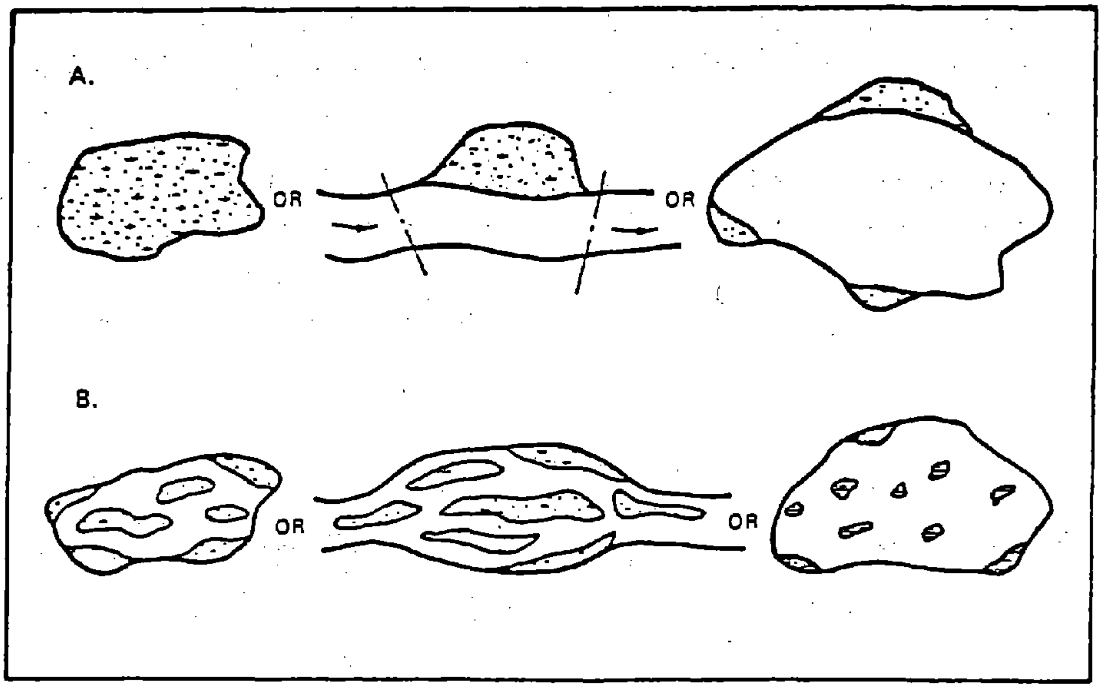


Figure 43. Examples of low and high vegetation/water interspersion (Note: In this figure, Part A exemplifies low vegetation/water interspersion (Question 15.1A = "Y"), and Part B exemplifies high vegetation water interspersion (Question 15.1C = "Y").)

16. VEGETATION CLASS INTERSPERSION

The horizontal pattern of vegetation classes (e.g., forested, aquatic bed, scrub-shrub) in the AA/IA consists of:

16.A Relatively homogeneous areas supporting a single vegetation class with little or no interspersion between these homogeneous areas (Figure 44)?

16.B A condition intermediate between the conditions described in 16.A and 16.C?

16.C A highly interspersed mosaic of relatively small areas (not less than 100 sq ft) which support different vegetation classes (Figure 44).

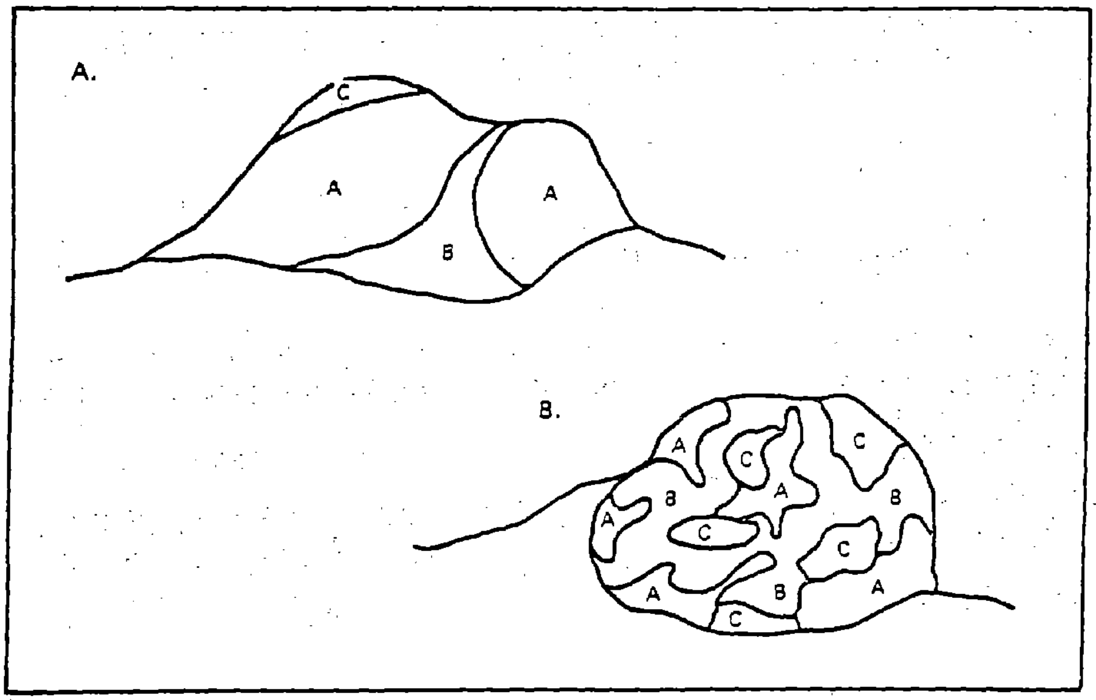


Figure 44. Examples of low and high vegetation class interspersion (Note: In the figure, Part A exemplifies low vegetation class interspersion (Question 16A = "Y"), and Part B exemplifies high vegetation class interspersion (Question 16C = "Y").)

17. VEGETATION FORM RICHNESS

Are any of the following statements true?

(a) The AA/IA is 1-10 acres <u>and</u> supports at least three vegetation classes (none of which comprises more than 70% of the AA/IA's vegetation) or at least four vegetation subclasses.

(b) The AA/IA is 10-100 acres <u>and</u> supports at least three vegetation classes (none of which comprises more than 70% of the AA/IA's vegetation) or at least six vegetation subclasses.

(c) The AA/IA is 100 or more acres <u>and</u> has 4 or more vegetation classes (none of which comprises more than 70% of the AA/IA's vegetation) <u>or</u> at least 8 vegetation subclasses.

18. SHAPE OF UPLAND/WETLAND EDGE

(Answer "I" if the AA/IA is longer than 10 miles or if there is no adjacent upland.) Is the boundary between the upland and the AA/IA irregular (Figure 45)?

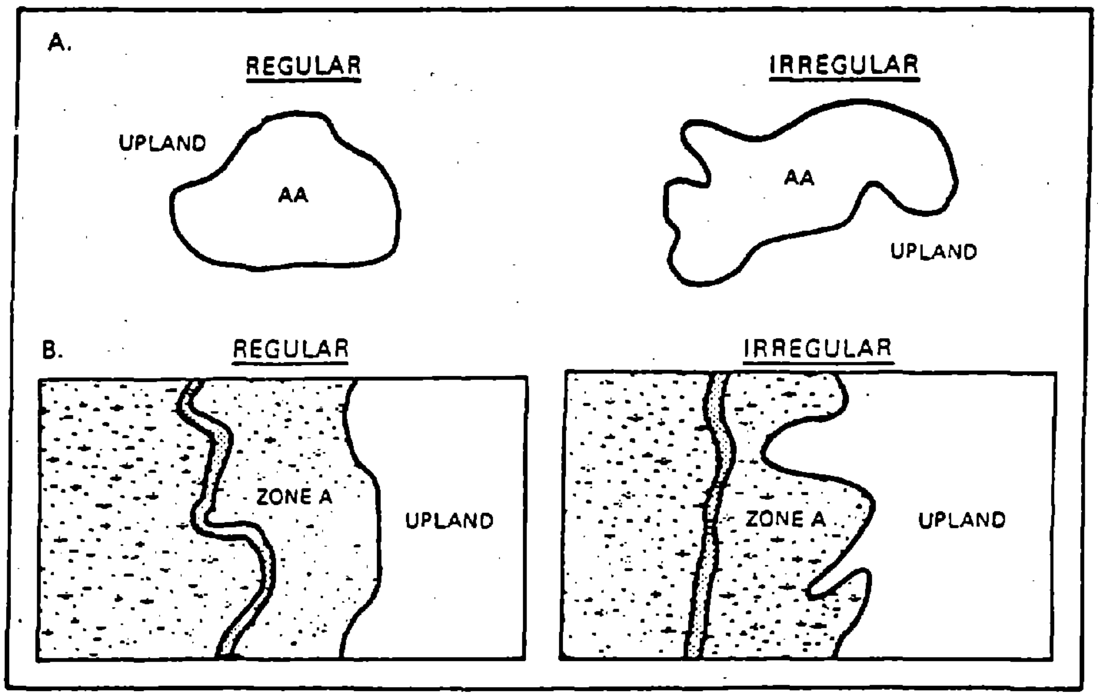


Figure 45. Regular and irregular boundaries between wetland and upland

19. FETCH/EXPOSURE

19.1A (Answer "I" if the AA/IA is predominantly Zone A.) Is either of the following true?

(a) Adjacent vegetation or topographic relief is sufficient[1] to shelter at least 1 acre of open water in Zones B or C from wind.

(b) Open water fetch is less than 100 ft (Figure 46)?

19.1B (Answer "I" if the AA/IA is mostly a riverine wetland system and narrower than 100 ft.) Is either of the following true?

(a) Vegetation or topographic relief adjacent to the AA/IA is insufficient[1] to shelter at least 1 acre of open water in Zone B or Zone C from wind and fetch is greater than 2 miles.

(b) Vegetation at the deepwater edge of Zone B is exposed to waves taller than 1 ft?

Guidelines:

[1] "Sufficient" is defined as the height of vegetation or relief multiplied by length of vegetation or relief (parallel to shore) is greater than 2,000 sq ft.

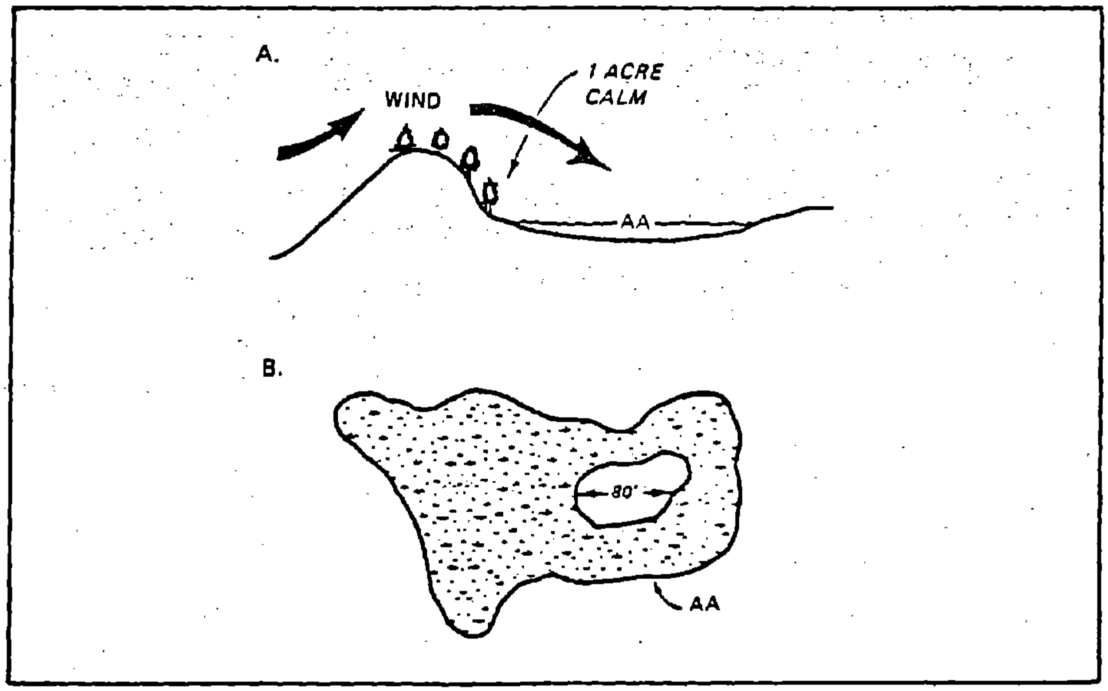


Figure 46. Examples of sheltered open water in the AA/IA (Note: In Part A of this figure, vegetation and topographic relief shelter open water in the AA/IA. In Part B of this figure, the maximum unobstructed distance is <100 ft.)

19.2 Is the AA/IA, or a portion of the AA/IA, an island, delta, bar, or peninsula that intercepts waves and thereby protects other nearby shores (Figure 47)?

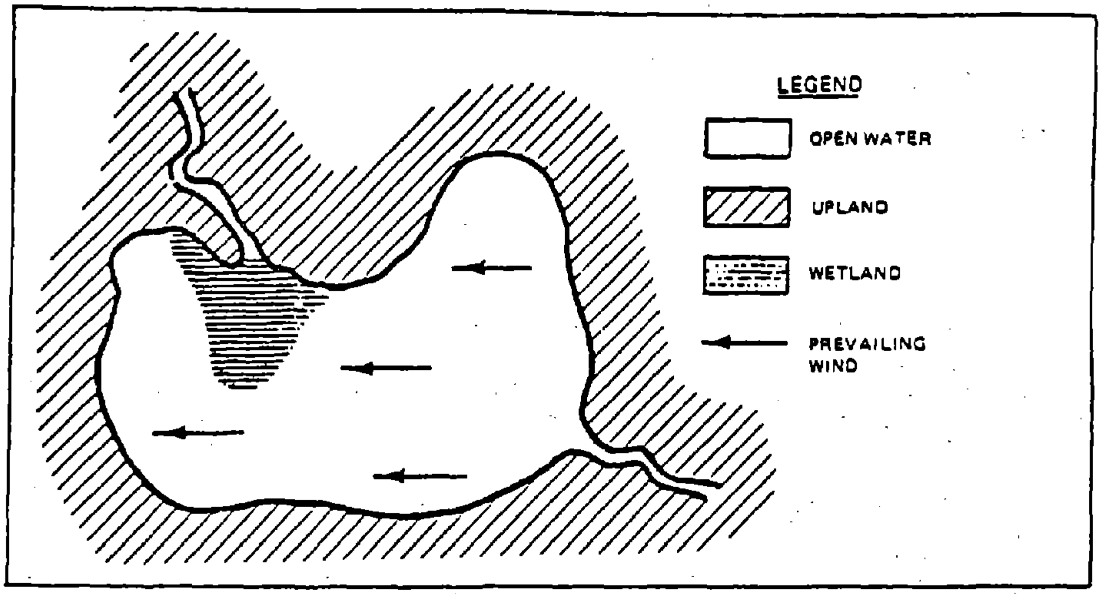


Figure 47. Example of a wetland-protected shoreline

19.3 (Answer "I" if there is no woody vegetation in AA/IA.) Does woody vegetation within the AA/IA shelter adjacent, otherwise unsheltered, uplands from wind (Figure 48)?

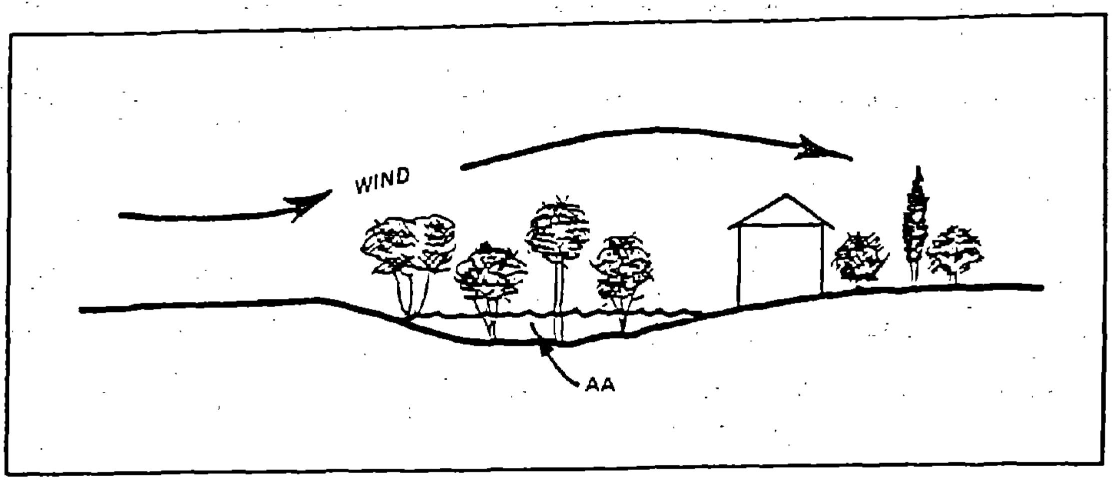


Figure 48. Example of vegetation within the wetland sheltering adjacent upland

20. VEGETATIVE CANOPY

(Answer "I" to 20.1 and 20.2 if there is no channel within the AA, or the AA is tidal.)

20.1 Is there sufficient vegetative canopy or topographic relief in and around the AA to shade at least 80% of Zone B at midday (Figure 49)?

20.2 Question deleted, answer "I".

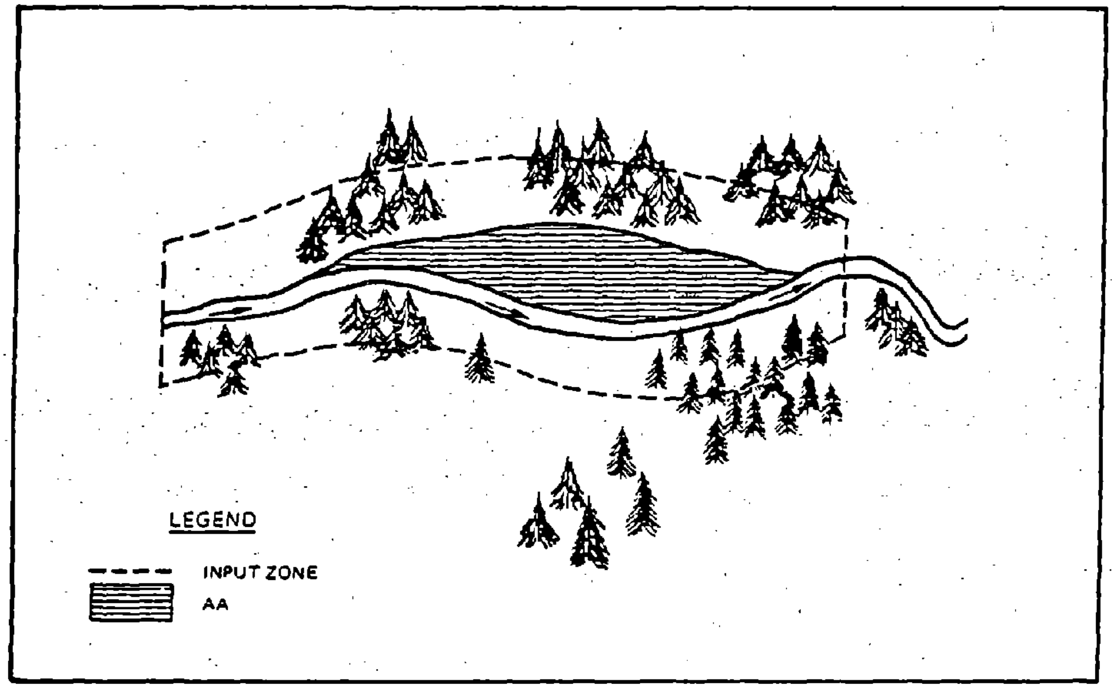


Figure 49. Example of balanced interspersion of shaded and unshaded areas in the input zone and AA

21. LAND COVER OF THE WATERSHED

The majority of the AA's watershed (excluding the AA) land cover is:[1]

- 21.A Forest and scrub-shrub.
- 21.B Impervious surfaces (urban or suburban areas, etc.).[2]
- 21.C Row crops, orchards, or vineyards.
- 21.D Nonurban pasture, hayland, perennial forbs, or grassland?
- 21.E Recently revegetated areas, landfills, surface mines, or other areas of exposed soil?

<u>Guidelines</u>:

[1] If 21B, 21C, and 21E together comprise a greater percentage than any other type, answer "Y" to the largest of these three land cover types.

[2] Impervious surfaces occur in developed areas where asphalt, concrete, etc., are extensive and where average lot size is less than 1/4 acre (10,000 sq ft).

22. FLOW, GRADIENT, DEPOSITION

22.1.1 Is any of the following true?

(a) The AA/IA contains a channel.

(b) The AA/IA has an outlet and an inlet.

(c) The AA/IA is tidal.

(d) The AA/IA has seasonal flow as suggested by gage data, scour lines, sediment deposition on vegetation, etc.

22.1.2 (Answer "I" if the AA/IA does not contain a channel.) Is the channel at least mildly sinuous with a meander ratio[1] exceeding 1.2?

22.2 Does the AA/IA include, or is it part of, an actively accreting delta (Figure 50)?

22.3 Do aerial photos or other sources of information indicate long-term erosion of the AA/IA?

<u>Guidelines</u>:

[1] Meander ratio is the distance from one point on a river to another point on the river via the channel, divided by the straight line distance between the same two points.

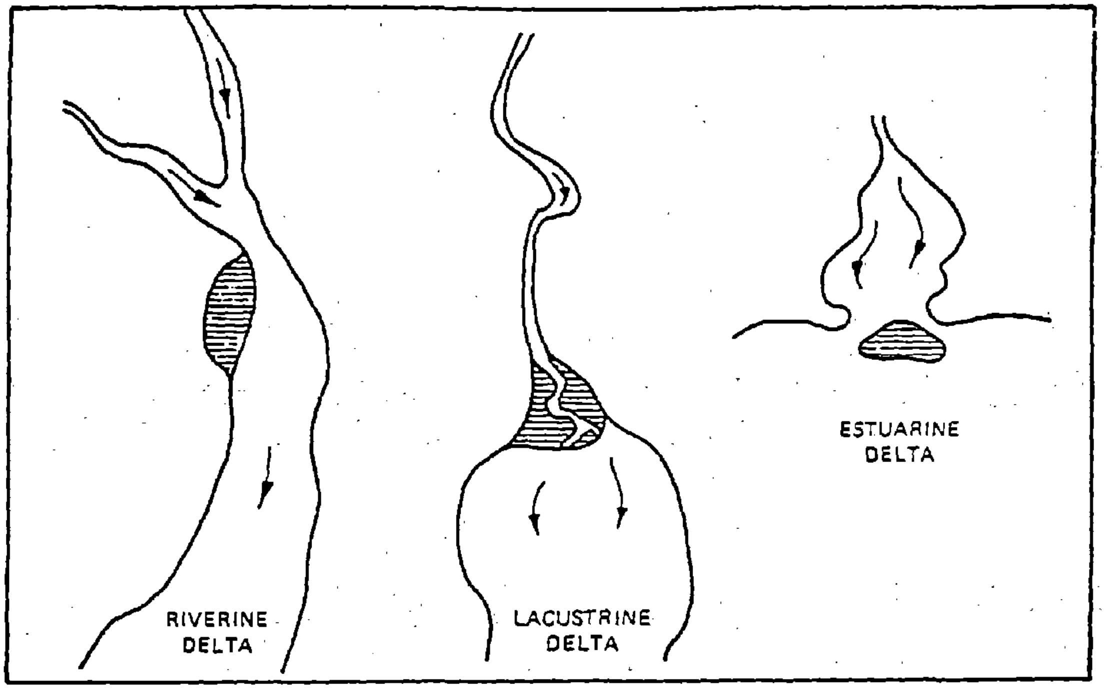


Figure 50. Examples of actively accreting deltas

23. DITCHES/CANALS/CHANNELIZATION/LEVEES

Do functioning ditches, canals, levees, or similar artificial features cause surface water to leave the AA/IA at a faster rate than it would if these features were not present?

24. SOILS

24.1 (Answer "I" if unknown.) Does analysis indicate that the soil types present in the AA/IA contain more than 4,000 mg/kg (dry weight) of amorphous extractable aluminum in the upper 8 in.?

24.2 (Answer "I" if Question 24.1 was answered "Y" or "N".) Are both of the following true?

(a) Soil maps or a site visit indicate the dominance of alluvial (e.g., fluvaquent), alfisol, ferric, clay, or other primarily fine mineral soils in the AA/IA.

(b) The map in Figure 51 shows the soils of this region to normally have elevated concentrations of aluminum (>6%) or iron, <u>or</u> analysis indicates there is less than 20% organic matter by weight in the upper 3 in. of sediment?

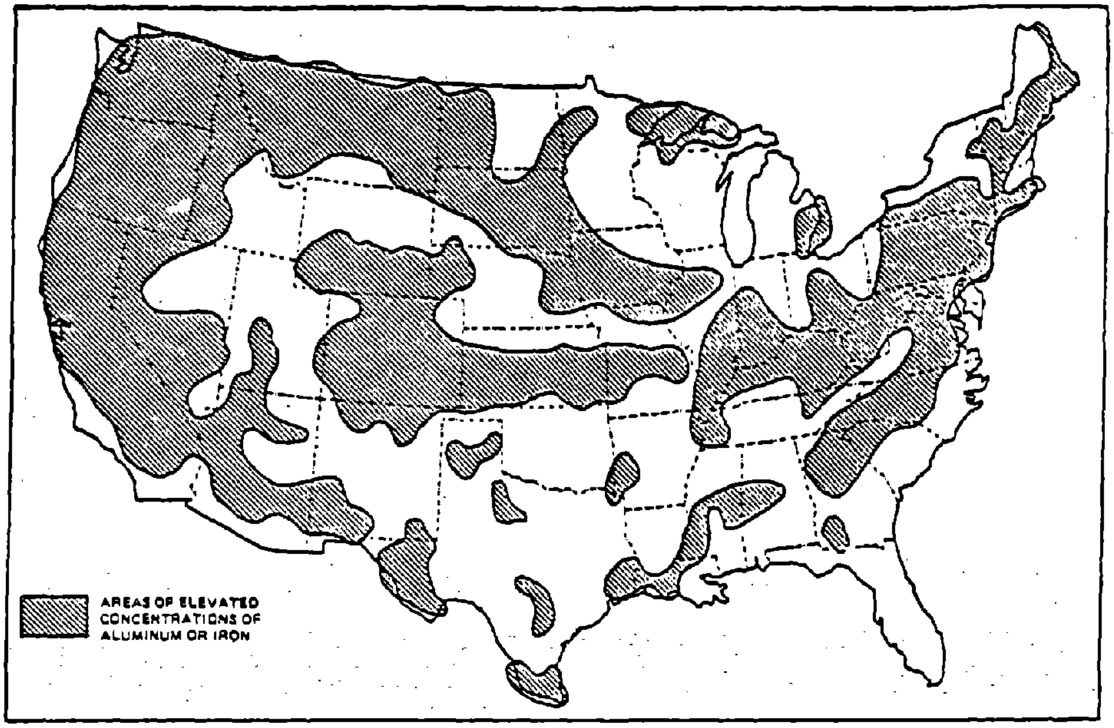


Figure 51. Geographic areas with elevated concentrations of aluminum or iron (interpreted from USGS 1984)

24.3 (Answer "I" if tidal or if unknown.) Do soil surveys indicate that soils in the AA/IA have very slow (<0.006 in./hr) infiltration rates due to the presence of impeding layers (fragipan, duripan, claypan) or very shallow depth to unfractured bedrock?

24.4 (Answer "I" if unknown.) Do soil surveys indicate that soils in the watershed (up to 1 mile away) have mostly slow infiltration rates, <u>or</u> are these soils impermeable due to fine texture, impeding layers, high water table, shallow depth to unfractured bedrock, or frozen condition during the usual time of greatest flooding?

24.5 Is the AA/IA in a karst (limestone) region?

25. SEDIMENT SOURCES

25.1 Are there a sediment sources that contribute inorganic sediment to the AA? Sources to consider include stormwater outfalls, irrigation return waters, surface mines, or areas[1] containing any of the following: exposed soils associated with agriculture, lands cleared within the last 2 years, soil-slope conditions classified by SCS as eroding or erosion hazard (e.g., subclass "e" in the SCS Land Classification Codes), gullies, sand or gravel pits, or severely eroding stream or road banks.

25.2A (Answer "I" if 25.1 = "N.") Is overland runoff the primary source of the sediment entering the AA?

25.2B (Answer "I" if 25.1 = "N.") Is channel flow the primary source of the sediment entering the AA?

25.3 Do any of the following conditions result in significantly elevated levels of suspended solids in a major portion of the AA?

(a) Erosion within the AA is caused by drastic fluctuation in water levels due to artificial manipulation or extensive urban runoff.
(b) Slopes immediately adjacent to the AA are steeper than 10% (or steeper than 1% if alluvial clays prevail) <u>and</u> are unstable.
(c) Boating activity causes frequent wakes that impinge on the deepwater fringes of the AA.
(d) Tributaries immediately upstream of the AA have been channelized.

<u>Guidelines</u>:

1 To be considered, an area must comprise 1 acre or 2% of the input zone (whichever is greater), or an area within 0.5 mile at least as large as the AA's wetland acreage.

26. NUTRIENT SOURCES

26.1 Is there evidence of high nutrient concentration in the AA (algal blooms or actual measurement of high concentration) <u>or</u> do any of the following sources contribute nutrients to the AA?

(a) Sewage outfalls, phosphate mines, tile drains, canals, or other nutrient-rich sources.
(b) Areas[1] containing any of the following: feedlots, active pastureland, landfills, septic fields, fertilized soils, or soils tilled, burned, or cleared within the last 2 years.
(c) Areas where the acreage of the AA divided by the number of houses with septic systems within the input zone is less than eight.
(d) Areas where the acreage of the AA divided by the number of people living within the input zone (including those beyond the input zone if their wastes are carried to the input zone, or AA, by a collector-outfall system) is less than 25.

26.2 (Answer "I" if 26.1 = "N.") Is overland sheetflow the primary source

26.3 (Answer "I" if 26.1 = "N.") Is channel flow the primary source of the nutrients entering the AA?

Guidelines:

[1] To be considered, an area must comprise 1 acre, 2% of the input zone, or an area within 0.5 mile at least as large as the AA's wetland acreage.

27. CONTAMINANT SOURCES

27.1 Is there evidence of waterborn contaminants (e.g., fish kills or actual measurements of hazardous concentrations) or is there a source that contributes waterborn contaminants (in concentrations hazardous to aquatic life) to the AA? Consider industrial and sewage outfalls, mines, landfills, leaking subsurface tanks, salt/brine seepage, pesticide-treated areas, contaminated aquifers, severe oil runoff, irrigation return water, heavily traveled highways, or water inputs significantly contaminated by the above farther upstream.

27.2 (If 27.1 is "N," circle "I" for 27.2.) Is sheetflow the primary source of the waterborn contaminants described above?

27.3 (If 27.1 is "N," circle "I" for 27.3.) Is channel flow the primary source of the waterborn contaminants described above?

Continue with Level 2 assessment on the next page.

4.2 Effectiveness and Opportunity Evaluation - Level 2 Assessment

The second level of assessment requires a field visit to the AA. Plan to spend 1 - 3 hours at the site. During the field visit, review your responses to the questions in social significance evaluation and the first level of assessment. Revise responses in light of field observations if necessary.

Take the following items with you to the field:

(a) Volume II of WET
(b) Data forms A, B, and C
(c) Topographic maps, aerial photos, and soil survey
(d) Measuring stick/depth meter, salinometer, pH meter, and sediment grab.
(e) Binoculars

If habitat suitability is to be evaluated, review Form C (Appendix B) for the types of fish and wildlife species and recreational activities to watch for during the field visit. In addition, complete Form C before you leave the field site.

28. DIRECT ALTERATION

Is either of the following conditions true?

(a) Most of the AA/IA has been tilled, filled, or excavated at least once in the past 3 years.

(b) An outlet has recently been added to the AA/IA where none previously existed, <u>or</u> an inlet has recently been blocked off and an outlet is still present.

29. WETLAND/UPLAND EDGE

29.1 Does the boundary between the wetland and upland support adequate understory vegetation (e.g., shrubs less than 3 ft tall, dense grasses, etc.) to serve as cover for vertebrates using the wetland?

29.2 Are slopes in most of the input zone less than 5%?

30. DISTURBANCE

Are <u>both</u> of the following conditions true?

(a) The AA/IA, or areas adjacent and visible to the AA/IA, are visited by people on foot, boat, or off-road vehicle at least three times daily.

(b) Surface water in the AA/IA is mostly less than 3 ft deep and less than 1,000 ft from the usual places of human activity <u>or</u> greater than 3 ft deep and less than 600 ft from the usual places of human activity.

31. WATER/VEGETATION PROPORTIONS

Considering the entire AA:

31.1 Are Zones A and B combined greater than Zone C (Figure 42)?

31.2 Is Zone B at least 10% of the AA?

31.3 Is Zone B larger than Zone A?

31.4 (Answer "I" if submerged vegetation is absent in Zone B.) Is the area of submerged vegetation in Zone B (sB) larger than the unvegetated areas of Zones B (oB) and C?

31.5 Is the area of Zone A at least 10% the area of Zones B and C?

31.6 (Answer "Y" to 31.6A if Zone B is absent.) What percent of Zone B and Zone C together are dominated by emergent vegetation (eB)?

31.6A 0
31.6B 1-30
31.6C 31-60
31.6D 61-99
31.6E 100

32. HYDROPERIOD (SPATIALLY DOMINANT)

The dominant[1] flooding regime of the AA/IA is (Figure 52):

32.A Permanently flooded nontidal.
32.B Intermittently exposed nontidal.[2]
32.C Semipermanently flooded nontidal.
32.D Seasonally flooded nontidal.
32.E Saturated (no standing water) nontidal.
32.F Temporarily flooded nontidal.
32.G Intermittently flooded nontidal.[2]
32.H Artificially flooded nontidal.[3]
32.I Regularly flooded tidal.
32.J Irregularly exposed tidal or subtidal.
32.K Irregularly flooded tidal.

Guidelines:

[1] "Dominant" is defined as the largest percentage of the AA. However, if 32.A and 32.B together comprise a greater percentage than any other type, answer affirmatively for the larger of the two types. Similarly, if any of the nonpermanent types (32.C-32.G) in combination comprise a greater percentage than any permanent type(s), answer "Y" to the largest of the nonpermanent types. Flooding regimes are defined in Cowardin et al. 1979

[2] Distinctions between 32.B and 32.C are usually not critical unless wildlife will be analyzed at the group or species level.

[3] If 32.H is "Y," also answer "Y" to the second most dominant hydroperiod.

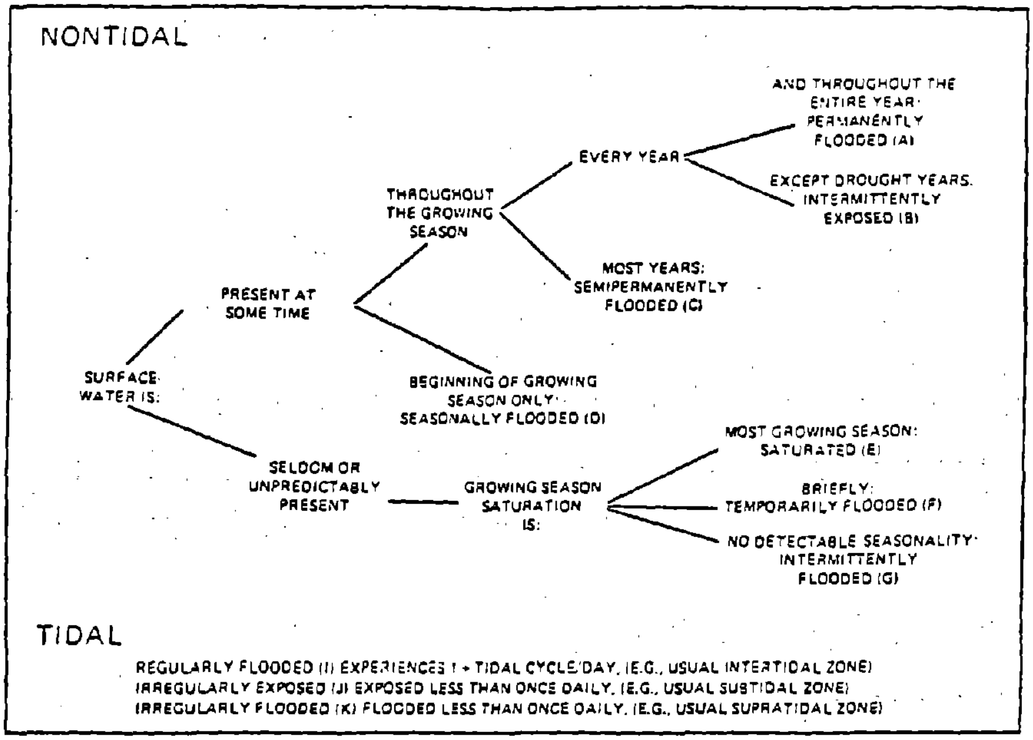


Figure 52. Key for determination of hydroperiod

33. MOST PERMANENT HYDROPERIOD

Which hydroperiod listed in Question 32 best describes the portion of the AA, or the contiguous deepwater, that is inundated or saturated for the longest part of the year and comprises at least 1 acre or 10% of the AA?[1]

Guidelines:

1 If 32.H is "Y," answer "Y" to the second most descriptive hydroperiod.

34. WATER LEVEL CONTROL

34.1 Is the AA/IA's existence dependent on upstream or downstream artificial control structures (other than those designed specifically for fish and wildlife management) built within the last 20 years?

34.2 Is the AA/IA located less than 2 miles downslope from a large impoundment (higher than 20 ft at outlet) or is the AA/IA's water table influenced by any other type of upstream impoundment?

34.3.1 Is any part of the AA/IA flooded (even seasonally) due to permanent or temporary ponding created by a dam or dike or is the AA/IA actively managed for stormwater or floodwater detention?

34.3.2 (Answer "I" if 34.3.1 is "N.") Is flooding in the AA/IA a result of beaver activity?

35. FLOODING EXTENT AND DURATION

35.1 (Answer "I" if tidal.) Does flooding cause surface water to expand to more than 3 times (200%) its extent under average conditions for more than 25 days during an average year (Figure 53) <u>or</u> is the relationship between extent and duration above the curve shown in Figure 54? [1]

<u>Guidelines</u>:

[1] Hydroperiod/flooding regime information can be determined using the following sources of information and/or guidelines:

(a) The best sources for flooding information include: gaging stations, direct observation, air photos, HUD/FEMA flood maps, local knowledge, and flood models of the Hydrologic Engineering Center and SCS (e.g., HEC and TR-20).

(b) Extent of flooding may also be determined in the field by observation of the following: water marks, drift lines, scour marks, absence of litter, beaver sign, sediment on leaves and stems, and the presence of flood-intolerant vegetation.

(c) If the information in (a) and (b) is unavailable, answer Question 35.1 "Y" if the wetland is low in the watershed <u>and</u> has a large Zone A that is devoid of upland plants. Answer Question 35.1 "N" if the wetland's Zone B has a sharp transition to upland.

35.2 (Answer "I" if tidal <u>or</u> if channel flow is absent.) Is any of the following conditions true?

(a) Base flow typically fills less than 60% of the channel volume.

(b) Surface water is absent 5 days after a mean monthly 24-hr storm, and the watershed is larger than 10 square miles (100 square miles in dry regions).

(c) The ratio of the high flow (measured in cubic feet per second) that is reached or exceeded 10% of the year, versus the typical low flow that is exceeded 90% of the year, is greater than 1.5.[1]

<u>Guidelines</u>:

[1] This analysis requires at least two complete years of daily streamflow records and a summarization of these according to the "percent exceedance" parameter. These data may be available for some streams with dams.

36. VEGETATED WIDTH

36.1 Is the average width[1] of the area dominated by emergent, scrub/shrub, or forest vegetation in Zones A and/or Zone B:

36.1.1 Less than 20 ft?

36.1.2 Greater than 500 ft, or the AA/IA is constricted and the vegetation is present throughout.

Guidelines:

1 Average width should be measured perpendicular to flow. If average width cannot be determined using this method, calculate average width by dividing the area of vegetation by twice its length parallel to open water (or, if no open water, by its maximum dimension).

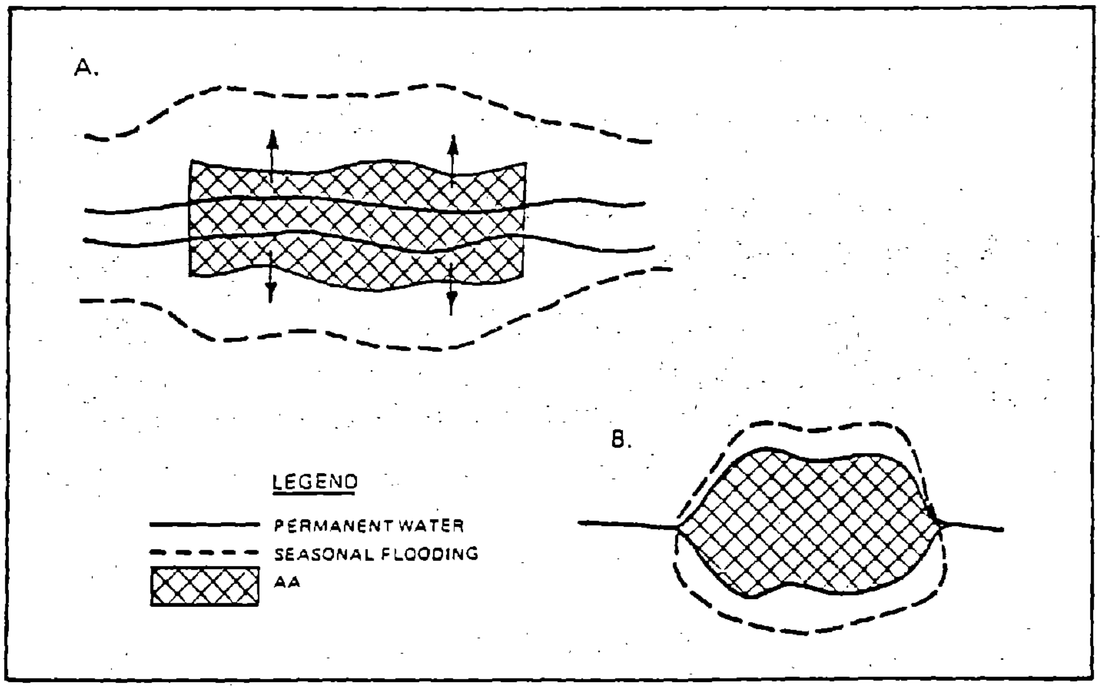


Figure 53. Examples of surface water expansion during flooding (Note: In Figure 53, Part A, surface water expands 400% for 20 days, therefore, Question 35.1 = "Y." In Part B, surface water expands 200% for 22 days, therefore, Question 35.1 = "N.")

36.2 (Answer "N" to 36.2.1, 36.2.2, and 36.2.3 if Zone B is absent.) Is the average width[1] of the area in Zone B that supports emergent vegetation and where depth seldom exceeds 50% plant height:

36.2.1 Less than 20 ft?

36.2.2 Less than 20 ft, and mainly persistent emergent vegetation?

36.2.3 Greater than 500 ft, or alternatively, the AA/IA is constricted, emergent vegetation is present throughout, and stem density is approximately 50 stems per meter^2 or greater?

Guidelines:

[1] Average width should be measured perpendicular to flow. If average width cannot be determined using this method, calculate average width by dividing the area of erect vegetation by twice its length parallel to open water (or, if no open water, by its maximum dimension).

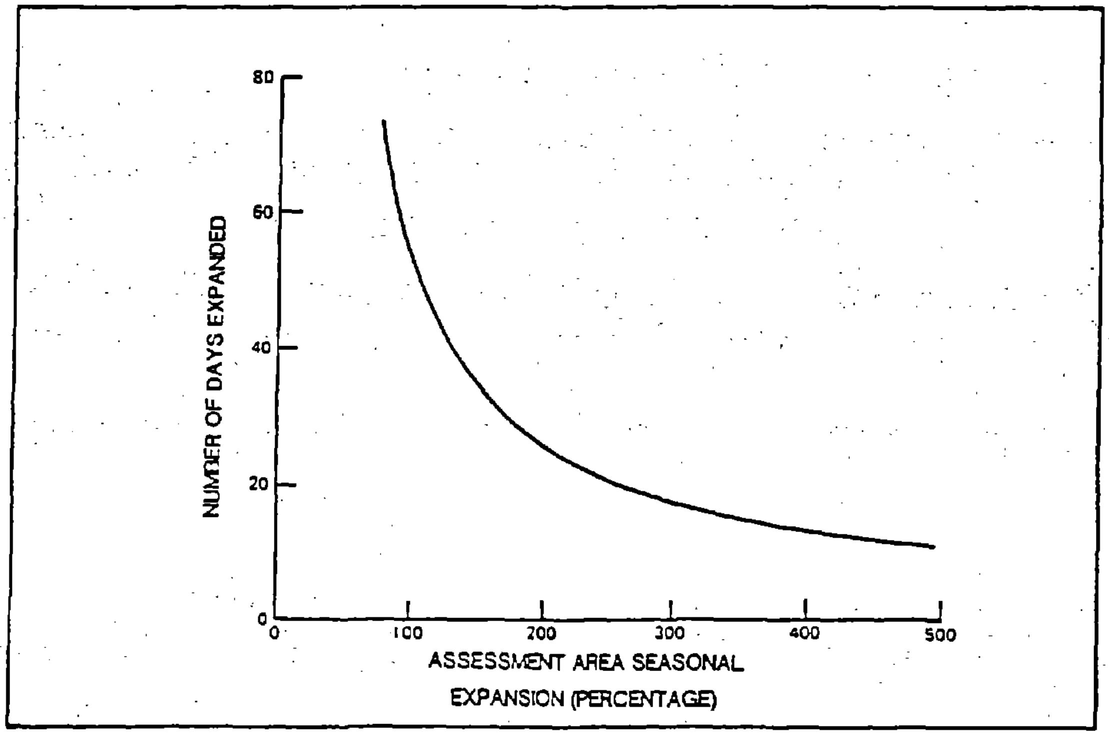


Figure 54. Seasonal expansion of surface water (Adapted from U.S. Army Corps of Engineers 1980) (Note: In the figure, if a point lies above the curve in the graph, Question 35.1 = "Y." If a point lies below the curve in the graph, Question 35.1 = "N.")

37. OPEN WATER WIDTH [question deleted]

Is there an area of open water in the AA/IA that meets all of the following conditions?

(a) Mostly devoid of aquatic bed vegetation.

(b) Depth exceeding 2 ft.

(c) Width greater than 6 ft.

(d) Length at least 1,000 ft (including accessible areas) <u>or</u> an area serving to connect two large water bodies.

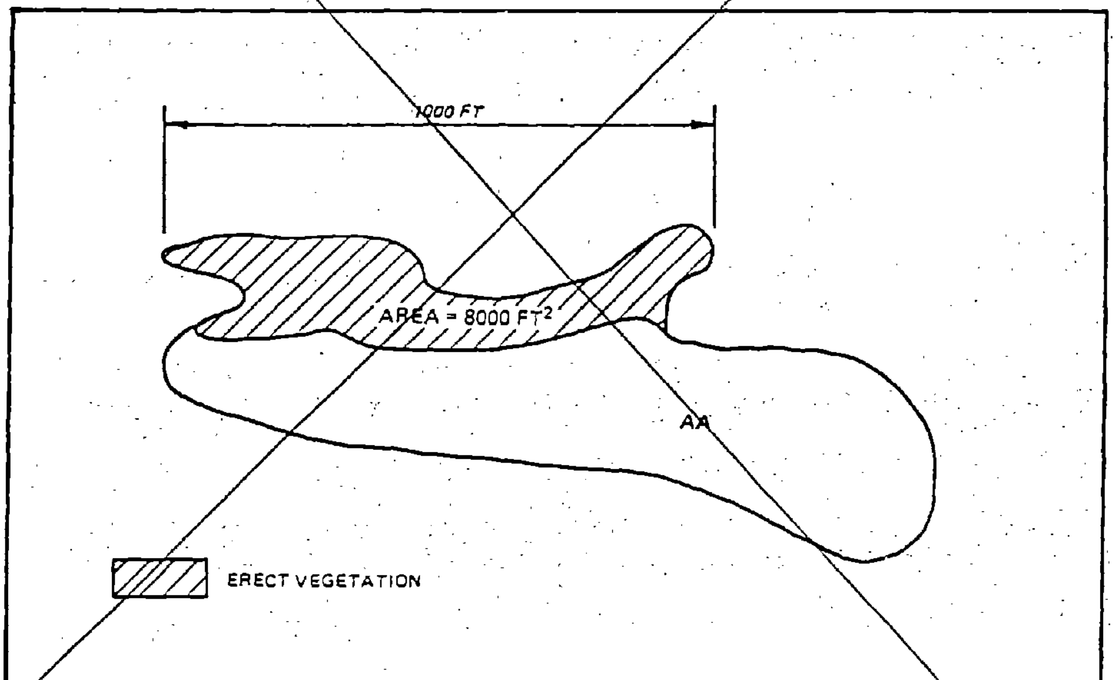


Figure 28. Example of average width calculation for erect vegetation in Zone B (eB) (Note: In the figure, the average width is 4 ft ($8,000\ ft^2/(1000\ ft \times 2)$).)

38. TYPE COMBINATIONS

38.1 The AA/IA is predominantly:

(a) Permanently flooded, nontidal <u>or</u>
(b) Seasonally flooded, forested and/or scrub-shrub.

<u>and</u> within 1 mile of the AA/IA there is a separate AA/IA where the other situation described in (a) or (b) is predominant. In addition, to answer this question "Y," both AA/IA's must be accessible to the same fish population for at least 20 days of the year.

38.2 The AA/IA:

[woody vegetation]

(a) Is predominantly nontidal with erect vegetation or rooted vascular floating-leaved vegetation in Zone B or
(b) Contains at least one acre of ~~hardwoods~~ (less than 6 in. diameter at breast height) with greater than 25% canopy closure.

<u>and</u> within 0.5 mile of the AA/IA there is a separate AA where the other situation described in (a) or (b) is predominant.

38.3 The AA/IA is predominantly:

(a) Estuarine or marine <u>or</u>
(b) Freshwater palustrine or lacustrine, <u>or</u> on a coastal island.

<u>and</u> within 5 miles of the AA/IA there is a separate AA/IA where the other situation described in (a) or (b) is predominant.

38.4 The AA/IA is predominantly:

(a) Mudflat <u>or</u>
(b) Tidal scrub-shrub.

<u>and</u> adjacent to the AA/IA there is a separate AA/IA where the other situation described in (a) or (b) is predominant.

38.5 The AA/IA contains:

(a) At least 5 acres of mudflat <u>or</u>
(b) At least 5 acres of emergent vegetation.

<u>and</u> adjacent to this area of at least 5 acres there is a separate area where the other situation described in (a) or (b) exists.

38.6 The AA/IA:

(a) Is predominantly agricultural <u>or</u> is predominantly early successional stage vegetation <u>or</u> contains at least 5 acres of emergent vegetation in Zone A <u>or</u>
(b) Contains at least 10 acres of evergreen forest.

<u>and</u> within 0.5 mile of the AA/IA there is a separate AA/IA where the other situation described in (a) or (b) exists.

38.7 The AA/IA is predominantly:

(a) Semipermanently flooded <u>or</u>
(b) Seasonally flooded <u>or</u>
(c) Permanently flooded, nontidal, intermittently exposed, or artificially flooded and managed for wildlife.

<u>and</u> within 1 mile of the AA/IA there are separate AA/IA's where the other situations described in (a), (b), and (c) are predominant in at least 1 acre of the AA/IA.

38.8 (Answer only if the AA/IA is located in a Southwestern riparian wetland. If not located in a Southwestern riparian wetland answer "I".) The AA/IA is predominantly:

(a) Cottonwood-willow stands (greater than 1 acre).
(b) Honey mesquite (greater than 1 acre).

<u>and</u> within the same AA/IA, or the adjoining upland, the other situation described in (a) or (b) occurs.

39. SPECIAL HABITAT FEATURES

Is either of the following conditions true?

(a) The AA/IA is less than 100 acres <u>and</u> two of the features listed below are present in the AA/IA or input zone at some time during the year.

(b) The AA/IA is more than 100 acres <u>and</u> three or more of the features listed below are present.

-- standing snags with cavities larger than 2 in.
-- trees with diameter exceeding 10 in.
-- plants bearing fleshy fruit (e.g., cherry, persimmon)
-- mast-bearing hardwoods (e.g., oak, beech, hickory)
-- cone-bearing trees or shrubs
-- tilled land with waste grains
-- evergreen tree stands with over 80% canopy closure
-- native prairie
-- exposed bars (e.g., unconsolidated gravel, mudflat)

40. BOTTOM WATER TEMPERATURE

(Answer "I" if estimation is not possible.) The average daily minimum summer water temperature at the deepest part of the AA/IA is usually:

40.1 Less than 50° F?
40.2 Greater than 69° F?

41. VELOCITY (SPATIALLY DOMINANT)

(Answer "I" to 41.1 and 41.2 if Question 7 was answered <u>or</u> if the AA/IA is tidal.) During peak, annual flow is the velocity throughout most of the AA/IA:

41.1 Less than 0.3 ft/sec?

41.2 Greater than 1.5 ft/sec, <u>or</u> greater than 3.3 ft/sec and substrate is cobble-gravel?

42. VELOCITY (SECONDARY)

42.1 (Answer "I" if the AA/IA is tidal.) Which velocity categories reflect seasonal flows that occur in at least 1 acre <u>or</u> 10% of the AA/IA.

42.1.1 0-1 ft/sec
42.1.2 1-3.3 ft/sec
42.1.3 3.3+ ft/sec

42.2 (Answer "I" if the AA/IA is tidal.) Which velocity categories reflect seasonal flows (wet and dry) that occur in other AA/IA's within 1 mile of the AA/IA <u>and</u> are accessible to fish for at least 20 days a year?

42.2.1 0-1 ft/sec
42.2.2 1-3.3 ft/sec
42.2.3 3.3+ ft/sec

43. WATER DEPTH (SPATIALLY DOMINANT)

Which depth category covers the greatest portion of the AA/IA?[1]

43.A Less than 1 in.
43.B 1-4 in.
43.C 5-8 in.
43.D 9-20 in.
43.E 21-39 in.
43.F 40-59 in.
43.G 5-6.5 ft
43.H 6.6-26 ft
43.I Greater than 26 ft

<u>Guidelines</u>:

[1] A precise answer is required only for habitat suitability evaluations.

44. WATER DEPTH (SECONDARY)

Which water depth categories cover at least 1 acre <u>or</u> 10% of the AA/IA or other AA/IA's within 1 mile that are accessible to fish from this AA/IA during at least 20 days of the year.[1]

44.A less than 1 in.
44.B 1-4 in.
44.C 5-8 in.
44.D 9-20 in.
44.E 21-39 in.
44.F 40-59 in.
44.G 5-6.5 ft
44.H 6.6-26 ft
44.I Greater than 26 ft

<u>Guidelines</u>:

[1] A precise answer is required only for habitat suitability evaluations.

45. SUBSTRATE TYPE (SPATIALLY DOMINANT)

Is the surface substrate (upper 3 in.) in the AA/IA predominantly[1]:

- 45.A Mineral soil[2] or mud?
- 45.B Muck (nonporous organic)?
- 45.C Peat (porous organic)?
- 45.D Sand?
- 45.E Cobble-gravel?
- 45.F Rubble?
- 45.G Bedrock?

Guidelines:

[1] Predominant is defined as the the largest percentage of total. However, if 45A, 45B, and 45C together comprise a greater percentage than any other type alone, answer "Y" to the largest of these three. Similarly, if 45D, 45E, 45F, and 45G together comprise a greater percentage than any other type alone, answer "Y" to the largest of these four.

[2] Mineral soils consist of substrates with at least 82% inorganic material if the soil is clay or 88% inorganic material if the soil is not clay.

If distinctions among types cannot be made using soils maps, physical analysis, or other means the following guidelines may be helpful:

(a) Assume sediments with undecomposed roots, stems, etc., are peat, and sediments with barely recognizable organic particles to be muck.
(b) Assume that sediments with a "rotten egg" smell are muck.
(c) Assume that areas with sphagnum moss are peat.
(d) Assume that sediments in Zone A, open water/unvegetated parts of Zone B, and Zone C are not muck or peat (but verify in tidal systems)
(e) Assume that streams or rivers with a channel gradient greater than 0.5% have cobble-gravel or coarser materials while those with a lesser gradient have sand or finer materials.

46. PHYSICAL HABITAT INTERSPERSION

(Answer 46.A "Y" and 46.B and 46.C "N" if Zones B and C are absent.) Within **Zones B and C** are substrate types, velocity and depth categories distributed:

- **46.A** Uniformly with similar substrate types, velocities and depth throughout the AA/IA?
- **46.B** Intermediate condition?
- **46.C** Mosaic of substrate types, velocities, and depths (e.g., good pool-riffle sequence if midorder stream)?

47. pH

(Answer 47.A "Y" if AA/IA is tidal.) Is pH of the water in the AA/IA:

47.A 6.0-8.5 (neutral)

47.B Below 6.0 (generally acidic)?

47.C Above 8.5 (generally alkaline)?

48. SALINITY AND CONDUCTIVITY

(Answer "I" if unknown and reasonable estimation is impossible, but see question guidelines[1].) Is the AA/IA's salinity/halinity or conductivity:

	Salinity/ Halinity (ppt)	Approximate Conductivity	Estuarine/ Marine	Riverine/Lacustrine Palustrine
48.A	<0.5	<800	fresh	fresh
48.B	0.5-5.0	800-8,000	oligohaline	mixosaline
48.C	5.0-18.0	8,000-30,000	mesohaline	mixosaline
48.D	18.0-30.0	30,000-45,000	polyhaline	mixosaline
48.E	30.0-40.0	45,000-60,000	euhaline	eusaline
48.F	>40.0	>60,000	hyperhaline	hypersaline

Guidelines:

[1] If salinity/halinity or conductivity cannot be measured, the presence of the plant species shown in Table 29 may serve as an indicator of nonfresh conditions.

Table 29. Wetland Plants Indicating Saline (Nonfresh) Conditions* (Sources: Millar 1976, Stewart and Kantrud 1972)

Suaeda depressa	Atriplex patula
Scirpus nevadensis	Polygonum pacificum
Scirpus paludosus	Lactuca scariola
Ruppia occidentalis	Triglochin maritima
Zannichellia palustris	Muhlenbergia asperifolia
Ruppia maritima	Spartina spp.
Potamogeton vaginatus	Ranunculus cymbalaria
Chenopodium salinum	Spergularia marina
Aster brachyactis	Heliotropium curvassavicum
Distichlis spicata	Alisma gramineum
Plantago eriopoda	Puccinellia nuttalliana
Potentilla anserina	Salicornia virginica

* Supplement this plant species list with local information if available.

49. AQUATIC HABITAT FEATURES

(Answer "I" if a tidal channel with a gradient of more than 0.01 is present.)

49.1.1 Does the AA include, or is it included in, a permanently flooded stream reach[1] comprised of 20-80% pools, backwaters, or similar slow-water areas?[2]

49.1.2 (Answer "N" if 49.1.1 is "N.") Does the AA include, or is it included in a stream reach with a cobble-gravel substrate <u>and</u> riffles[3] spaced at intervals of five to seven times the average stream width?

<u>Guidelines</u>:

[1] Stream reach is defined as the distance between tributaries, or a distance of 1 mile, whichever is greater.

[2] Slow-water areas include pools, backwaters, side channels, and other areas where flow velocity at the surface is generally less than 0.6 ft/sec.

[3] Riffles are naturally shallow areas with coarser substrate (generally cobble-gravel) and faster current.

49.2 Does the AA have fish cover[1] available for at least 20 days annually in at least 20% of Zone B <u>or</u> is fish cover available in other AA's that are within 1 mile and accessible to fish from this AA?

<u>Guidelines</u>:

[1] Fish cover is defined as moderately dense aquatic vegetation, submersed logs and stumps, tree roots, boulders, overhanging vegetation, crevices, undercut banks, etc.

49.3 Are carp prevalent in the AA?

50. PLANTS: WATERFOWL VALUE

(Answer "N" if AA/IA is unvegetated.) Does any plant or combination of plants listed in Table 30 comprise more than 10% <u>or</u> 1 acre of the AA/IA?

This completes level 2 assessment. At this point you may:

(1) Continue with level 3 assessment, or

(2) Interpret the responses to assessment levels 1 and 2 as outlined in Section 4.4.

Table 30. Wetland Food Plants Preferred by Waterfowl.* (Sources: Bagur 1977, Bellrose 1976, Kadlec and Wentz 1974, Martin et al. 1951.)

	PART 1: Preference by Region					PART 2: Preference by Waterfowl Group and Season															
						1		2		3		4		5		6		7		8	
AQUATIC BED SPECIES	NE	SE	PR	MT	PC	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW
Aneilema keisak		*					*														
Brasenia schreberi	*	*					*				*		*	*							
Ceratophyllum demersum	*	*	*	*	*						*		*								
Chara spp.		*	*	*	*		*						*								
Halodule spp.		*									*		*								
Lemna spp.	*	*	*	*	*				*		*										
Najas (except marina)	*	*					*				*										
Nuphar spp.	*	*			*					*											
Nymphaea spp.	*	*							*				*								
Polygonum spp.	*	*	*	*	*	*	*	*	*		*										
Potamogeton spp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Rorippa spp.	*	*					*										*				
Ruppia maritima	*	*	*	*	*	*	*						*	*		*	*				
Spirodela spp.	*	*	*	*	*				*		*										
Vallisneria spp.	*	*											*	*			*				
Wolffia spp.	*	*	*	*	*				*		*										
Zanichellia palustris		*	*	*		*	*						*	*							
Zostera marina	*				*						*		*				*	*			

	PART 1: Preference by Region					PART 2: Preference by Waterfowl Group															
						1		2		3		4		5		6		7		8	
EMERGENT SPECIES	NE	SE	PR	MT	PC	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW
Acnida cannabinus	*	*					*														
Atriplex patula		*	*				*														
Carex spp.	*	*	*	*	*	*	*			*	*										
Cladium jamaicense		*					*										*				
Distichlis spicata	*	*	*	*	*												*				
Echinochloa spp.		*	*		*		*														
Eleocharis spp.	*	*	*	*	*	*	*				*						*				
Equisetum spp.	*		*	*	*	*	*										*				
Juncus spp.	*	*	*	*	*	*															
Jussiaea spp.		*					*														

(Continued)

Table 30. Wetland Food Plants Preferred by Waterfowl (continued).

	PART 1: Preference by Region					PART 2: Preference by Waterfowl Group															
						1		2		3		4		5		6		7		8	
EMERGENT SPECIES	NE	SE	PR	MT	PC	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW	N	MW
Leersia oryzoides	*	*	*				*														
Leptochloa fasicularia	*	*	*				*														
Lophotocarpus calycinus	*	*	*				*														
Oryza		*				*	*						*		*		*			*	*
Panicum spp.	*	*	*			*	*														
Paspalum boscianum	*	*				*	*														
Peltandra virginica	*	*						*	*			*									
Sagittaria platyphylla		*					*														
Salicornia virginica	*	*	*	*	*												*				
Scirpus spp.	*	*	*	*	*	*	*		*	*	*	*	*								
Scolochloa festucacea		*	*				*														
Sesuvium portulascastrum		*	*																		
Setaria spp.	*		*				*														
Sparganium spp.	*		*	*	*	*	*		*								*				
Spartina spp.	*	*							*												
Triglochin maritima					*																
Zizania aquatica	*	*					*	*	*	*	*	*	*	*							

* All plants listed in Table 5 are of above average attractiveness to at least one waterfowl group in at least one region as indicated by the asterisks in the body of the table. Plants not listed are seldom preferred as food; nevertheless, they may sometimes be valuable as cover, nesting material, or as food when preferred plants are locally scarce. This table reflects the attractiveness of plants to waterfowl and not necessarily their nutritive value. Nuts, mast, and fruits of woody species may be important locally but are not considered here. It should be noted that the presence of adequate cover and dense concentrations of aquatic invertebrates may be at least as important as presence of preferred plants to some groups at some seasons. This is particularly true for groups 1 through 5 and group 8 during the breeding season. This fact is accounted for in the interpretation keys.

(Continued)

Table 30. Wetland Food Plants Preferred by Waterfowl (continued).

Part 1 of Table 5 indicates regions in which the plant is preferred (combining all waterfowl species and seasons). The regions are:

Northeast (NE): ME, NH, VT, MA, CT, RI, NJ, NY, PA, DE, MD, WV, OH, IN, MI, WI, KY, west NC, east TN, south IL, east MN, west VA.

Southeast (SE): SC, GA, FL, AL, MS, AK, LA, east OK, east TX, south MO, west TN, east NC, south VA.

Prairie (PR): IA, IL, KS, NE, SD, ND, east MT, east WY, east CO, east NM, west OK, west MN, north MO, central TX.

Mountains (MT): AZ, UT, NV, ID, west NM, west CO, west WY, west MT, east OR, east WA, southeast CA.

Pacific (PC): CA, west OR, west WA.

Part 2 of Table 5 indicates plants preferred by waterfowl species during particular periods of the year. The periods of the year are abbreviated: N = nesting and brood rearing; MW = migration and winter. The waterfowl groups are defined below.

Group 1: Prairie Dabblers
Group 2: Wood Duck and Black Duck
Group 3: Goldeneye and Bufflehead
Group 4: Canvasback, Redhead, Ruddy, and Ring-necked Duck
Group 5: Greater and Lesser Scaup
Group 6: Inland Geese and Swans
Group 7: Brant
Group 8: Whistling Ducks

APPENDIX C:

SITE SPECIFIC RAW DATA AND OUTPUT

The following is an example of the raw data and analysis output that are contained in volume II for each of the 17 pairs of study sites. A listing of dominant plant species and their corresponding abundance; WET 2.0 site documentation, evaluation results, and answer dataset printouts; and Hollands-Magee input data and resulting raw scores are provided for each site. The Galesburg, Illinois mitigation and control site information is duplicated in this appendix for the readers who may not have access to volume II.

Table 31. Plant species and estimated areal cover at the mitigation (A) and control (B) wetlands, Galesburg, IL.

A. Galesburg mitigation wetland
Field Date: 08/29/89

Scientific name	Common name	Abundance
Trees:		
Ulmus rubra	Slippery elm	10.0
Crataegus mollis	Hawthorn	8.0
Acer saccharinum	Silver maple	5.0
Salix nigra	Black willow	5.0
Acer negundo	Boxelder	5.0
Gleditsia triacanthos	Honey locust	3.0
Populus deltoides	Cottonwood	2.0
Shrubs:		
Salix sp.	Willow	10.0
Ulmus rubra	Slippery elm	5.0
Salix nigra	Black willow	3.0
Acer negundo	Boxelder	2.0
Rosa multiflora	Multiflora rose	2.0
Cornus racemosa	Red-panicle dogwood	0.1
Lianas:		
Vitis sp.	Grapevine	2.0
Herbs:		
Phalaris arundinacea	Reed canary grass	30.0
Amaranthus sp.	Amaranth	15.0
Urtica dioica	Stinging nettle	15.0
Panicum virgatum	Switch grass	5.0
Ambrosia artemesiifolia	Common ragweed	5.0
Eupatorium serotinum	Late-flower thoroughwort	4.0
Carex sp.	Sedge	4.0
Ambrosia trifida	Great ragweed	4.0
Polygonum pensylvanicum	Pink smartweed	3.0
Pilea pumilla	Clearweed	3.0
Apocynum cannabinum	Indian hemp	3.0
Bidens sp.	Beggar-ticks	2.0
Echinochloa crusgalli	Barnyard grass	2.0
Cirsium discolor	Two-colored thistle	2.0
Lysimachia nummularia	Moneywort	2.0
Elymus canadensis	Canada rye	2.0
Lemna sp.	Duckweed	2.0

Table 31. Plant species and estimated areal cover at the mitigation (A) and control (B) wetlands, Galesburg, IL (continued).

Scientific name	Common name	Abundance
Silphium perfoliatum	Cup-plant	2.0
Polygonum lapathifolium	Pale smartweed	2.0
Actinomeris alternifolia	Wingstem	2.0
Rudbeckia lacinata	Tall coneflower	2.0
Solidago canadensis	Canada goldenrod	2.0
Leersia oryzoides	Rice cut-grass	1.0
Geum aleppicum	Aleppo avens	1.0
Vernonia altissima	Tall ironweed	1.0
Potentilla norvegica	Norwegian cinquefoil	1.0
Solidago rugosa	Rough-leaved goldenrod	1.0
Aster sp.	Asters	1.0
Eleocharis obtusa	Blunt spikesedge	0.5
Cyperus strigosus	Umbrella sedge	0.5
Erigeron canadensis	Horse-weed	0.5
Gerardia tenuifolia	Slender-lvd gerardia	0.5
Potamogeton sp	Pondweed	0.5
Lycopus americanus	Cut-leaf water horehound	0.5
Solidago gigantea	Large goldenrod	0.5
Lythrum salicaria	Purple loosestrife	0.5
Typha latifolia	Cattail	0.5
Polygonum punctatum	Water smartweed	0.2
Solanum carolinense	Horse-nettle	0.1
Scirpus atrovirens	Darkgreen bulrush	0.1
Sagittaria latifolia	Arrowhead	0.1
Polygonum scandens	Climbing false buckwheat	0.1
Eryngium yuccifolium	Rattlesnake-master	0.1
Andropogon gerardi	Beardgrass	0.1
Alisma plantagoaquatica	Water-plantain	0.1

Table 31. Plant species and estimated areal cover at the mitigation (A) and control (B) wetlands, Galesburg, IL (continued).

B. Galesburg control wetland
Field Date: 08/29/89

Scientific name	Common name	Abundance
Trees:		
Ulmus rubra	Slippery elm	10.0
Crataegus mollis	Hawthorn	8.0
Acer saccharinum	Silver maple	5.0
Acer negundo	Boxelder	5.0
Salix nigra	Black willow	5.0
Gleditsia triacanthos	Honey locust	3.0
Populus deltoides	Cottonwood	2.0
Fraxinus americana	White ash	0.1
Shrubs:		
Salix nigra	Black willow	10.0
Ulmus rubra	Slippery elm	5.0
Rosa multiflora	Multiflora rose	2.0
Acer negundo	Boxelder	2.0
Cornus racemosa	Red-panicle dogwood	0.1
Lianas:		
Vitis sp.	Grapevine	2.0
Herbs:		
Phalaris arundinacea	Reed canary grass	40.0
Urtica dioica	Stinging nettle	15.0
Amaranthus sp.	Amaranth	15.0
Carex sp.	Sedge	4.0
Ambrosia trifida	Great ragweed	4.0
Eupatorium serotinum	Late-flower thoroughwort	4.0
Apocynum cannabinum	Indian hemp	3.0
Polygonum pensylvanicum	Pink smartweed	3.0
Ambrosia artemesiifolia	Common ragweed	3.0
Pilea pumilla	Clearweed	3.0
Solidago gigantea	Large goldenrod	2.0
Actinomeris alternifolia	Wingstem	2.0
Rudbeckia lacinata	Tall coneflower	2.0
Polygonum lapathifolium	Pale smartweed	2.0
Silphium perfoliatum	Cup-plant	2.0
Solidago canadensis	Canada goldenrod	2.0

Table 31. Plant species and estimated areal cover at the mitigation (A) and control (B) wetlands, Galesburg, IL (continued).

Scientific name	Common name	Abundance
Bidens sp.	Beggar-ticks	2.0
Oenothera biennis	Evening primrose	2.0
Panicum virgatum	Switch grass	1.0
Potentilla norvegica	Norwegian cinquefoil	1.0
Vernonia altissima	Tall ironweed	1.0
Lysimachia nummularia	Moneywort	1.0
Geum aleppicum	Aleppo avens	1.0
Polygonum scandens	Climbing false buckwheat	0.1
Solanum carolinense	Horse-nettle	0.1

Site Documentation: WET 2.0

Part 1 - Background Information

Evaluation Site: Illinois - Galesburg mitigation **Date:** 8/29/89

Site Location: Supplemental Freeway I74 and US 34 Cedar Creek, Galesburg, Knox and Warren Co, Illinois

Assessment levels to be completed: SS-1, SS-2, E/O - 1 & 2

Is the wetland tidal or nontidal? nontidal
If nontidal, indicate the month(s) that represents wet, dry, and average conditions, or if only average annual condition will be used, give rationale. Also, indicate if the previous 12 months of precipitation has been above, below, or near normal.
Wet: Apr-Jul; Dry: Oct-Mar; Avg: Aug & Sep. Precipitation during previous 12 months was below average.

Is this evaluation an estimate of past conditions or a prediction of future conditions? (If answer is yes, explain nature and source of predictive data.)
no

Water Quality Results: conductivity 430 **micromhos; pH** 8.2

Part 2 - Identification and Delineation of Evaluation Areas

See volume I for maps and explanation of procedures used to identify or delineate the AA, IA, IZ, service areas, and the watersheds of these areas.

Estimate the extent of the following areas:

Assessment Area = 35 ac (14.2 **ha)**
Impact Area = N/A
Watershed of AA = 30 **mi**^{2} (77.7 **km**^{2})
Service Area watershed = 47 **mi**^{2} (121.7 **km**^{2})
Wetlands in AA = 35 ac (14.2 **ha)**
Wetlands in the watershed of closest service area = 1075 **ac** (435 **ha)**
Wetlands & deepwater in the watershed of closest service area = 1075 **ac** (435 **ha).**

How were locality and region defined for this evaluation?
Locality: Cedar Creek valley

Region: loess-covered Illinoian till plain

Galesburg, IL mitigation

****

Summary of Evaluation Results for "fhglmt"

****

	Social Significance	Effectiveness	Opportunity
Ground Water Recharge	M	U	*
Ground Water Discharge	M	M	*
Floodflow Alteration	M	H	H
Sediment Stabilization	H	M	*
Sediment/Toxicant Retention	M	H	H
Nutrient Removal/Transformation	M	H	H
Production Export	*	M	*
Wildlife Diversity/Abundance	H	*	*
Wildlife D/A Breeding	*	H	*
Wildlife D/A Migration	*	L	*
Wildlife D/A Wintering	*	L	*
Aquatic Diversity/Abundance	M	M	*
Uniqueness/Heritage	H	*	*
Recreation	L	*	*

Note: "H" = high, "M" = moderate, "L" = low, "U" = uncertain, and "*"'s identify conditions where functions and values are not evaluated.

Galesburg, IL mitigation

WET Answer Dataset for "fhglmt"

s1 - u
s2 - y
s3 - n
s4 - n
s5 - n
s6 - y
s7 - n
s8 - n
s9 - n
s10 - n
s11 - u
s12 - n
s13 - u
s14 - n
s15 - u
s16 - n
s17 - u
s18 - i
s19 - y
s20 - n
s21 - n
s22 - y
s23 - n
s24 - n
s25 - y
s26 - n
s27 - n
s28 - n
s29 - n
s30 - y
s31 - y
1.1 - n
1.2 - n
1.3 - y
2.1.1 - n
2.1.2 - y
2.1.3 - n
2.2.1 - n
2.2.2 - y
3.1 - y
3.2 - y
3.3 - n
4.1 - n
4.2A - n
4.2B - y
4.2C - n
4.2D - n
5.1.1 - y
5.1.2 - n
5.2 - n
blank - u
6.1 - n
6.2 - y
7 - i
8.1 - y
8.2 - n
8.3 - y
8.4 - n
9.1 - y
9.2 - y
9.3 - n
10A - n
10B - y
10C - n
10D - n
10E - n
10F - n
11(x) - n
11(w) - n
11(d) - n
12A(x) - n
12A(w) - n
12A(d) - n
12Aa(x) - n
12Aa(w) - n
12Aa(d) - n
12Ab(x) - n
12Ab(w) - n
12Ab(d) - n
12Ac(x) - n
12Ac(w) - n
12Ac(d) - n
12Ad(x) - n
12Ad(w) - n
12Ad(d) - n
12Ae(x) - n
12Ae(w) - n
12Ae(d) - n
12B(x) - n
12B(w) - n
12B(d) - n
12Ba(x) - n
12Ba(w) - n
12Ba(d) - n
12Bb(x) - n
12Bb(w) - n
12Bb(d) - n
12Bc(x) - n
12Bc(w) - n
12Bc(d) - n
12Bd(x) - n
12Bd(w) - n
12Bd(d) - n
12Be(x) - n
12Be(w) - n
12Be(d) - n
12C(x) - n
12C(w) - n
12C(d) - n
12Ca(x) - n
12Ca(w) - n
12Ca(d) - n
12Cb(x) - n
12Cb(w) - n
12Cb(d) - n
12Cc(x) - n
12Cc(w) - n
12Cc(d) - n
12Cd(x) - n
12Cd(w) - n
12Cd(d) - n
12D(x) - y
12D(w) - y
12D(d) - y
12Da(x) - y
12Da(w) - y
12Da(d) - y
12Db(x) - n
12Db(w) - n
12Db(d) - n
12E(x) - n
12E(w) - n
12E(d) - n
13A(x) - y
13A(w) - y
13A(d) - y
13Aa(x) - n
13Aa(w) - n
13Aa(d) - n
13Ab(x) - n
13Ab(w) - n
13Ab(d) - n
13Ac(x) - n
13Ac(w) - n
13Ac(d) - n
13Ad(x) - n
13Ad(w) - n
13Ad(d) - n
13Ae(x) - y
13Ae(w) - y
13Ae(d) - y
13B(x) - n
13B(w) - n
13B(d) - n
13Ba(x) - n
13Ba(w) - n
13Ba(d) - n
13Bb(x) - n
13Bb(w) - n
13Bb(d) - n
13Bc(x) - n
13Bc(w) - n
13Bc(d) - n
13Bd(x) - n
13Bd(w) - n
13Bd(d) - n
13Be(x) - n
13Be(w) - n
13Be(d) - n
13C(x) - n
13C(w) - n
13C(d) - n
13Ca(x) - n
13Ca(w) - n
13Ca(d) - n
13Cb(x) - n
13Cb(w) - n
13Cb(d) - n
13Cc(x) - n
13Cc(w) - n
13Cc(d) - n
13Cd(x) - n
13Cd(w) - n
13Cd(d) - n
13D(x) - y
13D(w) - y
13D(d) - y
13Da(x) - y
13Da(w) - y
13Da(d) - y
13Db(x) - n
13Db(w) - n
13Db(d) - n
13E(x) - n
13E(w) - n
13E(d) - n
14.1(x) - n
14.1(w) - n
14.1(d) - n
14.2(x) - n
14.2(w) - n
14.2(d) - n
15.1A - y
15.1B - n
15.1C - n
15.2 - n
16A(x) - y
16A(w) - y

Galesburg, IL mitigation

WET Answer Dataset for "fhglmt"

16A(d) - y
16B(x) - n
16B(w) - n
16B(d) - n
16C(x) - n
16C(w) - n
16C(d) - n
17 - n
18 - n
19.1A - i
19.1B - n
19.2 - n
19.3 - y
20.1 - n
20.2 - i
21A - n
21B - n
21C - y
21D - n
21E - n
22.1.1 - y
22.1.2 - y
22.2 - n
22.3 - n
23 - n
24.1 - i
24.2 - y
24.3 - n
24.4 - y
24.5 - n
25.1 - y
25.2A - y
25.2B - n
25.3 - n
26.1 - y
26.2 - n
26.3 - y
27.1 - y
27.2 - n
27.3 - y
28 - n
29.1 - y
29.2 - i
30(x) - n
30(w) - n
30(d) - n
31.1(x) - y
31.1(w) - y
31.1(d) - y
31.2(x) - y
31.2(w) - y
31.2(d) - y
31.3(x) - n
31.3(w) - n
31.3(d) - n
31.4(x) - n
31.4(w) - n
31.4(d) - n
31.5(x) - y
31.5(w) - y
31.5(d) - y
31.6A(x) - n
31.6A(w) - n
31.6A(d) - n
31.6B(x) - y
31.6B(w) - y
31.6B(d) - y
31.6C(x) - n
31.6C(w) - n
31.6C(d) - n
31.6D(x) - n
31.6D(w) - n
31.6D(d) - n
31.6E(x) - n
31.6E(w) - n
31.6E(d) - n
32A - n
32B - n
32C - n
32D - n
32E - n
32F - y
32G - n
32H - n
32I - n
32J - n
32K - n
33A - y
33B - n
33C - n
33D - n
33E - n
33F - n
33G - n
33H - n
33I - n
33J - n
33K - n
34.1 - n
34.2 - n
34.3.1 - n
34.3.2 - i
35.1 - n
35.2 - y
36.1.1(x) - n
36.1.1(w) - n
36.1.1(d) - n
36.1.2(x) - y
36.1.2(w) - y
36.1.2(d) - y
36.2.1(x) - y
36.2.1(w) - y
36.2.1(d) - y
36.2.2(x) - y
36.2.2(w) - y
36.2.2(d) - y
36.2.3(x) - n
36.2.3(w) - n
36.2.3(d) - n
37 - i
38.1 - n
38.2 - y
38.3 - n
38.4 - n
38.5 - n
38.6 - n
38.7 - n
38.8 - i
39 - y
40.1 - n
40.2 - y
41.1 - y
41.2 - n
42.1.1(x) - y
42.1.1(w) - y
42.1.1(d) - y
42.1.2(x) - n
42.1.2(w) - n
42.1.2(d) - n
42.1.3(x) - n
42.1.3(w) - n
42.1.3(d) - n
42.2.1(x) - y
42.2.1(w) - y
42.2.1(d) - y
42.2.2(x) - y
42.2.2(w) - y
42.2.2(d) - y
42.2.3(x) - n
42.2.3(w) - n
42.2.3(d) - n
43A(x) - y
43A(w) - y
43A(d) - y
43B(x) - n
43B(w) - n
43B(d) - n
43C(x) - n
43C(w) - n
43C(d) - n
43D(x) - n
43D(w) - n
43D(d) - n
43E(x) - n
43E(w) - n
43E(d) - n
43F(x) - n
43F(w) - n
43F(d) - n
43G(x) - n
43G(w) - n
43G(d) - n
43H(x) - n
43H(w) - n
43H(d) - n
43I(x) - n
43I(w) - n
43I(d) - n
44A(x) - y
44A(w) - y
44A(d) - y
44B(x) - y
44B(w) - y
44B(d) - y
44C(x) - y
44C(w) - y
44C(d) - y
44D(x) - y
44D(w) - y
44D(d) - n
44E(x) - n
44E(w) - y
44E(d) - n
44F(x) - n
44F(w) - y
44F(d) - n
44G(x) - n
44G(w) - n
44G(d) - n
44H(x) - n
44H(w) - n
44H(d) - n
44I(x) - n
44I(w) - n
44I(d) - n
45A - y
45B - n
45C - n

Galesburg, IL mitigation

WET Answer Dataset for "fhglmt"

45D - n	48B(w) - n	49.2(x) - y	55.3 - u
45E - n	48B(d) - i	49.2(w) - y	55.4 - u
45F - n	48C(x) - n	49.2(d) - y	56.1 - u
45G - n	48C(w) - n	49.3(x) - n	56.2 - u
46A(x) - y	48C(d) - n	49.3(w) - n	57.1 - u
46A(w) - y	48D(x) - n	49.3(d) - n	57.2 - u
46A(d) - y	48D(w) - n	50(x) - y	58 - u
46B(x) - n	48D(d) - n	50(w) - y	59.1 - u
46B(w) - n	48E(x) - n	50(d) - y	59.2 - u
46B(d) - n	48E(w) - n	51.1 - u	60 - u
46C(x) - n	48E(d) - n	51.2 - u	61 - u
46C(w) - n	48F(x) - n	52.1 - u	62 - u
46C(d) - n	48F(w) - n	52.2 - u	63.1 - u
47A - y	48F(d) - n	53.1 - u	63.2 - u
47B - n	49.1.1(x) - y	53.2 - u	64 - u
47C - n	49.1.1(w) - y	54(x) - u	CR - 2
48A(x) - y	49.1.1(d) - y	54(w) - u	1 - n
48A(w) - y	49.1.2(x) - n	54(d) - u	2 - n
48A(d) - i	49.1.2(w) - n	55.1 - u	3 - n
48B(x) - n	49.1.2(d) - n	55.2 - u	4 - y

Site Documentation: WET 2.0

Part 1 - Background Information

Evaluation Site: Illinois - Galesburg control Date: 8/29/89

Site Location: Supplemental Freeway I74 and US 34 Cedar Creek, Galesburg, Knox and Warren Co, Illinois

Assessment levels to be completed: SS-1, SS-2, E/O - 1 & 2

Is the wetland tidal or nontidal? nontidal
If nontidal, indicate the month(s) that represents wet, dry, and average conditions, or if only average annual condition will be used, give rationale. Also, indicate if the previous 12 months of precipitation has been above, below, or near normal.
Wet: Apr-Jul; Dry: Oct-Mar; Avg: Aug & Sep. Precipitation during previous 12 months was below average.

Is this evaluation an estimate of past conditions or a prediction of future conditions? (If answer is yes, explain nature and source of predictive data.)
yes. Estimation of conditions prior to highway construction. Based on orthophotograph, DOT mapping, NWI maps, and remaining natural wetland as source.

Water Quality Results: conductivity 860 micromhos; pH 7.5

Part 2 - Identification and Delineation of Evaluation Areas

See volume I for maps and explanation of procedures used to identify or delineate the AA, IA, IZ, service areas, and the watersheds of these areas.

Estimate the extent of the following areas:

Assessment Area = 40 ac (16.2 ha)
Impact Area = N/A
Watershed of AA = 30 mi^2 (77.7 km^2)
Service Area watershed = 47 mi^2 (121.7 km^2)
Wetlands in AA = 40 ac (16.2 ha)
Wetlands in the watershed of closest service area = 1075 ac (435 ha)
Wetlands & deepwater in the watershed of closest service area = 1075 ac (435 ha).

How were locality and region defined for this evaluation?
Locality: Cedar Creek valley

Region: loess-covered Illinoian till plain

Galesburg, IL control

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Summary of Evaluation Results for "fhglcn"

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	Social Significance	Effectiveness	Opportunity
Ground Water Recharge	M	U	*
Ground Water Discharge	M	M	*
Floodflow Alteration	M	H	H
Sediment Stabilization	H	M	*
Sediment/Toxicant Retention	M	H	H
Nutrient Removal/Transformation	M	H	H
Production Export	*	M	*
Wildlife Diversity/Abundance	M	*	*
Wildlife D/A Breeding	*	L	*
Wildlife D/A Migration	*	L	*
Wildlife D/A Wintering	*	L	*
Aquatic Diversity/Abundance	M	L	*
Uniqueness/Heritage	M	*	*
Recreation	L	*	*

Note: "H" = high, "M" = moderate, "L" = low, "U" = uncertain, and "*"'s identify conditions where functions and values are not evaluated.

Galesburg, IL control

WET Answer Dataset for "fhglcn"

s1 - u
s2 - n
s3 - n
s4 - n
s5 - n
s6 - n
s7 - n
s8 - n
s9 - n
s10 - n
s11 - u
s12 - n
s13 - u
s14 - n
s15 - u
s16 - n
s17 - u
s18 - i
s19 - y
s20 - n
s21 - n
s22 - i
s23 - n
s24 - n
s25 - n
s26 - n
s27 - n
s28 - n
s29 - n
s30 - y
s31 - y
1.1 - n
1.2 - n
1.3 - y
2.1.1 - n
2.1.2 - y
2.1.3 - n
2.2.1 - n
2.2.2 - y
3.1 - y
3.2 - y
3.3 - n
4.1 - n
4.2A - n
4.2B - y
4.2C - n
4.2D - n
5.1.1 - y
5.1.2 - n
5.2 - n
blank - u
6.1 - n
6.2 - y
7 - i
8.1 - y
8.2 - n
8.3 - y
8.4 - n
9.1 - y
9.2 - y
9.3 - n
10A - n
10B - y
10C - n
10D - n
10E - n
10F - n
11(x) - n
11(w) - n
11(d) - n
12A(x) - n
12A(w) - n
12A(d) - n
12Aa(x) - n
12Aa(w) - n
12Aa(d) - n
12Ab(x) - n
12Ab(w) - n
12Ab(d) - n
12Ac(x) - n
12Ac(w) - n
12Ac(d) - n
12Ad(x) - n
12Ad(w) - n
12Ad(d) - n
12Ae(x) - n
12Ae(w) - n
12Ae(d) - n
12B(x) - n
12B(w) - n
12B(d) - n
12Ba(x) - n
12Ba(w) - n
12Ba(d) - n
12Bb(x) - n
12Bb(w) - n
12Bb(d) - n
12Bc(x) - n
12Bc(w) - n
12Bc(d) - n
12Bd(x) - n
12Bd(w) - n
12Bd(d) - n
12Be(x) - n
12Be(w) - n
12Be(d) - n
12C(x) - n
12C(w) - n
12C(d) - n
12Ca(x) - n
12Ca(w) - n
12Ca(d) - n
12Cb(x) - n
12Cb(w) - n
12Cb(d) - n
12Cc(x) - n
12Cc(w) - n
12Cc(d) - n
12Cd(x) - n
12Cd(w) - n
12Cd(d) - n
12D(x) - y
12D(w) - y
12D(d) - y
12Da(x) - y
12Da(w) - y
12Da(d) - y
12Db(x) - n
12Db(w) - n
12Db(d) - n
12E(x) - n
12E(w) - n
12E(d) - n
13A(x) - y
13A(w) - y
13A(d) - y
13Aa(x) - n
13Aa(w) - n
13Aa(d) - n
13Ab(x) - n
13Ab(w) - n
13Ab(d) - n
13Ac(x) - n
13Ac(w) - n
13Ac(d) - n
13Ad(x) - n
13Ad(w) - n
13Ad(d) - n
13Ae(x) - y
13Ae(w) - y
13Ae(d) - y
13B(x) - n
13B(w) - n
13B(d) - n
13Ba(x) - n
13Ba(w) - n
13Ba(d) - n
13Bb(x) - n
13Bb(w) - n
13Bb(d) - n
13Bc(x) - n
13Bc(w) - n
13Bc(d) - n
13Bd(x) - n
13Bd(w) - n
13Bd(d) - n
13Be(x) - n
13Be(w) - n
13Be(d) - n
13C(x) - n
13C(w) - n
13C(d) - n
13Ca(x) - n
13Ca(w) - n
13Ca(d) - n
13Cb(x) - n
13Cb(w) - n
13Cb(d) - n
13Cc(x) - n
13Cc(w) - n
13Cc(d) - n
13Cd(x) - n
13Cd(w) - n
13Cd(d) - n
13D(x) - y
13D(w) - y
13D(d) - y
13Da(x) - y
13Da(w) - y
13Da(d) - y
13Db(x) - n
13Db(w) - n
13Db(d) - n
13E(x) - n
13E(w) - n
13E(d) - n
14.1(x) - n
14.1(w) - n
14.1(d) - n
14.2(x) - n
14.2(w) - n
14.2(d) - n
15.1A - y
15.1B - n
15.1C - n
15.2 - n
16A(x) - y
16A(w) - y

Galesburg, IL control

WET Answer Dataset for "fhglcn"

16A(d) - y
16B(x) - n
16B(w) - n
16B(d) - n
16C(x) - n
16C(w) - n
16C(d) - n
17 - n
18 - n
19.1A - i
19.1B - n
19.2 - n
19.3 - y
20.1 - y
20.2 - i
21A - n
21B - n
21C - y
21D - n
21E - n
22.1.1 - y
22.1.2 - y
22.2 - n
22.3 - n
23 - n
24.1 - i
24.2 - y
24.3 - n
24.4 - y
24.5 - n
25.1 - y
25.2A - y
25.2B - n
25.3 - n
26.1 - y
26.2 - n
26.3 - y
27.1 - y
27.2 - n
27.3 - y
28 - n
29.1 - y
29.2 - i
30(x) - n
30(w) - n
30(d) - n
31.1(x) - y
31.1(w) - y
31.1(d) - y
31.2(x) - n
31.2(w) - n
31.2(d) - n
31.3(x) - n
31.3(w) - n
31.3(d) - n
31.4(x) - n
31.4(w) - n
31.4(d) - n
31.5(x) - y
31.5(w) - y
31.5(d) - y
31.6A(x) - y
31.6A(w) - n
31.6A(d) - y
31.6B(x) - n
31.6B(w) - y
31.6B(d) - n
31.6C(x) - n
31.6C(w) - n
31.6C(d) - n
31.6D(x) - n
31.6D(w) - n
31.6D(d) - n
31.6E(x) - n
31.6E(w) - n
31.6E(d) - n
32A - n
32B - n
32C - n
32D - n
32E - n
32F - y
32G - n
32H - n
32I - n
32J - n
32K - n
33A - n
33B - n
33C - n
33D - n
33E - n
33F - n
33G - y
33H - n
33I - n
33J - n
33K - n
34.1 - n
34.2 - n
34.3.1 - n
34.3.2 - i
35.1 - n
35.2 - y
36.1.1(x) - n
36.1.1(w) - n
36.1.1(d) - n
36.1.2(x) - y
36.1.2(w) - y
36.1.2(d) - y
36.2.1(x) - y
36.2.1(w) - y
36.2.1(d) - y
36.2.2(x) - y
36.2.2(w) - y
36.2.2(d) - y
36.2.3(x) - n
36.2.3(w) - n
36.2.3(d) - n
37 - i
38.1 - n
38.2 - y
38.3 - n
38.4 - n
38.5 - n
38.6 - n
38.7 - n
38.8 - i
39 - y
40.1 - n
40.2 - y
41.1 - y
41.2 - n
42.1.1(x) - y
42.1.1(w) - y
42.1.1(d) - y
42.1.2(x) - n
42.1.2(w) - n
42.1.2(d) - n
42.1.3(x) - n
42.1.3(w) - n
42.1.3(d) - n
42.2.1(x) - y
42.2.1(w) - y
42.2.1(d) - y
42.2.2(x) - y
42.2.2(w) - y
42.2.2(d) - y
42.2.3(x) - n
42.2.3(w) - n
42.2.3(d) - n
43A(x) - y
43A(w) - y
43A(d) - y
43B(x) - n
43B(w) - n
43B(d) - n
43C(x) - n
43C(w) - n
43C(d) - n
43D(x) - n
43D(w) - n
43D(d) - n
43E(x) - n
43E(w) - n
43E(d) - n
43F(x) - n
43F(w) - n
43F(d) - n
43G(x) - n
43G(w) - n
43G(d) - n
43H(x) - n
43H(w) - n
43H(d) - n
43I(x) - n
43I(w) - n
43I(d) - n
44A(x) - y
44A(w) - y
44A(d) - y
44B(x) - y
44B(w) - y
44B(d) - y
44C(x) - y
44C(w) - y
44C(d) - y
44D(x) - y
44D(w) - y
44D(d) - n
44E(x) - n
44E(w) - y
44E(d) - n
44F(x) - n
44F(w) - y
44F(d) - n
44G(x) - n
44G(w) - n
44G(d) - n
44H(x) - n
44H(w) - n
44H(d) - n
44I(x) - n
44I(w) - n
44I(d) - n
45A - y
45B - n
45C - n

Galesburg, IL control

WET Answer Dataset for "fhglcn"

45D - n	48B(w) - n	49.2(x) - y	55.3 - u
45E - n	48B(d) - i	49.2(w) - y	55.4 - u
45F - n	48C(x) - n	49.2(d) - y	56.1 - u
45G - n	48C(w) - n	49.3(x) - n	56.2 - u
46A(x) - y	48C(d) - i	49.3(w) - n	57.1 - u
46A(w) - y	48D(x) - n	49.3(d) - n	57.2 - u
46A(d) - y	48D(w) - n	50(x) - y	58 - u
46B(x) - n	48D(d) - n	50(w) - y	59.1 - u
46B(w) - n	48E(x) - n	50(d) - y	59.2 - u
46B(d) - n	48E(w) - n	51.1 - u	60 - u
46C(x) - n	48E(d) - n	51.2 - u	61 - u
46C(w) - n	48F(x) - n	52.1 - u	62 - u
46C(d) - n	48F(w) - n	52.2 - u	63.1 - u
47A - y	48F(d) - n	53.1 - u	63.2 - u
47B - n	49.1.1(x) - y	53.2 - u	64 - u
47C - n	49.1.1(w) - y	54(x) - u	CR - 2
48A(x) - n	49.1.1(d) - y	54(w) - u	1 - n
48A(w) - y	49.1.2(x) - n	54(d) - u	2 - n
48A(d) - i	49.1.2(w) - n	55.1 - u	3 - n
48B(x) - y	49.1.2(d) - n	55.2 - u	4 - y

Hollands-Magee input data - Illinois

A. Galesburg mitigation wetland, IL

Add plants? (T/F):T	Add soils? (T/F):F	Do evaluation?(T/F):T
Field Date: 08/29/89	Town code (2-4 Chr):GALE	
Investigator:EAD		Border Op Water (NLMH):H
	Topo Config (CSVH) :S	Lake Fetch (LH):L
Dom Wet Class (0-11) : 5	Wetland Size (LMH) :M	Lake Depth (SD):S
Special Elements :	Wetland Gradient(LH):L	Hydro Connect (NSRLC):S
Class Richness (1-5) :4	Surround Slope (LH):H	Accessibil by (RWI):R
Subtyp Richness (A-E):C	Topo Position (LMH):M	local Scarcity (LMH):H
Veg Interspers. (LMH):L	Dom Hydro Cond (1-6):4	Legal access (BVR):B
Surround. Habit (1-3):2	Inlet 1 (AEP):P	
Cover Dispers (A-E) :D	Inlet 2 (AEP):E	
% Open Water (LMHV) :L	Inlet 3 (AEP):E	Geology under (ALOT):A
Veg Density (LMH) :H	Inlet 4 (AEP):E	Geology surr (ALOT):A
Wetland Juxta. (LMH) :H	Inlet 5 (AEP):E	Hydrol Position (PWA):W
Wat.level fluct (LHV):L	Outlet 1 (AEP):P	Permeability (LMH):H
Vege Spec Richn (LMH):M	Outlet 2 (AEP):A	Thickness org (LMH):L
		Gr Water Rel (DRC):C
		Transmissivity (LMH):M

B. Galesburg control wetland, IL

Add plants? (T/F):T	Add soils? (T/F):F	Do evaluation?(T/F):T
Field Date: 08/29/89	Town code (2-4 Chr):GALE	
Investigator:EAD		Border Op Water (NLMH):H
	Topo Config (CSVH) :S	Lake Fetch (LH):L
Dom Wet Class (0-11) : 5	Wetland Size (LMH) :M	Lake Depth (SD):S
Special Elements :	Wetland Gradient(LH):L	Hydro Connect (NSRLC):S
Class Richness (1-5) :3	Surround Slope (LH):H	Accessibil by (RWI):R
Subtyp Richness (A-E):D	Topo Position (LMH):M	local Scarcity (LMH):M
Veg Interspers. (LMH):L	Dom Hydro Cond (1-6):4	Legal access (BVR):V
Surround. Habit (1-3):1	Inlet 1 (AEP):P	
Cover Dispers (A-E) :E	Inlet 2 (AEP):E	
% Open Water (LMHV) :L	Inlet 3 (AEP):E	Geology under (ALOT):A
Veg Density (LMH) :H	Inlet 4 (AEP):E	Geology surr (ALOT):A
Wetland Juxta. (LMH) :H	Inlet 5 (AEP):E	Hydrol Position (PWA):W
Wat.level fluct (LHV):L	Outlet 1 (AEP):P	Permeability (LMH):H
Vege Spec Richn (LMH):L	Outlet 2 (AEP):A	Thickness org (LMH):L
		Gr Water Rel (DRC):C
		Transmissivity (LMH):M

Table 32. Hollands-Magee model scores for Galesburg, IL.

Wetland Function	Mitigation	Control
Biological function	58.9	51.9
Hydrological support	72.4	72.4
Ground water recharge	64.2	64.2
Flood flow alteration	61.8	61.8
Sediment stabilization	20.7	20.7
Water quality protection	64.7	64.7
Recreation	37.0	34.2
Education	60.3	42.9

REFERENCES

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