WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Restoring Wetlands at a River Basin Scale

A Guide for Washington’s Puget Sound

Operational Draft

May 1997
Publication No. 97-99

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Washington State Department of Ecology
Shorelands and Water Resources Program

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An Invitation to Participate

The Puget Sound region is a unique and unparalleled ecological resource for the residents of Washington State and beyond. Recognizing the significance of this resource, the Legislature established the Puget Sound Water Quality Authority in 1985. Since that time, significant work has gone into development and implementation of the Puget Sound Water Quality Management Plan. This document directs activities which assist in reaching the overall goal of the Puget Sound Plan through the restoration of wetlands and the functions they provide.

But planning does not restore wetlands -- people do. We need your help, and the help of many other individuals, organizations, businesses, corporations, local jurisdictions, tribes, and government agencies to ensure the continued existence of this unique natural resource. Some will be able to commit their time, others money, knowledge, or expertise, while still others may choose to make portions of their land available for restoration work. Regardless of what you have to contribute, there is a place for you in this watershed-based wetland restoration program.

We cordially invite you to join hand-in-hand with us to explore opportunities to use wetland restoration as a tool to help restore and preserve the biological health and diversity of Puget Sound.

What This Document Does

This document:

- Establishes overall wetland restoration program goals;
- Presents a procedure for analyzing existing information and working with local partners to restore wetlands which help solve ecological problems and meet community needs within a river basin;
- Outlines a common sense, scientifically-based GIS procedure that identifies restoration sites having potential to provide wetland functions of importance to river basin health and the needs of residents;
- Focuses on identifying and restoring freshwater and saltwater wetlands, but provides flexibility for the restoration of other aquatic or upland sites such as riparian areas, deep water habitats, streams, and associated buffers when such work contributes to river basin goals and where these activities do not duplicate others' work;
- Focuses on Puget Sound river basins, but can be adapted to basins throughout the state;
- Outlines procedures for sharing all information and knowledge with interested residents and local jurisdictions;
- Promotes the restoration of wetlands and wetland functions at a local level;
- Reflects a new state and federal interest in developing tools which promote and encourage the voluntary non-regulatory restoration of wetlands;
- Presents methods which are consistent with President Clinton's wetlands policy which encourages non-regulatory wetland restoration programs to reduce the federal government's reliance upon regulatory programs as the primary means to protect wetlands resources and to accomplish long-term wetlands gains (White House Office on Environmental Policy 1993);
- Fulfills state and federal agency directives regarding element W-8.2 of the 1991 Puget Sound Water Quality Management Plan (Appendix A) and the Authority's Action Agenda developed in 1994; and
- Implements wetland restoration management measures identified in Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (United States Environmental Protection Agency 1993).

What This Document Does Not Do

This document:

- **Does not** provide a cookbook process to watershed characterization by non-professional people. It is intended to be a road map for an iterative, cooperative public/private venture which blends the technical skills of a diverse group of people with public outreach and education.

- **Does not** seek to "put things back" the way they were before Europeans arrived at Puget Sound. We recognize the need for a balance between economic development and environmental interests and seek to use voluntary wetland restoration as one tool to provide this stability.

- **Is not** the final methods document for wetland restoration analysis in Puget Sound basins. Rather, this is the initiation of analysis methods that will be refined and tailored as other basins are assessed.

- **Is not** the end product of this process, but rather a starting point for the on-the-ground restoration of wetlands and wetland functions within Puget Sound river basins.

Acknowledgments

The author wishes to acknowledge the U.S. Environmental Protection Agency, the Puget Sound Water Quality Action, Team, and the National Oceanic and Atmospheric Administration for providing financial support for development of this document.

The original working draft entitled "Working Together: A Non-Regulatory Wetland Restoration Plan for Puget Sound Basins" was created in 1994 by a diverse consortium of individuals representing all levels of government, tribes, and business, timber, agriculture, conservation, and civic groups. This draft was the framework used to develop the river basin analysis methods presented here. While only one author is listed, it must be acknowledged that this document would not have been possible without the continual technical support and encouragement of Wetland Restoration Technical Work Team members Ginny Broadhurst, Patrick Cagney, Curtis Tanner, Fred Weinmann, and Bob Zeigler and the dedicated financial support of the Puget Sound Water Quality Action Team and the US Environmental Protection Agency. Special recognition must also be given to Bill Blake for his dedicated work with landowners and willingness to share his wealth of information on the Stillaguamish River Basin, Mike Woodall for expert GIS support, Lin Sierra for Access database development, and Anita Stohr for GIS database development and technical support. Each of these colleagues worked far above expectations in the completion of their tasks.

The single most important element of any non-regulatory wetland restoration initiative is public participation and involvement. It must be acknowledged that this document was truly shaped and directed by the dedicated work of a diverse group of Puget Sound stakeholders. The author wishes to acknowledge the persons, tribes, organizations, and agencies listed in Appnedix B and C for their contributions here. The author would also like to thank Washington State Department of Ecology staff who served as facilitators and recorders for the stakeholder advisory group meetings. Their organizational skills were instrumental in the success of this group. Special thanks must also go to Jaime Kooser, Jane Rubey, and Ann Shipley (Washington State Department of Ecology) for their valuable comments and editing skills during the development of this document.

Executive Summary

The Puget Sound Water Quality Management Plan was developed in 1987 to guide and direct activities which restore and protect the biological health and diversity of Puget Sound. The 1991 revision of this plan established a new strategy which called for the restoration of Puget Sound wetlands to assist in meeting the overall plan goal. The wetland restoration plan which follows was developed to fulfill state and federal directives regarding program development of Element W-8.2 of the 1991 Puget Sound Water Quality Management Plan.

Solving real watershed problems such as flooding, salmon loss, and the degradation of water quantity and quality at the community level is the focus of the Puget Sound Wetlands Restoration Program. This document offers a balanced approach to river basin analysis, public empowerment, and problem resolution while providing primary guidance and direction for Washington State Department of Ecology's wetland restoration efforts within Puget Sound. The process is GIS intensive, requires the compilation of information on hydrology, geology, geomorphology, natural resources, and landuse, and necessitates qualitative judgments by a trained wetland ecologist. While the process of river basin analysis and database development warrants state involvement, we believe integration and implementation must be directed by local interests through a cooperative public/private venture to restore wetlands and the important functions they can provide.

Presented is a program framework and methods developed by a partnership of technical experts and interested individuals and organizations within Puget Sound. This framework consists of goals and assumptions which establish program direction, purpose, and structure. The technical methods consist of procedures for basin analysis and models for characterizing wetland functions at a river basin scale. The following wetland restoration program goals direct this effort:

Goal 1 - Restore and maintain wetlands of sufficient quantity and quality to assist in meeting the Puget Sound Water Quality Management Plan purpose of restoring and protecting the biological health and diversity of Puget Sound.

Goal 2 - Identify ecological problems within watersheds and, where wetlands restoration can address problems, reestablish lost or degraded natural functions.

Goal 3 - Identify community needs within watersheds and restore natural wetland functions which contribute to meeting human health, safety, and quality-of-life needs of residents.

Goal 4 - Support state and federal policy goals of no net loss and a long-term net gain in acreage and function of wetlands.

The technical methods presented here were developed in the 180, 000 hectare (707 square miles) Stillaguamish River Basin. Throughout the methods portion of this document, text boxes are provided which describe what was done in the Stillaguamish Basin and how this work shaped methods presented here.

A fourteen step implementation process is presented to achieve overall program goals. Procedures for completing the following fourteen steps are outlined along with the technical methods for characterizing wetland functions at a river basin scale:

1. Inform, involve, and develop lasting partnerships with river basin residents, tribes, organizations, and jurisdictions.

2. Identify river basin ecological problems and community needs.

3. Identify key wetland functions which address ecological problems and meet community needs.

4. Compile existing river basin technical information and GIS data layers.

5. Customize GIS data layers and prepare for analysis.

6. Identify the location and extent of predisturbance wetlands using existing wetland inventory and soil survey data.

7. Characterize the river basin to gain understanding of water movement, wetlands in the basin, and the processes which contribute to wetland formation and maintenance.

8. Stratify potential wetland sites using hydrogeomorphic features.

9. Establish and assign risk-based priorities to watersheds/drainages for each wetland function, when appropriate.

10. Characterize wetland potential for providing key functions.

11. Assess restoration potential of identified sites and establish a qualitative rank for each function.

12. Interpret and integrate findings.

13. Coordinate/facilitate the restoration of wetlands.

14. Evaluate program and prepare documents.

This document is considered an operational draft and will be revised as other river basins are analyzed and methods are refined.

Part 1: General Program Approach

Background and History

In 1985, the Washington Legislature established the Puget Sound Water Quality Authority (Authority). Their mandate was to develop and coordinate implementation of a comprehensive plan for water quality protection of Puget Sound. The Puget Sound Water Quality Management Plan (Plan) was written in 1987 and revised in 1989, 1991, and 1994. The goal of this plan is to restore and protect the biological health and diversity of Puget Sound.

In the 1991 revision, a new strategy was added which called for the restoration of Puget Sound wetlands to assist in meeting the overall goal of the Plan (Puget Sound Water Quality Authority 1990). This strategy called on the Washington State Department of Ecology (Ecology), US Environmental Protection Agency (EPA), US Fish and Wildlife Service (FWS), and US Army Corps of Engineers (COE) to develop and implement a voluntary community-based program to restore wetlands which improve water quality and provide fish and wildlife habitat within Puget Sound river basins (Figure 1).

In 1994, an interagency wetland restoration technical work team was formed to develop the conceptual framework for this wetland restoration initiative. The interagency work team consisted of wetland ecologists and fish and wildlife biologists representing Ecology, EPA, FWS, COE, Washington State Department of Fish and Wildlife, Northwest Indian Fisheries Commission, and the Authority. Agency representatives were selected for their expertise in wetland ecology, wetland restoration, or key functions that wetlands provide (e.g., fish and wildlife habitat, water quality) and are listed in Appendix B. The Technical Work Team met monthly to develop draft program goals and objectives, key definitions, a general process for watershed analysis, and detailed methods for prioritizing watersheds.

Late in 1994, a diverse group of Puget Sound stakeholders (Appendix C) was convened to take the technical framework developed by the work team and shape it into a plan with the greatest potential for addressing both river basin and landowner needs. Advisory group meetings where held to present the draft program goals, objectives, and framework developed by the Technical Work Team. Participants then broke up into small groups to facilitate discussion and comment on all information presented. Recommendations from the Stakeholder Advisory Group were then merged with Technical Work Team recommendations. This resulted in a draft plan entitled “Working Together: A Non-Regulatory Wetland Restoration Plan For Puget Sound Basins” (Gersib et al. 1994) which served as the framework for developing the technical methods required for river basin analysis. The Stillaguamish Basin was selected as the area in which methods are developed, tested, and evaluated.

In 1995, work began in the Stillaguamish Basin to take the technical framework and develop it into practical methods which evaluate wetland restoration potential at a river basin scale. Methods will continually be refined as additional river basins are analyzed.

Figure 1: Major Puget Sound River Basins as adapted from Washington State Department of Ecology, Water Resource Inventory Areas.

Wetland Assessment vs. Wetland Characterization

The misuse or overuse of the term wetland assessment has created substantial confusion regarding its meaning and applicability at various scales. Definitions for wetland assessment and wetland characterization are presented here to reduce misunderstanding.

Wetland assessment of function - a procedure which provides some quantitative estimates of wetland importance or value based on measured variables (Hruby et al. 1995). Typically wetland assessment procedures are used to evaluate or compare individual wetlands or a closely related group of wetlands (e.g., Mill Creek Special Area Management Plan, Everett Snohomish Estuarine Wetland Integration Plan) for regulatory purposes.

Wetland characterization of function - a simplified grouping process that identifies and evaluates basic biologic, hydrologic, geologic, geomorphic, and human induced factors of hundreds of wetlands to qualitatively predict which sites have the greatest opportunity or potential to provide a specific wetland function. While less technically rigorous, this characterization process is a landscape level tool that allows the use of available GIS tools to evaluate many potential restoration sites at the same time.

Spatial Scales Used in the Analysis

River basin was selected as the fundamental scale for all analysis and characterization work. This decision was based in part on the sheer number of management units in Puget Sound (18 river basins versus approximately 200 watersheds), limited staffing, the ability of GIS tools to manage large data sets, the perceived need for a glacier to estuary hydrologic perspective, and an efficiency in scale regarding public participation and outreach. Each river basin is subdivided into watersheds and, when appropriate, watershed drainages are subdivided to facilitate analysis of individual sites.

Program Area - Puget Sound Region; the outer boundary of the eighteen Puget Sound River Basins.

River Basin - Major Puget Sound river systems as defined by Washington State Department of Ecology, Water Resource Inventory Areas (WRIA). These are large, continuous areas of topographic integrity ranging from slightly less than 200 square miles to nearly 3000 square miles in size.

Watershed - Defined by Washington State Department of Natural Resources Watershed Administrative Units (WAU). These WAUs are subunits of a WRIA and range in size from approximately 10,000 to 50,000 acres.

Drainage - A subunit of a Watershed Administrative Unit.

Site - A specific wetland area within a drainage.

Wetland Terms

Common wetland terms used throughout this document are presented here. A more complete glossary of terms is provided in Appendix D.

Wetland - Those areas that are inundated or saturated by surface or groundwater 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 (US Army Corps of Engineers 1987). Wetlands include Estuarine, Riverine, Lacustrine, and Palustrine Systems as defined by Cowardin et al. (1979).

Wetland Creation - The conversion of a non-wetland area into a wetland through some activity of humans.

Wetland Enhancement - Actions taken which result in the alteration of natural wetland structure, processes, and functions to favor one or more functions, usually at the expense of other functions.

Wetland Restoration - Actions taken which result in the re-establishment of wetland structure, processes, and functions in areas where wetlands have been altered, degraded, or destroyed.

Wetland System - A wetland and surrounding aquatic resources, riparian areas, and adjacent uplands which contribute to the wetland's functions.

Goals

Wetland restoration program goals were developed by the Puget Sound Wetland Restoration Advisory Group and the Technical Work Team to establish overall program direction.

Goal 1 - Restore and maintain wetlands of sufficient quantity and quality to assist in meeting the Puget Sound Water Quality Management Plan purpose of restoring and protecting the biological health and diversity of Puget Sound.

Goal 2 - Identify ecological problems within watersheds and, where wetland restoration can address problems, reestablish lost or degraded natural functions.

Goal 3 - Identify community needs within watersheds and restore natural wetland functions which contribute to meeting human health, safety, and quality of life needs of residents.

Goal 4 - Support state and federal policy goals of no net loss and a long-term net gain in acreage and function of wetlands.

Assumptions

Clearly stated assumptions serve as guiding principles or philosophical building blocks which help mold and shape program goals into an implementation framework. The following assumptions are presented:

Problem Solving Premise - By solving ecological problems and meeting community needs within river basins, wetland restoration can be used as an important tool to improve the quality of life in Puget Sound.

Rationale - Program focus must be on reestablishing key wetland functions which contribute to solving targeted ecological problems and meeting community needs within a river basin. Indicators of potential ecological problems include depressed fish runs, sharp declines in migratory bird numbers, closed shellfish beds, reduced plant and animal species diversity, and threats to areas of special ecological significance such as bogs or fens. Examples of community needs which wetland restoration can address include water quality enhancement, flood control, recreation, groundwater aquifer recharge, shoreline stabilization, and outdoor education.

The river basin-scale function characterization of wetlands is used to determine each wetland restoration site's capability to help solve ecological problems and meet community needs. By targeting wetland functions which contribute to solving identified problems and needs, this program can maximize opportunities to improve the quality of life for residents and visitors.

> **Common Sense Approach** - The overall restoration program, its goals, methods, and approach to restoration must make sense to river basin residents.

Rationale - Non-regulatory wetland restoration initiatives will fail without the support and buy-in of landowners and river basin residents. Many rural landowners are business men and women who rely on common sense and a clear understanding of the issues to make decisions. Any program that makes sense to a landowner has an opportunity to be successful, while programs that don't make sense or are too complicated to be understood by the average person will fail.

> **Public Involvement** - Full public participation is desirable and necessary. .
>
> **Public Involvement** - Incorporation of perceptions, interests, and values of river basin residents is integral to decisions about watershed structure and function. .
>
> **Public Involvement** - Identifying and overcoming barriers to non-regulatory wetland restoration in the river basin is essential. .

Rationale - A successful wetland restoration program must hear and understand the concerns and needs of private individuals, communities, tribal governments, business, industry, organizations, and groups. This program seeks to foster the long-term involvement and stewardship of these interests by developing tools and lasting partnerships to achieve mutual goals. Wetland restoration work must be done in concert with existing watershed and nonwatershed-based water resource activities to maximize efficiency. Finally, to gain the broadest level of support, the program must focus on what can be done cooperatively in the future, rather than establishing blame for what was done in the past.

> **Public Involvement** - River basin residents must be informed, involved, and empowered to ensure long-term program success.

Rationale - This restoration program cannot be successful if carried out or maintained by persons who do not live in the river basin. Comments from the Advisory Group and work in the Stillaguamish Basin suggest that the program provide leadership in the restoration of wetlands and empower residents to establish individual river basin and watershed goals, strategies, and timelines. The restoration program will seek to provide river basin residents with timely information, skills, tools, and motivation necessary for them to steward wetland recovery.

> **River Basin Analysis** - River basin analysis provides the broad scale perspective needed to effectively define problems and assess how wetland restoration can contribute to problem resolution.

Rationale -Characterizing wetland resources at a river basin scale maximizes opportunities to gain an understanding of wetland diversity and primary drivers of function. This, in turn, provides the understanding necessary to restore and protect key wetland systems and the functions they provide.

> **River Basin Analysis** - Wetland ecosystems occur under a wide range of climatic, geologic, geomorphic, and hydrologic conditions.
>
> **River Basin Analysis** - Not all wetlands perform the same functions in the same manner, or to the same degree.

Rationale -Landscape position is an important factor in determining the type of wetland that exists and the functions each is capable of providing. Substantial variation in temperature, precipitation, elevation, and geologic parent material within a Puget Sound River Basin equates to substantial variation in wetland features and functions.

> **River Basin Analysis -** A foundational understanding of present and past geologic and geomorphic features and processes responsible for the formation and maintenance of wetlands is needed before wetland functions can be characterized.
>
> **River Basin Analysis** - A foundational understanding of surface and subsurface water movement through the river basin is needed before wetland functions can be characterized.

Rationale - Because it is assumed that wetlands do not all function the same, an understanding of the basic processes that have resulted in the formation and maintenance of wetlands must be identified and understood. Geologic and geomorphic processes influence both above and below groundwater movement. This knowledge provides insight into where and why wetlands occur, how they have been impacted by human activities, and how they have contributed or are contributing to overall river basin function.

River Basin Analysis - Wetland position in the landscape (geomorphic setting), dominant sources of water, and the flow and fluctuation of the water once in the wetland are wetland classification criteria which are "first principles" of wetland function and are responsible for the maintenance of most functions (Brinson 1995).

River Basin Analysis - Using Hydrogeomorphic Classification of Wetlands (HGM) criteria and regionally customized wetland classes and subclasses, wetland classification isolates most of the natural variation within a relatively homogeneous group of wetlands (Brinson 1995).

Rationale - HGM has received wide-spread acceptance in the professional wetland community as the logical first step to function characterization or assessment. The grouping or stratifying of wetlands into homogeneous groups is an important step in that process. When these homogeneous groups are developed using HGM criteria (i.e., common landscape position, water source, and hydrodynamics), attention is focused on the ecosystem and landscape position characteristics that control wetland function (Smith and Bartoldus 1994).

River Basin Analysis - To characterize the functions of hundreds of wetlands within a river basin, primary drivers must be identified and used to establish a wetland's opportunity to perform a particular function.

Rationale - The sheer scale of a river basin, and the large number of wetlands therein precludes a detailed, site-specific function assessment using all know factors or criteria needed to quantify a level of performance. Function characterization relies on the primary drivers of a particular function to identify river basin-scale opportunity and effectiveness (e.g., flood flow storage and desynchronization - location within floodplain or between rain-on-snow and major tributary, water source, landuse, soil type, retention capability).

River Basin Analysis - Primary drivers have been identified for each wetland function which can be used in function characterization.

Rationale - Existing function assessment methods, available technical information, best professional judgment, and common sense are available tools for identifying primary drivers for each wetland function.

Program Focus - Non-regulatory wetland restoration requires us to work directly and proactively with landowners.

Rationale - The restoration program seeks to help natural resource managers hear, understand, and respond to the needs and concerns of landowners. Voluntary programs require landowner participation and long-term stewardship commitments. This requires that direct communication with landowners be established and maintained at the local level.

Landowner Incentives - A diversity of financial and non-financial incentives are needed to encourage landowner involvement and project implementation.

Rationale - The lack of financial incentives to landowners continues to be a major stumbling block for most, if not all, non-regulatory wetland restoration programs. Government program cutbacks have reduced available funding even further. This program seeks to pool the available funds of many natural resource agencies and organizations to achieve mutual objectives. However, to maintain a stable program, a secure source of funding is needed to assist landowners with costs associated with wetland restoration and, in some cases, compensation for land use change. Flexibility in providing incentives is essential to meet the unique needs of each individual landowner.

Restoration Approach - Wetland restoration must focus on regaining lost natural functions through the reestablishment of pre-alteration hydrology and native plant and animal communities to the extent possible.

Restoration Approach - Wetland restoration must expand its focus beyond the wetland boundary to the surrounding buffer when possible, to ensure that all key components (i.e. aquatic resources, riparian areas, and adjacent uplands) which contribute to and maintain a wetland's functions are considered.

Rationale - This program seeks to use wetland restoration to maintain and restore biodiversity of native flora and fauna and their associated gene pools. It seeks to do this by promoting natural processes that heal damaged ecosystems and reestablish linkages between them. To restore the greatest range of wetland functions, actions may need to be taken to restore nearby aquatic resources, riparian areas and adjacent uplands which contribute to wetland function. All wetland restoration opportunities will be explored, but generally, activities will focus on hydrologically altered areas where the historic water source and flow can be reestablished, to assure the greatest probability of success. Wetland enhancement activities which replace lost wetland functions with other functions are discouraged. Significant restoration activity will not be considered when high floral and faunal species diversity or rare plant or animal species exist or where sites are maintaining a near pristine condition worthy of preservation.

Information Management - Wetland restoration decisions will be based on the best scientific information available.

Information Management - Existing information will be used to apply technical methods.

Rationale - This program is not an elaborate research effort to collect new technical data. This initiative will compile available technical data and use scientifically-based characterization methods to support the identification of wetland restoration sites. The past degradation of wetlands and watershed functions within the Puget Sound Basin dictates that corrective action, rather than more study, begin now.

Plan Flexibility - This program must establish and maintain flexibility.

Rationale - To ensure responsiveness to new opportunities and changing public needs program flexibility must be established and maintained.

Evaluation - Program success is measured by the acreage, functions, and values of wetlands restored and their contribution to maintaining and restoring degraded river basin functions.

Rationale - Evaluation at all levels is essential for maintaining an efficient, effective wetland restoration program. However, evaluation of overall program success ultimately rests on our ability to restore wetlands and the functions they provide.

Implementation

Overview of Program Implementation

The basic operational approach to program implementation in a river basin consists of:

- Informing residents and developing partnerships;
- Identifying river basin problems and needs that wetlands can address;
- Understanding water movement in the basin;
- Characterizing how wetlands function;
- Identifying wetland restoration sites that have potential to address problems and needs of the basin;
- Developing a database of these restoration sites and the functions gained through restoration; and
- Facilitating the on-the-ground restoration of wetlands and riparian areas.

Past attempts have shown that a broad base of long-term public involvement and support is necessary for a non-regulatory wetland restoration initiative to be successful. Further, public comments received during program development emphasize the need to provide training, information, and on-the-ground experience to river basin residents prior to and during plan implementation to maximize public support.

Public input is essential to identifying ecological problems and community needs of importance to river basin residents. This is done by working cooperatively with existing watershed advisory groups and local jurisdictions to access and, when necessary, compile new information. Experience has shown that local support can be developed most effectively by listening and incorporating the concerns and desires of local residents into program objectives. A lack of awareness and attention to community needs and desires results in little local interest or support and few, if any, projects.

Once ecological problems and community needs are identified, a list of wetland functions is developed which can address each specific problem and need. This provides a unique set of wetland functions that restoration activities are to target in each river basin. For example, the wetland function of flood storage/desynchronization will become a target function when residents identify flood control as a community need. In this way wetland assessment efforts focus on identifying and restoring wetlands which have the greatest potential for addressing problems and needs important to the people. A more complete list of functions which wetlands can provide is included in Appendix E.

The river basin characterization process begins with the compilation of available technical information relating to water movement both above and below ground. GIS data layers are also compiled and prepared for analysis efforts. Hardcopy maps of key data are digitized and added to the existing GIS data layers. Coverages are evaluated and rectified when possible to minimize overlay inconsistencies.

A GIS coverage showing the location and extent of existing and predisturbance wetlands is developed using available data coverages. All existing wetland inventory data are used to develop a coverage which identifies the location and extent of existing wetlands. Soils data are used to identify the predisturbance location and extent of wetlands in the basin.

Available hydrology, geology, geomorphic, topographic, and land use/landcover data are then reviewed in light of our current understanding of river basin water movement developed from other basin analyses. River basin characterization is used to help understand how water flows through the basin, both above and below ground, where and why wetlands occur, how they have been impacted by humans, and how they contribute to overall system function.

Wetland classification methods developed by Brinson (1993) and customized regionally (Granger et. al. 1996) are then used to group wetland resources having similar hydrology, hydrodynamics, and landscape position. All potential wetland sites are classified using available data and best professional judgment to predict post-restoration physical features. Because this process seeks to identify the functions a wetland provides after restoration, classification of potential sites is needed rather than a classification of existing wetland sites. This step is used to stratify potential sites in preparation for function characterization.

Risk-based priorities are established for each key wetland function. Our goal is to restore wetlands which have the greatest potential to help solve problems or meet needs. To do this, restoration work must focus first on watersheds/drainages where problems currently exist (primary watersheds) and then on watersheds/drainages where problems have the greatest potential of occurring in the near future (secondary watersheds). Wetland restoration sites located within a watershed or drainage which do not meet criteria for primary or secondary watersheds (tertiary watersheds) are considered to have limited capability to address the particular problem or need. Water quantity and quality data and river basin characterization work are used to establish primary, secondary, and tertiary watersheds for each function.

Targeted wetland functions to be characterized are then compared to the list of existing function characterization models developed during previous work in other river basins. Functions which have existing characterization models are submitted to local technical experts for evaluation and adaptation, where needed, to meet the specific physical and biological features of the river basin. Functions which do not have existing characterization models will require model development.

Function characterization models are then run to identify wetlands having the greatest potential to perform individual wetland functions based on physical, chemical, biologic, and landuse features of the site. As each model is run and sites identified, information is downloaded into a comprehensive wetland restoration site database. This GIS ArcInfo database and a mirrored Microsoft Access database have been developed to facilitate use by local natural resource managers.

After all function characterization models have been run, restoration potential of each wetland site is evaluated by comparing existing wetland area to potential wetland area. This information is then added to the restoration site database.

The final steps address interpreting results and integrating findings into local and regional watershed planning efforts, coordinating/facilitating the restoration of wetlands, and program evaluation and documentation. Analysis is essential to gain a river basin perspective, but it is only a planning tool which sets the stage for regaining wetland and system functions. The need to work cooperatively with landowners and other partners to restore wetlands is essential. This also requires that river basin analysis information be integrated into all existing and future river basin/watershed plans and that program methods be refined and documented to ensure that as errors are identified, they are used to increase our understanding of river basin analysis.

River basin analysis components (i.e., river basin characterization, wetland classification, and function characterization) are GIS intensive and require substantial ArcInfo and ArcView technician time.

A 14-step process is presented here to outline procedures to restore wetlands at a river basin scale. A detailed description of each step is presented in Part II of this document.

1. Inform, involve, and develop lasting partnerships with river basin residents, tribes, organizations, and jurisdictions.
2. Identify river basin ecological problems and community needs.
3. Identify key wetland functions which address ecological problems and meet community needs.
4. Compile existing river basin technical information and GIS data layers.
5. Customize GIS data layers and prepare for analysis.
6. Identify the location and extent of predisturbance wetlands using existing wetland inventory and soil survey data.
7. Characterize the river basin to gain understanding of water movement, wetlands in the basin, and the processes which contribute to wetland formation and maintenance.
8. Stratify potential wetland sites using hydrogeomorphic features.
9. Establish and assign risk-based restoration priorities to watersheds/drainages for each wetland function, when appropriate.
10. Characterize wetland potential for providing key functions.
11. Assess restoration potential of identified sites and establish a qualitative rank for each function.
12. Interpret and integrate findings.
13. Coordinate/facilitate the restoration of wetlands.
14. Evaluate program and prepare documents.

Relationship to Existing Analysis and Planning Processes

Information gained by characterizing wetland functions can assist other watershed analysis efforts at both the state and federal levels. For example, Washington Forest Practices Board (1993) can use this information when conducting biological inventories for watershed analysis at a watershed (WAU) scale. The US Forest Service (1994) has developed a comparable watershed analysis procedure and could employ this information and understanding in a similar way on federally-owned lands. Other watershed-specific initiatives can also use this information to help address declines in water quality and fish and wildlife habitats within Puget Sound.

In general terms, both state and federal watershed analysis procedures compile information and make interpretations of resource conditions and sensitivities at a watershed or larger scale. Then prescriptions are developed to minimize the future impacts of activities on these resources.

Products developed through the implementation of this procedure (i.e., river basin characterization information, hydric soils data, wetland restoration site data, a characterization of wetland functions) represent technical information that can be used by existing and future watershed-based and nonwatershed-based planning efforts to improve understanding of and corresponding management prescriptions for wetlands and adjacent buffer areas. Products from this document represent new technical information that has direct application in both water quality and fish and wildlife habitat improvement initiatives.

Location on the Learning Curve

This river basin analysis procedure must be considered only the first of many necessary iterations. A tremendous amount of insight has been gained from the work completed in the Stillaguamish Basin, but it also has revealed how primitive our understanding is of natural processes and how to go about characterizing them at a river basin scale. The fledgling nature of the technical methods in this document reflects our low position on the learning curve and work that must be done before this procedure can be considered a tested resource management tool.

The struggle here, as with all watershed scale analyses, is to provide a balance between oversimplifying system complexity and developing gridlock with data overload. As analysis work proceeds in other Puget Sound river basins, this analysis process will serve as the starting point or framework for new iterations on this theme.

Time and Staffing Requirements

Program implementation requires public participation, river basin analysis, and a post analysis presence in the river basin to facilitate wetland restoration. Ideally, program implementation would require:

- Approximately 4-6 months for initial public participation;
- 3-6 months for river basin analysis;
- One river basin resident hired for the initial 9 to 12 months of program implementation to expedite public participation and landowner involvement during the initial public participation and river basin analysis phases;
- One technical staff person/project coordinator;
- Approximately 500-600 hours of GIS technical support;
- An estimated $3000 for acquisition of GIS data and aerial photography; and
- One-third FTE for a minimum of three to five years to facilitate restoration activities in the river basin.

However, we believe that this schedule and staffing requirements can be reduced substantially if an existing river basin advisory group is active, key basin stakeholders are actively involved in the advisory group, technical literature and GIS coverages have been compiled, local staffing support is available to coordinate program activities such as informational meetings, technical discussions, local peer review of function models, etc., and local jurisdictions, tribes, and natural resource management groups are interested and willing to take a lead role in non-regulatory wetland restoration activities within the river basin. Under this scenario, we believe the analysis effort will require 4-6 months of time with one project coordinator and 400-500 hours of GIS support. Work in the future river basins will help us more closely estimate time and staffing requirements under this scenario.

Selection of Priority River Basins

Each Puget Sound river basin is unique in the ecological and social functions provided to inhabitants. Further, each is unique in the amount of past function loss and future threat to functions. Because of these differences and staff limitations, river basins must be ranked to ensure that the areas of greatest need and opportunity are addressed first.

In 1994, the Puget Sound Wetland Restoration Technical Work Team established initial criteria for the selection of river basins to be analyzed (Appendix F). This criteria was used to select the 180,000 hectare (707 square miles) Stillaguamish Basin in which river basin scale analysis methods were developed and tested.

On April 1, 1994, Governor Lowry signed Executive Order 94-04 (Appendix G) which directs state agencies involved in watershed-based natural resource management and environmental protection efforts to first coordinate watershed planning, implementation, and restoration processes; and second, establish priorities based on the restoration and enhancement of habitat, including water quality, for healthy, high priority fish and wildlife populations. To establish priority river basins, a Watershed Coordinating Council was created by Engrossed Substitute House Bill No. 2741 of the 1994 Legislative session.

This program adopts the Watershed Coordinating Council's priority list for wetland restoration program implementation. Puget Sound river basins will be addressed in the order or rank established by the Council as operational funding and staff allow.

Priority determinations by the Coordinating Council to date indicate the following river basin sequence:

1. Stillaguamish River Basin - Water Resource Inventory Area 5 - completed
2. Nooksack River Basin - Water Resource Inventory Area 1
3. Snohomish River Basin - Water Resource Inventory Area 7
4. Skagit River Basin - Water Resource Inventory Areas 3 and 4
5. Elwha/Dungeness River Basin - Water Resource Inventory Area 18

Products

Products developed during river basin analysis include:

- A detailed database of wetland restoration sites and the functions each has potential to provide if restored.
- New or customized GIS coverages developed during river basin analysis.
- An improved understanding of water movement both above and below ground.
- An improved understanding of how human impacts outside of a wetland can affect wetland functions and restoration potential.
- New working relationships with local natural resource managers, tribes, local jurisdictions, organizations and landowners which can facilitate and expedite restoration work.
- A case study document that summarizes the methods and results of wetland restoration analysis in each river basin.

Part II: River Basin Analysis Strategy

STEP 1: Inform, involve, and develop lasting partnerships with river basin residents, tribes, organizations, and jurisdictions.

Purpose

- To ensure program implementation has the broadest possible support, credibility, and opportunity to succeed.
- To identify and develop effective lines of communication and cooperation.
- To gain direct public input and involvement into all phases of activities.
- To empower residents to shape and direct development of the wetland restoration program to meet established river basin goals and objectives.
- To inform and educate river basin residents.

Products

- An awareness of the wetland restoration program, its purpose, and products by landowners, local jurisdictions, tribes, agricultural and environmental groups, and elected officials.
- Working relationships with community leaders, local jurisdictions, tribes, business, industry, and landowners.

Process

1. Develop lasting partnerships with local, state, and federal agencies, tribal governments, business, industry, organizations, and private individuals.

1.1. Use existing watershed advisory groups to facilitate communication/coordination within the river basin.

1.1.1. Identify key individuals, organizations, tribes, and governments within the river basin and invite/encourage participation on a watershed advisory group. Seek to involve minority groups and others which may not traditionally become involved with wetland programs.

1.1.2. Identify groups already involved in wetland and watershed restoration in the area and invite to participate.

1.1.3. Inform/educate advisory group members about the program and the need and benefits of wetland restoration.

1.1.4. Use knowledge provided by advisory group to customize wetland restoration program to meet individual river basin needs.

1.1.5. Identify potential communication tools (i.e., newsletters, environmental hot lines, internet links) and use to effectively interact with individuals, organizations, tribes, and governments.

1.2. Work directly with local jurisdictions to develop lasting partnerships.

1.2.1. Identify local jurisdiction needs and desires regarding wetland restoration and build into river basin plan.

1.2.2. Work to merge restoration products with local jurisdiction needs.

1.2.3. Involve people who write city/county plans.

1.3. Work directly with landowners to develop lasting partnerships.

1.3.1. Identify respected landowners throughout the river basin and work to inform them of, and involve them in this program.

1.3.2. Identify landowners that have an interest in restoration and provide encouragement, incentives, and technical assistance.

1.3.3. Identify landowner needs and desires regarding wetland restoration and build into river basin plan. Identify landowner needs and desires through:

- Watershed advisory groups
- Discussion with local landowner groups
- Questionnaire or survey in local newsletter
- Direct contact with large and small landowners

1.3.4. Work one-on-one with landowners to identify and restore wetland restoration sites.

1.4. Work directly with tribes to develop lasting partnerships.

1.4.1. Identify tribal natural resource staff and work to inform them of, and involve them in this program.

1.4.2. Identify tribal needs and desires regarding wetland restoration and incorporate into the river basin plan.

1.5. Work directly with business and industry to develop lasting partnerships.

1.5.1. Identify respected business/industry leaders and work to inform them of, and involve them in this program.

1.5.2. Identify business/industry needs and desires regarding wetland restoration and incorporate into river basin plan.

1.6. Work directly with existing student and citizen watershed protection networks to promote watershed protection and implementation of Executive Order 94-04.

1.7. Work directly with Washington State Department of Natural Resources, US Fish and Wildlife Service, US Forest Service, US Department of Agriculture, Washington State Department of Fish and Wildlife, Conservation Districts, and others to develop lasting partnerships.

1.8. Identify and work with local technical experts that can assist with technical river basin analysis.

2. Increase knowledge and understanding of wetlands and aquatic resources within a river basin.

2.1. Identify existing educational materials that can be used by residents.

2.2. Educate river basin residents and landowners about wetland restoration.

2.3.1. Work with private/business newsletters and other media (e.g., Wetnet, Washington State Grange News, Farm-City Forum television program, local radio programs) to get wetland restoration information to residents.

2.3.2. Work with local newsletter editors (e.g. city/county, tribal, Cooperative Extension, Conservation District, USDA Agricultural Stabilization and Conservation Service) to distribute restoration educational material.

2.3. Educate local jurisdictions/regulatory agencies about wetland restoration program and products.

2.4.1. Demonstrate how program information can be used to help local jurisdictions with regulatory and non-regulatory mandates such as community plans, GMA ordinances, mitigation banking, etc.

2.4. Educate community leaders about wetland restoration program and products.

2.5.1. Use presentations and information handouts to demonstrate how program information/data can be used by constituents.

2.5. Educate/train resident volunteers to assist with wetland restoration and monitoring.

3. Identify existing river basin goals, objectives, and strategies and incorporate into program process.

3.1. Compile established goals and objectives from existing plans and, where appropriate, incorporate into wetland restoration planning.

Lessons Learned in the Stillaguamish Basin

Program development in the Stillaguamish River Basin revealed three important keys to success. First, lasting partnerships must be developed with river basin residents, tribes, organizations, and jurisdictions. Second, the involvement of a respected Stillaguamish resident greatly facilitated partnership development. Third, the restoration of wetlands during program development established credibility and partnerships that could not be developed in other ways.

We quickly found that the terms “wetland” and “Department of Ecology” had negative connotations to many Stillaguamish River Basin residents due to the agency’s regulatory mandates. Working within a non-regulatory framework, we found that involvement with river basin residents meant: listening rather then telling, one-on-one contacts, being aware of landowner needs and concerns at all times, gaining mutual trust through open honest communication, and being creative and cost effective when trying to solve problems. Developing partnerships would not have been possible without active public participation and the direct involvement of a respected river basin resident. The hiring of Stillaguamish resident, Bill Blake, increased overall visibility of the program, established program credibility, allowed representation at all pertinent meetings or community functions, and opened lines of communication with landowners that were otherwise reluctant to work with outside government agencies.

Initially, substantial time was spent informing all interested groups, organizations, tribes, local jurisdictions, and individuals about the program, process, and anticipated products. It soon became obvious in the Stillaguamish Basin that certain groups or individuals needed to be directly involved with wetland restoration analysis and implementation. Involvement and guidance by staff of the Tulalip Tribes, Stillaguamish Tribe, Snohomish Conservation District, Snohomish County Surface Water Management, Washington State Department of Fish and Wildlife, the Stillaguamish Implementation Review Committee, the Stilly-Snohomish Fisheries Enhancement Task Force, and local natural resource experts was crucial to completing Step 1.

STEP 2: Identify river basin ecological problems and community needs.

Purpose

- To help direct and prioritize wetland restoration activities to sites which have the greatest potential to help solve ecological problems and community needs of importance to river basin residents.

Products

- A list of river basin specific ecological problems and community needs.
- A list of drainages and watersheds which have documented water quality and quantity parameters exceeding established local or state standards.

Process

1. Identify ecological problems that have been documented by technical field studies or monitoring programs.

1.1. Acquire available technical reports/data on surface water quality and quantity, fish and wildlife, and groundwater in the river basin.

1.1.1. Contact watershed advisory group(s), local jurisdictions, tribal natural resource departments, local Washington State Department of Fish and Wildlife staff, and others to access existing bibliographies or technical papers relating to natural resources and ecological problems in the river basin.

1.1.2. Conduct literature search of state library for river basin specific technical information.

1.2. Compile and summarize existing information regarding ecological problems from the technical literature.

1.3. Submit information compiled to all local interests for review and comment. Make revisions as needed.

2. Identify ecological problems and community needs of importance to residents of the river basin.

2.1. Conduct community needs assessment using existing data and public input.

2.1.1. Use watershed advisory group, local jurisdictions, tribes, and others to identify existing information on community needs within the river basin.

2.1.2. If existing information on community needs and values is limited, work directly with local interests to create list, or develop and distribute questionnaire to river basin residents which identifies ecological problems and community needs of importance to river basin residents. See Appendix H for sample questionnaire used in the Stillaquamish Basin.

2.1.3. Work with advisory group, local jurisdictions, tribes, and the public to ensure the list compiled reflects current needs and values of local residents.

2.2. Compile and summarize information regarding needs and values of river basin residents.

3. Combine information on ecological problems from the literature and community needs assessment and develop a list of ecological problems and community needs for the river basin.

Lessons Learned in the Stillaguamish Basin

Technical information was compiled to summarize the known location and extent of water quality and quantity problems in the Stillaguamish Basin. The Stillaguamish Implementation Review Committee, Stillaguamish Tribe, Tulalip Tribes, Snohomish County Surface Water Management, and Ecology provided important water quality data or served to identify the sources of data needed to complete this step. Qualitative data associated with flooding problems were compiled by the Stillaguamish Implementation Review Committee. From this data, a matrix was developed which summarizes the results of these studies by watershed or drainage within the Stillaguamish Basin. Water quality parameters which exceeded state standards were highlighted in the matrix as were areas having water quantity problems identified by the watershed advisory group.

While information exists to document water quality and quantity problems, no information was available which identified ecological problems and community needs of importance to residents of the Stillaguamish River Basin. A non-statistical survey was developed and distributed to approximately 250 residents throughout the river basin. This survey asked residents to identify ecological problems and community needs that were important to them or their business or livelihood. In addition to surveying residents, interviews were conducted with the Tulalip Tribes, Stillaguamish Tribe, Snohomish Conservation District, Snohomish County Surface Water Management, Washington State Department of Fish and Wildlife, and US Forest Service**.** These interviews with the resource management groups were used to ensure that their needs and concerns where reflected in the survey results.

Survey results indicated that residents of the Stillaguamish Basin were interested or concerned about a broad and diverse group of ecological problems and community needs. Survey results were used to produce a list of ecological problems and community needs of importance to residents in the Stillaguamish River Basin, while water quality and quantity data are being used to focus restoration activities on sites having the greatest opportunity to help solve identified problems.

STEP 3: Identify key wetland functions which address ecological problems and meet community needs.

Purpose

- To identify wetland functions capable of helping solve ecological problems and meeting community needs in the river basin.

Product

- A list of wetland functions which can help solve ecological problems and meet community needs existing in the river basin.

Process

1. Identify key wetland functions which can contribute to solving ecological problems and meeting community needs.

1.1. Review list of ecological problems and community needs compiled for the river basin.

1.2. Use best professional judgment to develop a draft list of wetland functions which are capable of addressing ecological problems and community needs of importance to river basin residents. See Appendix E for list of wetland functions/values which can be used as a starting point for list development.

1.3. Gain peer review of draft list by technical experts working in the river basin.

Lessons Learned in the Stillaguamish Basin

After the list of ecological problems and community needs was developed for the Stillaguamish Basin, best professional judgment was used to match each listed problem and need with an appropriate wetland function. This information was then presented to the interagency technical work team for review. A final list of target wetland functions was established. This list formed the basis for all function characterization models.

STEP 4: Compile existing river basin technical information and GIS data layers.

Purpose

- To access available technical information for methods development and GIS analysis.

Products

- A list of available GIS data sets for river basin analysis.
- A bibliography of available technical reports and literature for the river basin.

Process

1. Identify available technical reports and literature on river basin processes and resources that relate to wetlands and river basin function.

1.1. Contact local jurisdictions, tribes, watershed advisory groups, federal agencies with large land holdings, and organizations and groups involved with natural resource management in the river basin and request available bibliographies, source information, and GIS coverages for the following subjects:

- Surficial geology
- Groundwater recharge and movement
- Surface water hydrology and movement
- Precipitation data
- Land use/landcover
- Water quality
- Location of natural areas
- Historic aerial photos
- Soil surveys
- Topography data
- Transportation coverages
- Past and present finfish and shellfish information
- Sensitive, threatened, endangered, and priority species and habitats
- Floodplain management maps
- Wetland inventory data
- Wetland loss/threat data
- Peat resources data
- Stream data
- USGS quadrangle digital data
- Section/township/range digital data
- Digital Elevation Model data
- Major public lands coverage
- USGS point coverage of rivers, lakes, and schools

1.2. Conduct literature search of state library to identify additional technical information on the river basin.

2. Acquire available river basin technical information and GIS data layers.

Lessons Learned in the Stillaguamish Basin

The compilation of available literature and GIS data layers for the Stillaguamish River Basin took a substantial amount of time and energy. Accessing available data layers was a stumbling block at times as staff limitations at different data sources caused long delays between data request and receipt. Additional delays were experienced in compiling data coverages which were not anticipated at the start of methods development. We learned the value of requesting all possible GIS coverages very early in the process. Work with GIS coverages in the Stillaguamish also revealed that both the GIS technician and the person doing methods development and analysis must have access to a complete data dictionary for each data layer. Data dictionaries define the type and extent of data imbedded in the coverage and proved to be invaluable in the development of models for each wetland function.

While not available in the Stillaguamish Basin, many of the river basin advisory groups being formed by the Governor's Watershed Coordinating Council have compiled or are compiling existing GIS data sets for river basin applications. This type of interagency coordination will expedite wetland analysis procedures in river basins.

GIS data used in the Stillaguamish Basin include data layers for: river basin, watershed, and drainage boundaries, USGS 7.5 minute quadrangles, transportation, landuse/landcover, soils, surficial geology, digital elevation models, floodplain, streams and lakes, existing wetlands, potential wetlands, wildlife resources, fish resources, rare, threatened and endangered species, dikes and levies, groundwater resources, public ownership, and precipitation (rain-on-snow) data.

STEP 5: Customize GIS data layers and prepare for analysis.

Purpose

- To prepare GIS data sets for river basin characterization, wetland classification, and the characterization of wetland functions.

Products

- Customized GIS data layers for river basin characterization, wetland classification, and function characterization.

Process

1. Establish refined river basin and watershed boundaries.

1.1. Use Washington State Department of Natural Resources (DNR) hydro, Digital Elevation Model (DEM), USGS 7.5 minute quadrangles, and National Wetland Inventory (NWI) data to correct/refine Ecology WRIA boundary for the river basin as needed (see Appendix J for coverage documentation).

1.2. Use DNR hydro, DEM data, USGS 7.5 minute quadrangles, and NWI data to refine existing watershed (DNR Watershed Administrative Units) and drainage boundaries within the river basin (see Appendix J for coverage documentation).

2. Develop an existing wetland coverage.

2.1. Using local expertise, identify the most accurate digital stream data.

2.2. Using local expertise, identify the relative accuracy of available digital wetland polygon data sites. Available coverages may include NWI, Department of Fish and Wildlife, Priority Habitats and Species data, DNR Hydro data, U.S. Forest Service wetland inventory data, and local wetland inventories. Assign a rank priority order for each wetland inventory coverage (e.g., most accurate inventory - #1, next accurate - #2, etc.) (see Appendix J for coverage documentation).

2.3. Overlay all ranked wetland inventory coverages so that the highest ranking coverage is on top and the lowest ranking coverage is below all others. Define the location and extent of each wetland by using the polygon configuration of the highest ranking coverage which identifies the site. Sites which are identified on the top ranking coverage are defined by the polygon of that coverage. If a wetland exists on the second and third ranked coverage, but not on the top coverage, that wetland is defined by the polygon configuration of the second ranking coverage.

2.4. A composite existing wetland polygon coverage is then established and overlayed with arcs from the preferred stream coverage to form an existing surface water coverage.

3. Evaluate and, if necessary, modify floodplain boundaries.

3.1. Access available floodplain boundary data and gain input into data accuracy from local jurisdictions and floodplain management staff. If accuracy is acceptable using the best professional judgment of local floodplain authorities, use existing floodplain data layer.

3.2. If accuracy is not acceptable, correct floodplain boundary map using best professional judgment of floodplain management personnel and surficial geology data.

4. Develop a standardized hydric soils coverage.

4.1. Compile available soils data. If one soil survey is available for the entire river basin, no additional work is needed. When a Natural Resources Conservation Service (NRCS) soil survey covers a portion of the river basin and a US Forest Service (USFS) or National Parks Service (NPS) soil survey covers the remainder, soil survey data will need to be standardized and merged (see Appendix J for coverage documentation).

4.2. Using USDA Soil Conservation Service (1991) report titled “Hydric Soils of the State of Washington” and existing USDA soil survey data from the appropriate county soil survey, identify hydric soil mapping units which are considered “hydric soils with no upland soil inclusions” and “hydric soils with upland soil inclusions”. Create a GIS coverage which identifies the location and extent of all soil mapping units included in these two hydric soils groups. It is assumed that the majority of wetlands occur or had once occurred on soil mapping units which fall within these two hydric soil groups. Because analysis methods must focus on the areas that have the greatest potential to support wetlands, it is assumed that the two wettest hydric soil groups best meet this definition unless field experience or best professional judgment indicate otherwise.

4.3. When a separate soil survey is available for federal lands, examine the data for hydric soil designations comparable to those listed in USDA soil surveys and merge with NRCS hydric soils data. Unfortunately, past experience has shown that USFS soil surveys have little if any hydric soils data comparable to that of NRCS or DNR data on non-federal lands. To assign USDA NRCS hydric soil groupings to USFS or NPS soil surveys, a decision matrix is recommended. To develop this matrix, evaluate the data dictionary or published soil survey data for information that will help group soil units. When available, hydrologic grouping, and drainage class designation are beneficial. When available, overlay existing wetland inventory data on top of USFS soils data and identify the frequency of wetland occurrence and the proportion of total soil mapping unit area which supports wetlands for each inventory. Use best professional judgment to select Forest Service soil mapping units which meet hydric soil criteria. A matrix developed to identify hydric soils on Forest Service lands in the Nooksack Basin is presented in Appendix I.

4.4. All information and decision-making criteria is presented to the appropriate USFS or NPS soil scientists for review and final hydric soil grouping. Create final list of federal soil mapping units which fall within the two wettest USDA hydric soil groups.

4.5. Merge hydric soil data for non-federal lands with newly developed federal lands data and create a composite hydric soil data layer for the river basin.

5. Establish a surficial geology coverage.

5.1. Evaluate existing surficial geology data and digitize if not available in a digital format.

5.2. Where more then one data set exists and neither data set is inclusive, establish the most current data set as the base layer and add pertinent information from the other data sets.

6. Establish GIS coverage identifying the location of dikes and levies within the river basin.

6.1. Determine if digital or hard copy data on the location of dikes and levies is available from county or state floodplain management staff. When available, assess data and digitize if necessary.

6.2. When data is not available, compile hard copy data from Bortleson et al. (1980), USDA soil surveys, USGS 7.5 minute quadrangles, and other available data sources and create a custom composite dike/levy data layer.

7. Establish GIS coverage identifying the location of stream reaches that have extensive solar exposure.

7.1. Identify available data on the location of exposed stream reaches and digitize if necessary. Establish riparian data layer.

7.2. When information is not available or comprehensive, develop a custom data layer. Use current aerial photography of river basin to identify exposed stream reaches. Use landuse/landcover data layer and aerial photography to identify timber production areas and delete these areas from consideration. It is assumed that riparian areas managed for timber production have maintained timbered corridors or have been replanted if exposed during timber harvest. Transfer exposed stream reach information to a base DNR hydro layer and establish a riparian restoration coverage.

8. Establish GIS coverage which distinguishes timber production landuse from all other landuses (e.g., urban, industrial, agricultural, residential, open space) and identify watersheds and drainages having 30 percent or greater non-timber landuse.

8.1. Display landuse/landcover coverage.

8.2. Review coverage attribute dictionary and identify attributes which fall under timber production landuse and non-timber landuse.

8.3. Overlay landcover data onto the watershed/drainage boundary coverage.

8.4. Calculate the proportion of each watershed/drainage in non-forest production landuse.

8.5. Highlight watersheds/drainages which reach or exceed 30 percent non-timber production landuse.

Lessons Learned in the Stillaguamish Basin

Substantial time was spent trying to develop one comprehensive surface water base layer that contained stream, wetland, fish, and wildlife data from many existing layers. After many trials, it was determined that the subtle differences in data sets and problems associated with merging large sets of data precluded the efficient development of such a comprehensive base layer. With this determination made, analysis reverted to the use of basic overlays of large data sets as needed with discrepancies resolved using best professional judgment.

Sole source data layers were used as is. However, when more than one data set was available, the opportunity existed to create custom data layers. For example, the customized data layer used to identify existing wetlands was a compilation of wetland inventory data from USFWS National Wetland Inventory, Washington State Department of Fish and Wildlife Priority Habitats and Species, and DNR hydro data sets. In a similar manner, surficial geology information from two published sources was used to build a single GIS surficial geology layer. In both situations, multiple data sets existed which had useful information that the others did not have. In these examples, data sets were combined to produce a composite layer used in the analysis of Stillaguamish Basin wetlands. Conversely, some custom coverages were subsets of one layer. For example, a data layer was needed to display specific soil mapping units for analysis. In this example, organic hydric soils and soils mapping units characteristic of groundwater discharge sites were extracted from the soils layer and used as a separate layer for the analysis of several wetland functions.

STEP 6: Identify the location and extent of predisturbance wetlands using existing wetland inventory and soil survey data.

Purpose

- Establish the location and extent of potential wetland restoration sites.

Product

- A GIS coverage of potential wetland restoration sites with accompanying database.

Process

1. Identify all potential wetland sites. Assign a unique identification number and build a standardized database for each site.

1.1. Overlay the hydric soil coverage (representing potential wetland area) onto the surface water coverage (representing existing wetland area).

1.2. Establish the maximum potential extent of each wetland site by dissolving all interior polygons created when existing and potential wetland polygons are overlaid. In cases where a polygon exists in the surface water base layer but not in the hydric soil coverage, the hydric soil area is assumed to be identical to the existing wetland area.

1.3. Create a potential wetland coverage and assign an individual site number to each polygon.

1.4. Establish a standardized database for each potential wetland site in ArcInfo. At a minimum, the database should include the individual site number, HGM class and subclass, potential area, existing area, difference in area between potential and existing, and a column for each wetland function identified in Step 3.

Lessons Learned in the Stillaguamish Basin

To identify the maximum extent of predisturbance wetland area, the hydric soils coverage was overlaid with existing wetland inventory data and all interior polygons were removed. Data coverages used in the Stillaguamish Basin showed that while some alignment discrepancies were noted between hydric soils and wetland inventory coverages, the error was considered acceptable at this scale of analysis.

Over much of the river basin, the area of hydric soil consistently exceeded the area of existing wetland. This was expected, based on the extent of wetland degradation over the past 100 years. In some cases, the wetland inventory coverage identified a wetland which had no overlaying hydric soil area. In these cases it was assumed that the hydric soil area equaled the area of existing wetland.

STEP 7: Characterize the river basin to gain understanding of water movement, wetlands in the basin, and the processes which contribute to wetland formation and maintenance.

Purpose

- To gain understanding of how water flows through the river basin, both above and below ground.
- To gain understanding of where wetlands occur and why.
- To gain understanding of how wetlands contribute to overall river basin function.
- To gain understanding of how wetlands have been impacted by human activities.

Product

A general understanding of the movement of water through the river basin and the landscape scale features that influence it.

Process

1. Compile available information on surficial geology, hydrology, soils, geomorphology, and topography.

2. Gain understanding of how surficial geology, soils, and soil geomorphology influence the location of wetlands and how they function.

2.1. Review all available literature on surficial geology and soils for the river basin.

2.2. Gain understanding of the relationship between geology, soils, and soil development and how soils affect water movement, both horizontally and vertically. Access local geologists, soil scientists, and hydrologists to ensure that assumptions developed are valid for the river basin.

3. Gain understanding of surface and subsurface hydrology.

3.1. Review available surficial geology information for the river basin and gain an understanding of the influence of surficial geology on water movement, both above and below ground.

3.2. Review available groundwater information for the river basin and identify the location of groundwater aquifers and recharge areas and their relation to surficial geology features.

3.3. Overlay wetland and stream data onto the Digital Elevation Model (DEM) coverage and produce a map of river basin surface features. Gain understanding of surface features and their relation to wetlands and surface water movement. Access geologists and hydrologists to assure that assumptions developed are valid.

3.4. Overlay wetland and stream coverages onto the surficial geology layer. Gain understanding of the relationships between differing geologic features and subsurface water movement.

4. Gain understanding of past and present landuse practices, their impacts to water movement both above and below ground, and their impacts to wetlands and native aquatic plant communities.

4.1. Review available historic information and aerial photography to gain a general understanding of pre-European settlement vegetation conditions.

4.2. Use landuse data and current aerial photography to gain an understanding of the extent of vegetative change between pre-settlement and current conditions.

4.3. Review available information on impacts of landuse change on surface water runoff, subsurface flow, and groundwater recharge. Use surficial geology as a tool to gain understanding of direct and indirect landuse impacts to wetlands and water movement.

5. Gain understanding of where and why wetlands occur, how they have been impacted by humans, and how they contribute to watershed function.

5.1. Overlay wetland and stream data layers onto DEM and surficial geology coverages. Use surficial geology to gain an understanding of the relationship between geologic features and the presence or absence of wetland resources. Use DEM map to understand the distribution of wetlands throughout the river basin and their ties to other surface water resources (i.e., lakes and streams).

5.2. Overlay landuse data onto surficial geology and surface water coverages and gain an understanding of how landuse is affecting surface and subsurface water movement.

5.3. Overlay wetland information onto landuse data to help gain an understanding of general landuse impacts that have occurred, are occurring, or potentially will occur to wetlands in the future.

5.4. Overlay wetland and stream layers onto the DEM coverages to gain a perspective of wetland landscape position, connectivity to surface water streams, water flow pattern, and geographic relation to other wetlands.

Lessons Learned in the Stillaguamish Basin

Without question, this is the most critical step in river basin analysis. Unfortunately, this is also the step that has no defined boundaries, only limited guidelines, and requires a diverse background. This step requires creativity, perseverance, a detective-like attitude, and an ability and willingness to work in other scientific disciplines. If only one person is available to do this work, that person must develop a basic understanding of hydrology, geology, soils, geomorphology, groundwater movements and storage, river, lake, and wetland ecology, watershed processes, wetland functions, landuse, environmental indicators, and a broad enough vision to integrate them together at a river basin scale. Work in the Stillaguamish Basin clearly demonstrates that site specific activities require specialists, but river basin activities require a natural resource generalist. Access to specialists in the fields listed above are essential, but without an overall understanding of all of these disciplines by at least one person, it will be difficult to fit all the pieces together.

Each river basin is unique in the physical and biological processes affecting water and energy movement. Wetland classification and the characterization of wetland functions are tied closely to these processes. River basin characterization is essential to understanding these processes, how the system as a whole functions, and how existing river basin models can be adjusted to more closely fit the unique features of different basins.

If river basin characterization is, as suspected, the most critical step in basin analysis, then surficial geology is the most critical component of characterization. In the Stillaguamish Basin, it became obvious that an understanding of surficial geology and its affect on water movement was the foundation for any river basin characterization.

STEP 8: Stratify potential wetland sites using hydrogeomorphic features.

Purpose

- To increase efficiency in predicting potential functions each wetland is providing or has the potential to provide, if restored.

Products

- Map showing location and extent of potential wetlands and their potential hydrogeomorphic classification.
- Narrative characterization of each hydrogeomorphic wetland class and subclass.

Process

1. Define hydrogeomorphic wetland classes and subclasses.

1.1. Review "A Hydrogeomorphic Classification for Wetlands" by Brinson (1993) (HGM) and other more recent HGM literature or classification work. Ensure compatibility with regional HGM applications (Granger et al. 1996). HGM class definitions used in the Stillaguamish River Basin analysis are presented in Appendix K. These terms and their definitions will change as the development of regional HGM procedures progress.

1.2. Establish appropriate wetland classes and subclasses for the river basin based on current national and regional classification methods. Define each wetland class and subclass, when needed. Maintain consistency with current regional HGM definitions.

2. Stratify potential wetland resources within the river basin.

When classifying wetlands, it is imperative that each site be classified based on its physical features after restoration (predisturbance condition) rather than its current physical features. For example, a depressional wetland which had no surface water outlet has been drained. In its current condition, this wetland would be classified as a riverine open wetland. However, historically it functioned as a depressional closed wetland. To be most effective at predicting how a wetland will function after restoration, the site must be classified based on its anticipated physical features after restoration. Because the program seeks to restore natural functions of degraded sites, restoration efforts focus on reestablishing predisturbance physical features when possible.

2.1. Review data dictionaries for available GIS data sets to know what classification criteria are available via computer-based information. Wetland classification criteria of special interest include information which helps determine presence or absence of a surface water connection to a stream, retention time of water, the extent of tidal influence, the organic content of the soil, location within the floodplain, and the site's relation to deepwater habitats (see Appendix J for coverge documentation).

2.2. Compile aerial photography of the river basin. Stereo pairs are preferred but ortho photos under illuminated magnification can be used.

2.3. Use individual site numbering system developed in Step 5 to define total potential wetland population.

2.4. Use available GIS data sets to assign an HGM class and subclass to each potential wetland site.

Special Note*:* The methods presented here represent the original class designations presented by Brinson (1993). Revisions in this method (Brinson 1995) and refinements made by the Washington State Wetland Function Assessment Project dictate that future classification methods will differ from those presented here.

The following guidelines are presented in an ordered manner to facilitate wetland classification. As each potential wetland restoration site is assigned a class and subclass, enter the appropriate designation in the site database, and remove from further class consideration until all wetlands have been initially classified. This simplifies the classification process and eliminates potential for double classifying a site.

Use the following criteria as a starting point for classifying each potential wetland site:

Fringe Class - Overlay NWI data onto potential wetland site data. Select all lacustrine and estuarine systems. Also select sites classified by NWI as palustrine systems and having an unconsolidated bottom or open water class designation greater than 20 acres in size. Identify all aquatic bed, emergent, scrub-shrub, or forested wetlands adjacent to the open water portions of selected lacustrine, estuarine, and palustrine systems. These sites are fringe wetlands. Establish subclass using the following criteria:

> *Estuarine Fringe Subclass* - Wetlands in the fringe class which have plant composition influenced by tides and ocean saltwater. Use Bortleson et al. (1980), dike/levee location data, and local expertise to establish limits of existing estuarine fringe.
>
> *Lacustrine Fringe Subclass* - All remaining fringe wetlands.

Extensive Peat Class - Overlay soils data onto potential wetland site data and use GIS to select all sites which have a peat soil mapping unit. Identify sites listed in "Peat Resources of Washington" by Rigg (1958) and add them to this GIS data layer if not identified as having a peat soil mapping unit. These sites are extensive peat wetlands. Establish subclass using the following criteria:

Extensive Peat Open Subclass - Extensive peat wetlands having surface outflow to a stream system. Overlay stream data onto sites identified as extensive peat. Select sites which have a surface water outlet to a stream and classify as extensive peat open. DNR hydro data and WARIS stream data denoting anadromous fish to the site are two tools which can be used to determine if a surface water connection exists.

Extensive Peat Closed Subsystem - Extensive peat wetlands having no surface outflow to a stream system. All remaining extensive peat sites not coded as open, are classified extensive peat closed.

Depressional Open Subclass - Select all potential wetland polygons which have not received an initial wetland class and subclass designation. Identify all sites having a surface water connection to a stream by overlaying DNR stream data and WARIS anadromous fish access data onto selected polygons. Highlight all potential wetland sites intersected by a stream. Sites highlighted will fall in either the depressional open or riverine open class. From this subset, use the following criteria to identify depressional open wetlands:

a) Polygons classified as palustrine system and unconsolidated bottom class or lacustrine system within the NWI data set,

b) Polygons having a lake or shoreline boundary (DNR Hydro line 30) or uncoded polygons (DNR Hydro line 0) within the DNR hydro data layer,

c) Polygons having a lake designation (DNR water body type 421),

d) Polygons having a marsh designation (DNR water body type 111) and having DNR water body type 5-9 at inflow, and

e) Polygons with no stream inlet (on DNR hydro) and a DNR water body type 5 or 9 outlet. Code all sites depressional open which meet one of these criteria.

Riverine Open Subclass - Select all unclassified polygons which have been identified as having a surface water connection to a stream but did not meet depressional open criteria listed above. Code these sites riverine open.

Riverine Closed Subclass - Select remaining unclassified polygons. Overlay floodplain boundary coverage onto these polygons and reselect sites located within the floodplain. Code these sites riverine closed.

Depressional Closed Subclass - Select all remaining sites occurring outside the floodplain and code all sites depressional closed.

Slope Class - No procedures were identified which were capable of identifying slope wetlands using river basin scale GIS tools.

2.5. Use aerial photography and GIS data sets to verify or refute initial potential HGM class designation. Areas of greatest potential for change include:

Depressional open wetlands - Overlay the potential wetland site coverage with stream data onto the landuse/landcover data layer. Highlight all sites classified as depressional open. Using NWI data, highlight all depressional open sites which have been identified as partially drained, diked, or impounded and determine how the situation has affected classification. Using available aerial photography under magnification, evaluate all depressional open site to support or refute the initial determination. Identify sites initially classified as depressional open but which have a well defined channel through the wetland. Use landscape position and best professional judgment to determine if this channel was formed naturally (i.e., riverine open wetland) or if the channel or ditch was the result of human alteration. Sites which display natural riverine open features should be reclassified accordingly. Sites displaying partially drained conditions resulting from human alteration should remain in the depressional open subclass.

Depressional closed wetlands - Overlay the potential wetland site coverage with stream data onto a topography coverage. Highlight all depressional closed sites. Using NWI data, highlight all depressional closed sites which have been identified as partially drained, diked, or impounded and determine how this alteration has affected classification. Using available aerial photography under magnification, evaluate all depressional closed sites to support or refute the initial determination. Identify sites having a surface water connection. Sites having a naturally occurring surface water connection should be reclassified to depressional open class. Sites having a surface water connection resulting from human alteration should remain in the depressional closed class.

Riverine open wetlands - Overlay the potential wetland site coverage with stream data onto the landuse/landcover data layer. Highlight all sites classified as riverine open. Using NWI data, highlight all riverine open sites which have been identified as partially drained, diked, or impounded and determine how this alteration has affected classification. Using available aerial photography under magnification, evaluate all riverine open sites to support or refute the initial determination. Identify riverine open sites having no well defined channel through the wetland or a channel or ditch resulting from human alteration. Sites which display clear depressional open features (i.e., no well defined natural channel) should be reclassified accordingly. Sites displaying riverine open conditions resulting from human alteration should be reclassified as riverine closed if within the floodplain and depressional closed if outside the floodplain.

Riverine closed wetlands - Overlay the potential wetland site coverage with stream data onto the topography data layer. Highlight all riverine closed sites. Using NWI data, highlight all riverine closed sites which have been identified as partially drained, diked, or impounded and determine how this alteration has affected classification.. Using available aerial photography under magnification, evaluate all riverine closed sites to support or refute the initial determination. Identify sites having a surface water connection. Sites having a naturally occurring surface water connection should be reclassified to riverine open class. Sites having a surface water connection resulting from human alteration should remain in the riverine closed class.

Fringe and extensive peat wetlands - These wetland classes have limited opportunity for changes in classification due to their unique physical features. Use methods described above to verify or refute a surface water connection to each site.

2.6. Assign a final potential HGM wetland class and subclass to each potential wetland site.

3. Characterize each HGM wetland class and subclass.

3.1. Using established HGM class and subclass definitions, develop a short narrative that characterizes each class and subclass using the following information when appropriate:

- Landscape position, hydrologic source, hydrodynamics,
- Extent of distribution,
- Proportion of total wetlands,
- General land use,
- Type and extent of alteration/loss, and
- Description of past and present conditions.

Lessons Learned in the Stillaguamish Basin

Wetland stratification or classification is not an end product but rather a means of more rapidly facilitating the characterization of wetland functions. In the Stillaguamish Basin, the original five wetland classes developed by Brinson (1993) (riverine, depressional, slope/flat, fringe, and extensive peat) were adapted for the Stillaguamish Basin and its classification needs. Since this initial work, the original five wetland classes have been expanded to six (Brinson 1995). Future river basin analysis should incorporate the newest available national guidance on HGM classification and preferably the Pacific Northwest regional HGM work currently underway by the Washington State Function Assessment Project (Granger et al. 1996).

Substantial time was spent developing and evaluating GIS procedures for classifying existing and potential wetlands in the Stillaguamish Basin. The following were crucial points learned:

1) Know what data you have to work with. The up-front, extensive review of each GIS data dictionary and available imbedded data is essential before developing a strategy to classify wetlands. In the Stillaguamish Basin it became clear that both the project manager and the GIS technician needed to know this information to plan and implement a strategy for classifying wetlands.

2) Refine process through an iterative procedure of trial and evaluation based on field experience and best professional judgment. Use field experience and best professional judgment to make final class determinations relating to water permanence of the wetland. This is a key factor in determining if a wetland falls within the riverine open or depressional open class. In the Stillaguamish, information from aerial photography and best professional judgment were used to change 10-20 percent of all potential wetland sites initially classified by GIS analysis.

3) Finally, the products derived from this procedure are only as good as the data used in the analysis. In the Stillaguamish Basin, field experience and best professional judgment indicate that most wetlands have some form of surface water connection to a stream which would put them in an open subclass. However, because of the scale of available GIS data, many non-perennial surface water connections are missed. This error in the existing data results in a number of sites being incorrectly classified as either depressional closed or riverine closed. Arieal photography is an essential tool to minimize errors in GIS-based classification.

STEP 9: Establish and assign risk-based priorities to watersheds/drainages for each wetland function, when appropriate.

Purpose

- To target restoration sites which have potential to provide a specific function in watersheds and drainages which have the greatest need for that function.

Product

- A list of primary and secondary target watersheds and drainages for each appropriate wetland function.

Process

1. Establish watershed or drainage boundaries for risk-based assessment.

1.1. At a minimum, use DNR Watershed Administrative Unit (WAU) boundaries to define area of risk-based assessment.

1.2. Compile all water quality and quantity studies conducted within the river basin. Identify watersheds and drainages which have water quality or quantity data. When data exists at a drainage scale, subdivide the watershed into drainages to accommodate this information. This is necessary only when data indicate that water quality or quantity standards are exceeded in only a portion of the watershed.

2. Determine which wetland functions allow targeted restoration activities within subunits of the river basin.

2.1. Use best professional judgment to determine which wetland functions allow for the targeting of key watersheds and drainages and which require evaluation of the entire river basin. If some watersheds or drainages are experiencing specific problems (e.g., elevated fecal coliforms or nutrient levels) while others are not, then the wetland function associated with the problem is a candidate for this risk-based assessment. Other wetland functions, such as migratory bird habitat, flood storage/desynchronization, recreation, or outdoor education will require restoration to occur throughout the entire river basin to address a problem. In these cases, subdividing the river basin is not necessary or desirable. Develop list of wetland functions which allows the targeting of specific watersheds or drainages at risk and another list of functions which require the entire river basin to be targeted.

3. Identify primary target areas for each wetland function determined to benefit from risk-based river basin subdivision. A primary target area is defined as a watershed or drainage having docu-mented water quality or quantity problems associated with a specific wetland function. Each wetland function will have a specified group of primary watersheds and drainages that will be used to prioritize restoration activities.

3.1. Use existing water quality studies to identify watersheds and drainages which have water quality parameters that exceed state water quality standards.

3.2. Use existing published reports, watershed advisory groups, and local jurisdictions to identify watersheds and drainages which have documented flooding and/or low flow problems.

3.3. Summarize findings for each water quality/quantity parameter by compiling a table of watersheds and drainages having documented problems. Correlate each problem with the appropriate wetland function and establish a list of primary target watersheds and drainages for each wetland function.

4. Identify secondary target areas for each water quality and quantity parameter. A secondary target area is defined as a watershed or drainage which does not have documented problems for a specific water quality or quantity parameter but which has high potential for future problems due to geomorphic features and landuse change.

4.1. Use understanding gained during river basin characterization and available technical information for each water quality and quantity parameter to identify the major causes of degradation for each parameter.

4.2. Use characterization information, local expertise, and best professional judgment to establish where major causes of water quality/quantity degradation have the greatest potential to occur in the future. Identify the watersheds and drainages considered susceptible to future degradation and designate them as secondary target areas.

5. Identify tertiary watersheds and drainages for each water quality and quantity parameter. A tertiary target area is defined as a watershed or drainage which has no documented water quality or quantity problem and little if any potential for the problem to develop in the future due to ownership, landuse trends, and watershed characterization. All watersheds or drainages not meeting primary or secondary criteria are considered to be tertiary.

Lessons Learned in the Stillaguamish Basin

To be most effective at helping to solve problems and meet needs, restoration activities must be targeted to specific wetland functions that address identified problems. For example, to help address high stream temperatures in the Stillaguamish Basin, wetland restoration must focus first on the primary watersheds and drainages which have documented temperature problems. To a lesser extent, efforts should also focus on secondary watersheds and drainages which have potential for problems in the future. This means restoration work to improve high stream temperatures must focus on watersheds such as Pilchuck Creek where temperature problems are documented rather than Squire Creek watershed where no temperature problems exist and where there is little potential for this problem to occur in the future.

STEP 10: Characterize wetland potential for providing key functions.

Purpose

- To identify wetland and riparian restoration sites which have potential to contribute to solving river basin problems and meeting community needs.
- To assess each restoration sites potential to restore key functions.

Products

- A list of sites which have the greatest potential to provide each wetland function.
- A customized model for characterizing each wetland function at a river basin scale.

Process

1. Customize most current function characterization models to meet target river basin needs.

1.1. Compare the list of wetland functions compiled in Step 3 with the existing list of models developed for function characterization. If all target functions have models developed, proceed to 1.2. If one or more target functions lack a preexisting model, models must be developed.

1.2. Use information gained from watershed characterization, wetland classification, existing function characterization methods, and best professional judgment to customize existing function characterization models or develop new ones.

1.2. Distribute most current function characterization models to a diverse group of local wetland experts, hydrologists, geologists, and fisheries and wildlife biologists working in the river basin for review and comment. Make revisions to models based on comments received.

2. Run each model and produce a list of wetland restoration sites which have the greatest potential to provide that function.

2.1. Complete procedures specified in each function characterization model. Sites found to have the greatest potential to provide each function are designated as such in each sites individual database within ArcInfo.

2.2. Use best professional judgment to evaluate if the sites identified in each function characterization procedure are logical and proper. Adjust methods as needed.

3. Use most current ArcInfo and mirrored Microsoft Access database models or create a customized database which facilitates the use of the analysis data by local jurisdictions, tribes, organizations, and individuals interested in restoring wetlands in the river basin.

3.1. Evaluate existing database for applicability in current river basin.

3.2. Make database modifications as needed to satisfy all anticipated applications.

3.3. Download site specific ArcInfo data into the mirrored Access database.

Lessons Learned in the Stillaguamish Basin

Foundational knowledge gained through river basin characterization proved to be instrumental in the development of each model for characterizing a wetlands opportunity and effectiveness to provide a particular wetland function.

A combination of best available literature, past experience, local expertise, and common sense were used to develop the function characterization models for the Stillaguamish Basin. Model development using this available literature, experience, expertise, and common sense has been received favorably at presentations to a diverse group of professionals and nonprofessionals. However, in the Stillaguamish Basin, model refinement has been limited by the time constraints of key peer reviewers. Understanding this limitation, the models are proving to be a logical technically-based procedure that people can understand, relate to, and agree with.

Based on key physical and biological factors affecting water processes, the methods developed for function characterization in the Stillaguamish Basin are believed to have relevance to other Puget Sound river basins. Models developing in the Stillaguamish Basin will be used as a starting template for model development in other river basins.

STEP 11: Assess restoration potential of identified sites and establish a qualitative rank for each function.

Purposes

- To screen wetland sites for restoration potential based on existing GIS data and individual site knowledge.
- To provide a rank order which can be used to prioritize wetland and riparian restoration activities.

Products

- A list of wetland sites which have potential for wetland or riparian restoration.
- A ranked list of potential wetland and riparian restoration sites for each wetland function.

Process

1. Score wetland sites for potential to increase wetland area and performance.

1.1. Using individual site data from GIS database, identify all potential wetland restoration sites having an existing wetland area that is 90 percent or more of the potential wetland area. Designate these sites as potential preservation sites and remove from further restoration consideration.

Rationale: It is assumed that the increase in wetland function gained through restoration is directly proportional to the increase in wetland area. Sites having limited potential for a gain in wetland area are assumed to have a limited potential to measurably improve an ecological problem. It is assumed that sites having an existing area of 90 percent or more of potential area should be considered for preservation rather than restoration measures.

1.2. Establish a potential score for each remaining wetland restoration site using the following equation:

Potential Score = (.25)(Existing Area) + (Potential Area - Existing Area)

An example is provided in the following table. In this example, five hypothetical wetland sites are ranked based on the established criteria above.

Site Number	Potential Area	Existing Area	Difference in Area	Potential Score
H1053	29 ac.	27 ac.	2 ac.	Preservation Site
H1054	6 ac.	1 ac.	5 ac.	5.25
H1055	100 ac.	10 ac.	90 ac.	92.5
H1056	3 ac.	2 ac.	1 ac.	1.5
H1057	36 ac.	24 ac.	12 ac.	18

Rationale: The potential score equation was developed to emphasize the potential gain in wetland area through restoration. However, experience has shown that restoration has the potential to also improve how the existing wetland area will function. For this reason, the equation was developed to recognize the potential gain in function from the existing wetland area while emphasizing the gain in wetland area and ultimately wetland function.

2. Establish a rank order for each potential wetland restoration site by Function.

2.1. Select all sites which are capable of performing Function 1.

2.2. Review results from Step 9 to determine if Function 1 has only primary watersheds/drainages or primary and secondary watersheds/drainages.

When the function to be ranked has only primary watersheds/drainages, all restoration sites which have potential to provide this function are ranked by potential score in descending order. A rank number of 1 is assigned to the site having the largest potential score.

When the function to be ranked has both primary and secondary watersheds/drainages, all restoration sites which have potential to provide this function are first grouped into primary and secondary watersheds/drainages. Tertiary watersheds are not considered. All sites within primary watersheds/ drainages are arranged in descending order of potential score. A rank score of 1 is assigned to the site having the largest potential score, a rank score of 2 is assigned to the site having the second largest potential score, and so on. All sites within secondary watersheds/drainages are then arranged in descending order of potential score like those of primary watersheds/drainages. The site having the largest potential score within secondary watersheds/drainages receives the next rank score below the lowest scoring site in a primary watershed/drainage, and so on.

Rationale: The rationale for this relates back to the goal of helping solve problems and meet needs. It is assumed that wetlands that are restored in watersheds having documented problems (primary watersheds) have the only potential to help solve those problems. The restoration of sites in secondary watersheds can only help prevent problems from occurring in the future. To meet this program goal, restoration efforts must first focus where problems are known to exist in the river basin.

2.3. After all sites capable of providing Function 1 have received a rank score, rank scores are added to the ArcInfo and Access databases.

2.4. Rank sites for all remaining wetland functions and add each function rank score to the site ArcInfo and Access databases.

3. Rank riparian sites for potential to increase riparian area and performance.

3.1. Use GIS to establish a distance figure for each exposed riparian reach. This distance measure will serve as the potential score.

3.2. Review results from Step 9 to determine which functions have primary and secondary watersheds/drainages.

When the function to be ranked has only primary watersheds/drainages, all riparian reaches which have potential to provide this function are ranked by potential score in descending order. A rank number of 1 is assigned to the site having the largest potential score.

When the function to be ranked has both primary and secondary watersheds/drainages, all riparian reaches which have potential to provide this function are first grouped into primary and secondary watersheds/drainages. Tertiary watersheds are not considered. All reaches within primary watersheds/drainages are arranged in descending order of potential score. A rank score of 1 is assigned to the reach having the largest potential score, a rank score of 2 is assigned to the reach having the second largest potential score, and so on. All reaches within secondary watersheds/drainages are then arranged in descending order of potential score like those of primary watersheds/drainages. The reach having the largest potential score within secondary watersheds/drainages receives the next rank score below the lowest scoring reach in a primary watershed/drainage, and so on.

Rationale: The rationale for this relates back to the goal of helping solve problems and meet needs. It is assumed that riparian reaches restored in watersheds having documented problems (primary watersheds) have the only potential to help solve those problems. The restoration of riparian reaches in secondary watersheds can only help prevent problems from occurring in the future. To meet this program goal, restoration efforts must first focus where problems are known to exist in the river basin.

3.3. After all reaches capable of providing Function 1 have received a rank score, rank scores are added to the ArcInfo and Access databases.

3.4. Rank sites for all remaining functions which seek to restore riparian habitat and add each function rank score to the ArcInfo and Access databases.

Documentation for ArcInfo database development is presented in Appendix L.

Lessons Learned in the Stillaguamish Basin

The Stillaguamish experience clearly shows that when work is done at a river basin scale, the certainty of site specific field work is replaced by uncertainty resulting from the introduction of multiple error factors. At a river basin scale, one must recognize and accept the fact that we are working with probabilities rather than certainty. For example, wetland classification identifies sites having physical and biological features that have the greatest probability of falling within a specific class definition; function characterization identifies sites having the greatest probability of providing a certain function; and now the assessment of restoration potential identifies sites having the greatest probability for significant wetland gain. This approach creates problems for many technical people who are trained to always work with exact site-specific data.

Assessing wetland restoration potential at a river basin scale is an oversimplified process of comparing existing wetland area to potential hydric soil area. The difference in potential and existing wetland areas is assumed to equate to the maximum wetland gain through restoration. Field experience has shown that existing wetland inventory data is, at times, inadequate at identifying wetlands under a forest canopy. This error can result in a smaller existing wetland area and an accompanying overestimation of wetland restoration potential. This uncertainty is unavoidable when working at this scale with data sets that always have an error factor associated with them.

Proper perspective is essential. Our past experience with site specific evaluations has resulted in demands for certainty, appropriately so. However, working with probabilities appears to be a necessity when working at a river basin scale. The key concept here is to recognize that site specific evaluation and river basin evaluation are two separate tools for two separate purposes rather than two tools competing for the same task. Our assumption is that we can accept a loss in accuracy when looking at hundreds of potential restoration sites, if the procedure allows us to more precisely focus detailed work on a few sites which have the highest potential to provide a target function.

To be effective at identifying wetland and riparian restoration sites which have the greatest opportunity to help solve ecological problems or meet community needs in a river basin, it is logical that you first must target areas where problems are known to exist. The simple ranking system developed in the Stillaguamish Basin relies on the assumption that more wetland area restoring is better for each function. We know this is not always the case, as in the example of amphibian habitat. However, in general it is believed that the larger the wetland area restored, the greater the opportunity to see measurable improvement in system function. While the rankings are presented as one way to prioritize restoration activities, the database provides opportunities for local jurisdictions, tribes, and others to develop their own ranking system based on their own priority criteria.

STEP 12: Interpret and integrate findings.

Purposes

- To integrate information and understanding gained through watershed analysis into products useful for project implementation.
- To facilitate use of the wetland restoration site database by local jurisdictions, tribes, and others interested in the restoration of wetlands.

Products

- A database of potential wetland restoration sites with functions for distribution to all interested in identifying and restoring wetlands and riparian areas.
- GIS data layers produced during river basin and function characterization work.
- Technical support for integrating findings into local jurisdiction, tribal, and conservation organization planning efforts to protect and restore wetlands and riparian areas.

Process

1. Develop database for managing potential wetland and riparian restoration site data.

1.1. Use existing database template for potential wetland and riparian restoration sites or evaluate and modify database format developed from past river basin analysis efforts. Database must be capable of allowing the user to identify sites by wetland functions provided, area gained through restoration, watershed status (primary or secondary), rank by function, and HGM subclass. Documentation for existing Microsoft Access database template is presented in Appendix M.

1.2. Test and evaluate ease of use. Make database revisions as needed.

2. Distribute technical information to local jurisdictions, tribes, conservation districts, and others in the river basin.

1.1. Compile list of GIS data layers developed during the analysis process.

1.2. Identify which local jurisdictions, tribes, and organizations have ArcView or ArcInfo capabilities and distribute GIS data layers when appropriate.

1.3. Distribute Microsoft Access database to all non-GIS users accompanied by a set of 7.5 minutes maps of the river basin showing the location and extent of each potential restoration site in the database.

3. Provide support for the integration of technical information into local and regional planning efforts.

3.1. Make staff available to ensure that wetland management planning efforts by federal and state agencies, tribes, local jurisdictions, conservation districts, and others have and use technical products produced during river basin analysis.

Lessons Learned in the Stillaguamish Basin

Two databases were developed for the Stillaguamish River Basin. The first is an ArcInfo database with information on individual wetland and riparian restoration sites for use by those with ArcView or ArcInfo GIS capabilities. The second is a Microsoft Access database which mirrors the ArcInfo database but allows access to data by non-ArcView users.

Database development is time consuming and rigorous. The database developed for the Stillaguamish Basin will be used in future analysis efforts.

The distribution and application of these databases to individuals, organizations, and agencies is essential to the success of this program. At the time this document was written, data transfer and technical support with local jurisdictions, tribes, and other interested organizations and individuals was just beginning. However, interest in the Stillaguamish databases and associated GIS data layers has been positive.

STEP 13: Coordinate/facilitate the restoration of wetlands.

Purpose

- Ensure that river basin residents and natural resource managers have the best available technical information to restore wetlands which contribute to problem resolution in the river basin.

Products

- Working relationships with natural resource agencies, local jurisdictions, technical people, tribes, and landowners regarding wetland restoration analysis and tools.
- Local wetland restoration facilitators within the river basin which empower residents, capture opportunities, and encourage/promote restoration activities at a grassroots level.

Process

1. Establish, maintain, and nurture open communication and cooperation with local jurisdictions, tribes, and private organizations.

1.1. Become involved with watershed advisory groups and others which manage or impact wetland resources.

1.1.1. Help identify opportunities to restore wetlands and provide technical support on wetland restoration issues.

1.1.2. Share information and GIS data.

1.2. Keep all interested local jurisdictions, tribes, conservation districts, and organizations informed and involved in river basin analysis and wetland restoration planning.

1.2.1. Provide briefings and informal updates on program status and products.

1.3. Involve all willing participants in wetland restoration program activities.

2. Inform, involve, and empower representatives for local, state, and federal natural resource agencies to restore wetlands.

3.1. Inform of watershed analysis methods, distribute the wetland restoration database, and provide adequate training to all interested local, state, and federal agencies involved with wetland restoration in the river basin.

3.2. When funding is available, provide small grants to key stakeholder groups, which allow staff to use the database to identify and contact landowners having wetland restoration sites, which rank high for functions which they choose to target.

3.3. Encourage local government staff to facilitate wetland restoration at a grassroots level.

3.4. Encourage and involve all interested agencies in wetland restoration projects.

Lessons Learned in the Stillaguamish Basin

Work in the Stillaguamish Basin has clearly shown that local natural resource managers are the right people to discuss wetland restoration opportunities with private landowners. A familiar face from a respected local agency or organization is essential to any nonregulatory program. In Stillaguamish Basin, the Snohomish Conservation District, Snohomish County Surface Water Management, the Stillaguamish and Tulalip Tribes, local Washington State Department of Fish and Wildlife staff, and the Stilly-Snohomish Fisheries Enhancement Task Force are in contact with private landowners on a daily basis and are most suited to work directly with landowners. While the program must develop trust and credibility with landowners, local staff are the best people to contact private landowners about wetland restoration opportunities.

Good communication and cooperation have equated to wetland restoration projects in the Stillaguamish Basin. The Stillaguamish Implementation Review Committee and the conservation district, county, tribes, and local organizations have been supportive of program efforts and have become equal partners in ongoing efforts to restore wetlands in the river basin. One restoration project called Tributary 80 has received funding and/or technical support from ten different agencies, groups, or individuals. Even more impressive is the fact that different people took charge of different parts of the project that fell within their area of expertise. This partnering allows projects to be considered that would otherwise not be possible without this diverse technical and financial support.

Every effort is being made to ensure that those who want information, receive it. The wetland restoration site database and all custom GIS data layers are being provided at no charge to those involved with wetland restoration and resource management in the Stillaguamish Basin.

STEP 14: Evaluate program and prepare documents.

Purpose

- Provide a feedback step capable of recognizing when program or project adjustments need to be made.
- Provide a means to evaluate individual wetland restoration projects to assure anticipated functional gains are actually being realized.
- Provide a means for technical peer review of methods.

Products

- Recommendations for improving process and procedures.

Process

1. Record and track program activities/expenditures.

1.1. Record steps taken, methods used, and rationale for methods required to implement the restoration plan within a river basin.

1.2. Monitor major project expenditures.

2. Evaluate effectiveness of program implementation in the river basin and make recommendations to enhance program efficiency.

2.1. Evaluate methods used to identify wetland restoration sites and the functions they will provide.

2.1.1. Distribute case study report for peer review.

2.1.2. Include recommendations for methods improvement in the case study document.

2.2. Evaluate program effectiveness at communicating with and involving local jurisdictions, local staff of state agencies, tribes, and private organizations in the river basin.

2.2.1. Contact key persons with each local jurisdiction, agency, tribe, and organization and ask them how the program could be more effective at informing and involving them in wetland restoration.

2.3. Make corrections to program methods as needed.

3. Evaluate effectiveness of methods to identify potential wetland restoration sites which help solve problems and meet needs within the river basin.

3.1. Work with local tribes and resource management agencies and organizations to conduct site specific function assessment of potential restoration sites after being restored, to evaluate the predictive accuracy of function characterization models.

4. Prepare case study report to document methods used and results produced.

4.1. Identify what works and what doesn't and communicate it to others.

Lessons Learned in the Stillaguamish Basin

Steps taken, methods developed, and rationale for methods used in the Stillaguamish Basin are presented in this document. Evaluation and tracking of program implementation was of reduced importance in the Stillaguamish Basin because of our need to develop procedural methods. Program implementation in subsequent river basins will track relative costs and time commitments to ensure procedures specified here are efficient and effective. Further, as river basins are analyzed and wetlands restored, there is a great need to document what wetland functions each site is providing as a means of verifying the function characterization models. This will require that working relationships be maintained and nurtured for all analyzed river basins.

A case study document for the Stillaguamish River Basin is being written.

Part III: Function Characterization Models

Function 1
Temperature Maintenance

Introduction

Within selected watersheds, abnormally high seasonal water temperatures can limit a stream's overall habitat value for fish and wildlife. High water temperatures also increase unionized ammonia concentrations and contribute to low dissolved oxygen levels by increasing plant growth and respiration rates (Creager et al. 1993). Weather, streamflow, streamside vegetation, groundwater inputs, and water releases from industrial plants (Thornburgh 1993) are factors known to influence stream temperature. Increases in temperature can effect fish survival/mortality, increase metabolic activity, provide conditions for the growth of disease-causing organisms and undesirable algae, and lower dissolved oxygen (Thornburgh 1993). Solar heating is recognized as a critical stressor which effects stream water temperature (Creager et al. 1993).

Wetlands can play a role in maintaining desirable temperatures in streams. In summer, groundwater discharge wetlands help maintain cool water temperatures suitable for year-round use by anadromous and resident fish. In winter, wetlands receiving substantial groundwater discharge maintain ice-free conditions required by wintering waterfowl. Riparian areas serve an important role in shading the stream from direct solar heating.

Goal

Restore wetlands and reparian areas which have the greatest potential to help reestablish and maintain desirable stream temperatures for fish and wildlife.

Objectives

- Target restoration efforts to watersheds which have known water temperature problems.
- Identify native riparian corridors which shade stream reaches and wetlands exposed to solar heating.
- Identify wetlands which receive groundwater discharge and release it to a stream either through surface or subsurface flows.
- Identify wetlands which recharge aquifers discharging water to a stream.
- Identify headwater wetlands which maintain base flows during summer low flows.

Assumptions

- Greatest opportunities for using wetland restoration to help improve water temperature conditions occur where degradation results from piecemeal activities over time rather than from one or more large mass wasting events.
- Wetlands are not capable of capturing and retaining adequate sediments during and after a large mass wasting event to help minimize adverse impacts to water temperature.
- Bottomland and depressional areas with seasonally high water table can generate substantial amounts of saturated overland flow (Dinicola 1990).
- When comparing vegetated and unvegetated wetlands, measurements during sunny summer days showed plant shading resulted in 2-4° C cooler surface water temperatures at midday (Tanner et al. 1995)
- Groundwater influx can have an important depressing effect on stream temperature. This effect will depend on the rate of groundwater influx relative to the volume of flow in the stream, and on the groundwater temperature compared to the mean stream temperature (Adams and Sullivan 1989).
- Custer-Norma soil units occur on nearly flat areas and have high water tables that can generate saturated overland flow (Dinicola 1990).
- Subsurface flow is the predominant runoff mechanism from undisturbed glacial till on hillslopes. Disturbance of glacial till on hillslopes increases the likelihood of generating Horton overland flows (Dinicola 1990).
- The largest base-flow indexes were obtained for streams draining permeable unconsolidated glacial and alluvial sediments in parts of the lowlands adjacent to Puget Sound (Hidaka 1973).
- The smallest indexes were computed for streams draining areas underlain by relatively impermeable igneous, sedimentary, and metamorphic rocks or by relatively impermeable glacial till (Hidaka 1973).
- Periods of low stream flow are usually the most critical factor in relation to instream water use, such as fish propagation. During low flows, the stream is more susceptible to rises in temperature and to a higher degree of pollution from industrial, municipal, and agricultural wastes (Hidaka 1973).
- By restoring historic water holding capacity of headwater wetlands, water will be stored longer and will have increased potential to contribute to stream flow during low flow periods.
- Increased base flow can dampen water temperature increases.
- Low flows of low-altitude streams occur during late summer. Minimum flows of these streams are dependent largely upon groundwater effluent as almost all the winter precipitation falls as rain and no snow or ice is stored for summer runoff. The extent to which groundwater supports streamflow is a function of the amount of groundwater in

storage and the rate of movement toward surface streams. High altitude may cause low flow periods to occur both during the summer and winter depending on the amount of runoff coming from snow melt. Streams with winter low-flow periods drain basins sustained by melt water from glaciers and perennial snowfields (Hidaka 1973).

- The lack of glaciers in some Puget Sound basins provide little melt water during low flow season. Larger low flow indexes for some drainages can be attributed to their fairly large areas of highly permeable recessional outwash and the abundance of precipitation over the basins. The small low-flow index for some drainages may be due to the smaller amount of precipitation and the low permeability of the consolidated sedimentary rocks that underlie most of the basin. Creeks draining lowlands underlain by glacial till can be expected to have small low-flow yield indexes (Hidaka 1973).
- Forest practices may influence stream temperature by reducing riparian shading of the stream due to harvest or debris torrents (Washington Forest Practices Board 1993).
- Stream temperature can both warm up and cool down along its course due to the amount of shade provided by tree canopy closure (Sullivan et al. 1990).
- Based on study results, total stream shading of 50-75 percent after cutting is needed to maintain water temperature in most streams within water quality standards. However, because the importance of shade varies with elevation, a shading guideline based on elevation of the site is recommended (Sullivan et al. 1990).
- By the time a free-flowing stream has traveled 1000 feet or more under relatively uniform canopy closure, water temperatures will be in equilibrium with local environmental conditions (Sullivan et al. 1990).
- The physical changes imposed by urban development on the landscape result in a decline in function of aquatic systems. Marked degradation occurs at about 8-10 percent impervious area with almost no exceptions on either side of that value. Within western Washington, approximately 10 percent impervious area in a watershed typically yields demonstrable, and probably irreversible, loss of aquatic-system function (Booth and Reinelt 1994).
- Four environmental variables primarily regulate heat input and output from the stream environment, and thereby determine stream temperature under any given solar loading. These are: riparian canopy, stream depth, local air temperature, and groundwater inflow (Sullivan et al. 1990).
- Moving from headwaters downstream, groundwater inflow decreases in importance compared to the volume of flow already in the channel in larger rivers (Sullivan et al. 1990).
- Non-fish-bearing Type 3-4 tributaries contributing 20 percent of the flow to fish-bearing Type 1-3 waters will significantly influence water temperature (Caldwell et al. 1991).
- At elevations above 3600 feet in western Washington, environmental conditions are such that streams are not likely to exceed water quality standards for maximum temperature (Sullivan et al. 1990).

- Riparian shade is unlikely to have a significant influence on stream temperatures where the natural low flow stream width exceeds 100 feet (Sullivan et al. 1990).
- Logging prescriptions identified during Timber/Fish/Wildlife watershed analysis will minimize impacts of commercial timber harvest on stream temperature.
- Watersheds having greater than 30 percent of area in non-forest uses are at substantial risk of water temperature increases in the future.
- Wetlands with watersheds in which more than 40 percent of the landcover is urban were significantly more likely to have reduced amphibian richness than an undisturbed watershed (Richter and Azous 1995).
- A 60 percent level of impervious area in a one-square mile drainage can increase the mean annual peak discharge by a factor of three (Stockdale 1991).
- Precipitation that falls on the land surface will flow over it, remain ponded in depressions, and/or infiltrate into the subsurface. The relative distribution of water involved in each of these processes depends on the slope and permeability of the land surface. In areas of steep uniform slope and high permeability, the water that does infiltrate and that is not transpired will move downgradient in the subsurface and discharge in the lowlands near streams or lakes (Winter 1988).
- In most environments, only minimal quantities of water percolate through the unsaturated zone to recharge groundwater during the growing season. Large quantities of water will percolate past the root zone if the water uptake capacities of the plants are met during extended rainy periods, or during the nongrowing season. In areas with high precipitation and where soil water does not freeze [such as parts of western Washington], groundwater recharge is high, beginning in the fall after plants become dormant (Winter 1988).
- One principle conclusion from numerical modeling of generalized settings is that recharge commonly is localized where thickness of the unsaturated zone is small relative to contiguous points of the landscape. Assuming the water table is relatively flat and the land surface is hummocky, the areas of minimal thickness of the unsaturated zone occur directly adjacent to surface water or at depressions in the landscape [i.e., wetlands]. The actual volume of recharge at a depression will be variable in space, depending on the size of the depression, permeability of the soil, and amount and type of vegetation that may transpire the water before it percolates past the root zone (Winter 1988).
- Detrimental effects of altering recharge are caused by removal of water. Increasing the efficiency of water removal from areas of flat slope by ditching reduces recharge to groundwater. Not only is less water available because of drainage, but the resulting lowered water table reduces the hydraulic head that provides the driving force for recharge. If a depressional wetland that recharges groundwater is drained, the recharge function is lost. If a recharge wetland is adjacent to a groundwater flow-through or groundwater discharge wetland, these adjacent wetlands will receive less groundwater inflow (Winter 1988).
- The impact of wetland drainage on regional flow systems is not as great as it is for local flow systems. For upland areas, some of the water that seeps from recharge wetlands

serves as recharge to regional flow systems. Whether or not the recharge point shifts from one local depression to another in uplands makes little difference to the total regional recharge process (Winter 1988).

- Wetlands on till tend to occupy higher elevations, and as a result are often linked to the headwaters of streams. This juxtaposition of wetlands with streams and permeable materials associates them with aquifers and raises the potential for moderating streamflow (O'Brien 1988).
- Freeze and Witherspoon have indicated that in small aquifers where the water table is near the surface, the recharge area tends to be large in proportion to the discharge area. Therefore, a wetland that overlies a discharge area is in a position to exercise considerable control over groundwater discharge (O'Brien 1988).
- Groundwater discharge has been shown to be important to streamflow in several studies. Groundwater levels may be particularly critical to streamflow in some areas as researchers have shown that a small decline in groundwater level can lead to a cessation of streamflow (O'Brien 1988).
- The alteration of wetlands can have a direct effect on groundwater (O'Brien 1988).
- Wetlands perched above the main zone of saturation are commonly in a position to recharge the regional aquifer, whereas those in contact with the major groundwater zone generally serve as a discharge area for the regional aquifer (O'Brien 1988).
- A wetland which has an organic mat containing a highly permeable upper peat layer, might contribute significantly to streamflow but be highly sensitive to changes in groundwater levels, whereas an organic mat with an overall low hydraulic conductivity (common with muck) might have very different effects on streamflow (O'Brien 1988).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to help reestablish and maintain desirable stream temperatures for fish and wildlife.***

Objective 1: ***Target restoration efforts to watersheds which have known water temperature problems.***

Strategy 1.1: Identify watersheds to be targeted for water temperature attenuation. Primary target watersheds are streams or stream reaches having documented temperature readings which exceed state or local water quality standards. Secondary target watersheds are streams or stream reaches which lack documentation of elevated temperatures but have the greatest potential for problems due to developmental impacts. Tertiary target watersheds are all other streams.

Rationale: Restoration activities should focus on areas of greatest need. The 30 percent landuse alteration criteria used to define secondary watersheds is subjective in nature and based in part on work by Booth and Reinelt (1994), Rickter and Azous (1995), and Stockdale (1991).

Strategy 1.2: Identify stream reaches having elevated temperatures resulting from large mass wasting events. Delete these watersheds from list developed in Strategy 1.1.

Rationale: In general, the greatest opportunities to use wetland restoration to help improve temperature conditions occur where degradation results from piece-meal activities over time rather than from one or more large mass wasting events. An example of piece-meal degradation is the agricultural and residential impacts to Portage Creek, Stillaguamish Basin. An example of a large mass wasting event is Deer Creek, Stillaguamish Basin. Large mass wasting events rapidly overload a stream's capability to naturally handle sediment inputs. The result is a stream system that looks and functions differently for many decades. It is assumed that wetlands are not capable of capturing and retaining adequate sediments during and after a large mass wasting event to help reduce adverse impacts to water temperature.

Procedure:

1. *Identify primary watersheds having known temperature problems from a search of the technical literature and subsequent review by local technical experts.*

2. *Identify watersheds/drainages not having existing temperature problems. Use landuse/landcover layer to calculate which of these watersheds/drainages have greater than 30 percent of their area in non-forest uses. Use knowledge gained from river basin characterization to identify watersheds or drainages which do not meet the 30 percent non-forest criteria but have substantial landcover change and geologic features which increase the areas vulnerable to elevated stream temperature.*

3. *Compile information from Steps 1 and 2 and establish a GIS coverage which highlights primary and secondary watersheds for this function.*

4. *From the coverage developed in Step 3, delete watersheds/drainages from consideration which have temperature problems resulting primarily from major mass wasting events.*

5. *Finalize data layer identifying primary and secondary watersheds/drainages for temperature maintenance.*

Product:

A list of primary and secondary watersheds/drainages where wetland or riparian restoration has the greatest potential to help address temperature problems.

Objective 2: Identify native riparian corridors and wetland buffers which shade stream reaches and wetlands exposed to solar heating.

Strategy 2.1: Identify stream reaches not having a predominant scrub-shrub or forested vegetation class and target for restoration. Delete stream reaches from consideration that occur above 3600 feet in elevation or within timber production areas.

Rationale: Stream reaches exposed to solar heating can elevate water temperatures (Creager et al. 1993). At elevations above 3600 feet in western Washington, environmental conditions are such that streams are not likely to exceed water quality standards for maximum temperature (Sullivan et al. 1990). Logging prescriptions identified during Timber/Fish/Wildlife watershed analysis will minimize impacts of commercial timber harvest on stream temperature.

Strategy 2.2: Identify riverine open and depressional open wetlands which had a forest or shrub canopy prior to disturbance but which are now exposed to solar radiation due to clearing or other human alteration.

Rationale: Riverine open and depressional open wetlands discharge directly into adjacent streams. Elevated water temperatures caused by solar heating of wetlands can contribute to elevated stream temperatures.

Procedure:

1. *Overlay landuse/landcover data onto the potential wetland and DNR stream data. Using aerial photography under magnification, identify exposed stream reaches below 3600 feet in elevation and associated with non-timber landuses.*

2. *Establish a data layer of exposed riparian stream reaches and assign each a unique site number. Reach identification numbers (e.g., R1637) should be discernible from numbers assigned to potential wetland restoration sites (e.g., H0108).*

3. *Overlay riparian reach data onto a data layer highlighting primary and secondary watersheds/drainages for this function. Code riparian reaches within primary and secondary watersheds/drainages F1=2. Select riparian reaches occurring outside of primary and secondary watersheds/drainages, code F1=0, and delete from consideration.*

4. *Select all potential wetland restoration sites classified as riverine open or depressional open within primary and secondary watersheds. Reselect sites classified as Palustrine Emergent (PEM) from the NWI data and code F1=2.*

5. *Overlay landuse/landcover coverage onto sites identified in Step 4. Using available aerial photography, landuse/landcover data, and best professional judgment, identify F1=2 sites and determine which were palustrine emergent systems prior to any human disturbance and recode F1=0.*

6. *When multiple wetland inventories are used to develop the existing wetland coverage, identify existing wetlands which were not mapped by NWI. Use aerial photography, landuse/landcover, and best professional judgment to determine sites with forested or shrub canopies that have been altered by human landuse and code F1=2.*

Product:

A list of riparian and wetland restoration sites which have the greatest potential for maintaining or reestablishing acceptable stream temperatures through surface water shading.

Objective 3: Identify wetlands which receive groundwater discharge and release it to a stream either through surface or subsurface flows.

Strategy 3.1: Identify predisturbance wetlands having significant groundwater inputs to their water budget. The following criteria can be used:

a) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and having hydric soil mapping units which are known to occur at groundwater discharge sites (see soil survey data).

b) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and occurring on alluvium at the toe of escarpments which border outwash areas or within alluvial plains having escarpments.

c) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and having evidence of spring/seep areas where groundwater discharge is occurring (see surficial geology and topography maps).

d) Gain information from local hydrologists, geologists, and ecologists regarding local landscape features which consistently denote groundwater discharge areas.

Rationale: Riverine open, depressional open, and extensive peat open wetlands have a direct hydrologic connection to streams. In a predisturbance condition, many of these wetlands stored groundwater discharge under a forested canopy and slowly released it to streams throughout the summer months. Many riverine open, depressional open, and extensive peat open wetlands adjacent to streams have been drained. Drainage facilitates the rapid removal of surface water and reduces water storage for release during the warm, dry late summer/fall months when elevated water temperatures can be a problem. Custer-Norma soil units occur on nearly flat areas and have high water tables that can generate saturated overland flow (Dinicola 1990). Field work within the Stillaguamish basin indicates that groundwater discharge regularly occurs at the toe of escarpments on both younger and older alluvium. Physical evidence of groundwater discharge is needed where other criteria are not met.

Strategy 3.2: When available, use site specific temperature models to evaluate which sites identified in Strategy 3.1 have the greatest potential for improving stream temperatures.

Procedure:

1. *Review county soil survey data and gain input from local soil scientists. Identify hydric soils areas which are characteristic of groundwater discharge areas.*

2. *Select and highlight potential wetlands classified as riverine open, depressional open, and extensive peat open within primary and secondary watersheds/drainages.*

3. *Overlay soil mapping units identified in Step 1 onto polygons selected in Step 2. Identify the polygons having soil mapping units characteristic of groundwater discharge areas.*

4. *Use best professional judgment to select those sites having an adequate groundwater discharge area to support this function. Code sites selected F1=3. All other sites remain F1=0.*

5. *Overlay digital elevation model data, surficial geology, and potential wetland site data. Identify escarpments which border alluvium or outwash. Then select potential wetland sites which lie adjacent to these escarpments and code F1=3.*

6. *Identify potential wetland sites selected in Step 2 and having a function code of F1=0. Use field work, local experts, and other available information to identify potential wetland sites which are known to receive groundwater from springs and seeps. Code these sites F1=3.*

Product:

A list of potential wetland restoration sites which have the greatest potential for storing and releasing groundwater to a stream during base flow summer conditions.

Objective 4: Identify wetlands which recharge aquifers discharging water to a stream.

Strategy 4.1: Identify areas of highest surficial recharge potential. Then identify areas on outwash and alluvium adjacent to target streams which discharge groundwater as springs and seeps into the stream (F1=3). Finally, identify potential wetland sites within areas of highest recharge potential which have opportunity to support groundwater discharge wetlands that help maintain low stream temperatures.

Rationale: The extent to which groundwater supports streamflow is a function of the amount of groundwater in storage and the rate of movement toward surface streams. Wetlands occurring on, or adjacent to, groundwater recharge areas retain water for extended periods of time, allowing maximum groundwater recharge potential. Conversely, drained wetlands which historically recharged groundwater aquifers have greatly diminished retention time and reduced recharge potential.

Strategy 4.2: Use the following criteria to evaluate which potential restoration sites within groundwater recharge areas have the greatest potential to recharge groundwater aquifers:

a) A high proportion of the wetlands water budget comes from channel flow, overland runoff, or precipitation;

b) Extended water retention times;

c) Wetland is located near an escarpment where both the topography and groundwater table slope sharply downward from the wetland; and

d) Presence of a constricted surface water outlet or no outlet.

Rationale: Selected groundwater recharge criterion were taken from Marble (1990). Wetlands which retain water for extended periods of time allow for maximum groundwater recharge potential. Conversely, drained wetlands which historically recharged groundwater aquifers have greatly diminished retention time and reduced recharge potential.

Strategy 4.3: When available, use site specific temperature models to evaluate which sites identified in Strategy 4.1 have the greatest potential for improving stream temperatures.

Procedure:

1. *Compile existing groundwater resource data for the river basin and identify areas of highest surficial recharge potential. If specific data is not available for the river basin, use surficial geology and digital elevation model data to identify areas of non-tidally influenced alluvium, recessional outwash, and advance outwash.*

2. *Identify areas of greatest groundwater recharge potential within primary and secondary watersheds/drainages. Overlay potential wetland site data on data compiled in Step 1 and select all sites which occur on areas of high groundwater recharge potential. Reselect all sites which are coded F1=0. Code these sites F1=4.*

3. *Select sites coded F1=4. Overlay hydric soil layer which highlights soils characteristic of groundwater discharge. Identify potential sites having groundwater discharge soils and recode F1=0. In cases where the site has groundwater discharge soils over only a portion of the site, use best professional judgment to determine potential for groundwater recharge and code accordingly.*

4. *Select sites coded F1=4. Reselect riverine open wetlands and examine for evidence of a constricted outlet. Use best professional judgment to select riverine open sites having no constricted outlet and recode F1=0.*

Product:

A list of potential wetland restoration sites having the greatest potential to recharge groundwater aquifers supporting groundwater discharge wetlands which, in turn, help maintain stream flow and temperature.

Objective 5: Identify headwater wetlands which maintain base flows during summer low flows.

Strategy 5.1: Identify depressional open and extensive peat open potential wetland sites located at or near the headwaters of streams that were capable of storing water for release during summer low flows.

Rationale: Maintaining adequate base flow is an important factor in maintaining acceptable summer water temperatures. Hidaka (1973) notes that during low flows, streams are more susceptible to rises in temperature. Increased base flow can dampen water temperature increases.

Procedure:

1. *Select depressional open and extensive peat open potential wetland sites occurring within primary and secondary watersheds/drainages. Overlay these sites onto DNR stream coverage and select sites having an outflow but no inflow and having a headwater landscape position. Code these sites F1=5.*

2. *Identify depressional open and extensive peat sites having an inlet and outlet and use best professional judgment to identify sites having the greatest potential to store and release water during base flow conditions. Evaluation criteria should*

include the location of wetland in relation to stream initiation, water source using surficial geology and soils, and water permanence. Aerial photographs can be used to assist in making this determination. Code sites selected F1=5.

Product:

A list of potential wetland restoration sites having the greatest potential to increase stream base flows during low flow periods.

Objective 6: Evaluate all sites for coding consistency.

Strategy 6.1: Ensure that all selected potential wetland and riparian restoration sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands and riparian areas are restored within primary and secondary watersheds/drainages.

Strategy 6.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F1>0. Highlight sites coded F1=2, F1=3, F1=4, and F1=5 by assigning each a different polygon/arc color. All sites coded F1=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F1 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products

- A list of watersheds/drainages where wetland restoration has the greatest potential to help address temperature problems.
- A list of riparian and wetland restoration sites which have the greatest potential for helping maintain acceptable temperatures.

- A list of potential wetland restoration sites which have the greatest potential for moderating stream temperatures during base flow summer conditions.
- A list of potential wetland restoration sites having the greatest potential to recharge groundwater aquifers that support groundwater discharge wetlands that, in turn, help maintain stream flow and temperature.
- A list of potential wetland restoration sites having the greatest potential to increase stream base flows during low flow periods.

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Function 2
<u>Fecal Coliform Control</u>

Introduction

Pathogenic members of a large group of intestinal bacteria can pose a substantial health risk to humans (LaLiberte and Grimes 1982). Intestinal bacteria come from human and animal waste. Fecal coliform bacteria (*Escherichia coli*) is used as a general indicator of the presence of this group of bacteria. Control of these bacteria in aquatic systems maintains human health and safety through direct water contact, and allows the use of shellfish for domestic use and commercial production. Primary sources of bacteria include septic tank failure, poor pasture management and animal keeping practices from commercial and noncommercial livestock keepers, city sewage, pet wastes, urban runoff, and sewage from stormwater overflows.

Wetlands can play a role in retaining and destroying fecal coliform bacteria. Wetland location and water source are key factors in determining what opportunity a particular wetland has to perform this function. Riparian areas also serve an important role by buffering streams from direct fecal coliform inputs.

Goal

Restore wetlands and riparian areas which have the greatest potential to reduce fecal coliform levels in rivers and estuaries.

Objectives

- Target restoration efforts to watersheds which have known or anticipated fecal coliform problems.
- Identify wetlands which have the greatest potential to retain and destroy fecal coliform bacteria.
- Identify riparian areas which serve to buffer streams from fecal coliform inputs.

Assumptions

- Fecal coliform bacteria occur naturally in all watersheds. Sources of bacteria include mammals such as elk, deer, and beaver, marine mammals, and migratory birds. Beyond these background levels, primary sources of fecal coliform bacteria are associated with residential development (septic system failures, sewage treatment, urban runoff) and agriculture (poor pasture/livestock waste management).
- Undisturbed riparian vegetation serves as a filter/buffer strip to protect streams from direct fecal coliform inputs.

- It is estimated that cattle excrete approximately 5,428,000,000 fecal coliforms per cow per day (URS Company 1977).
- Bacteria are stored on or near the surface of the land and are influenced by slurry spreading, stocking density, and other management considerations and by decay controlled largely by the microhabitat at the site. Bacteria from this store are transferred to a second store associated with the river channel. McDonald et al. (1982) showed that a ten-fold elevation in fecal coliform levels could be induced in a stream without runoff of any sort simply by releasing water from an upstream reservoir.
- Sediments provide substrate for fecal coliform bacteria and allow them to survive and perhaps reproduce.
- Watersheds having greater than 30 percent of area in non-timber uses are at substantial risk of increased fecal coliform inputs in the future.
- Constructed wetlands operating at nominal retention times between two and seven days show considerable potential for the removal of fecal coliform levels from dairy farm wastewaters after pretreatment in oxidation ponds (Tanner et al. 1995).
- The closer the fecal coliform source is to shellfish beds, the greater the potential risk of elevated fecal coliform levels in shellfish.
- On sites where dairy or other nonpoint pollution exists, it is important to determine the maximum expected mass loading prior to wetland restoration or creation to ensure the site is large enough to treat anticipated waste flows (Hammer 1994).
- To treat wastewater with wetlands, primary treatment should be provided by a single- or multi-stage lagoon system or settling basin capable of a 50 percent reduction of organic load (BOD5) and suspended solids (TSS) (Hammer 1992).
- Equations from Hammer (1992) can be used to compute the minimum wetland size to treat a specific waste load. To estimate organic load (BOD5) for dairy cattle, multiple the number of stock by 773 grams and convert to kilograms. Add an additional 20 percent for waste hay or other feed. This estimates the total organic load generated per day. To determine the effective treatment area needed, divide the daily organic load by 100 to derive the answer in hectares (Hammer 1992).
- Increased fecal coliform counts occurring in the immediate vicinity of maintenance dredging was attributed to the disturbance and relocation of bottom sediments and a concomitant release of sediment-bound fecal coliforms (Grimes 1975).
- Native microfloral competition/antagonism (including bacterial predation) and protozoan predation are major biotic factors influencing fecal coliforms and fecal streptococci survivals (Marino and Gannon 1991).
- The longer undesirable bacteria are exposed to bacterial predators, the greater the chance for bacterial control.
- The role of the protozoa in eradication of the coliform from the muck was indicated by a sixfold increase in the protozoan population in natural soil amended with E. coli. Higher

organic matter content in a Histosol compared with a mineral soil resulted in an increased survival of the fecal coliforms (Tate 1978).

- The ability of *E. coli* to survive for several days in aquatic sediment in situ suggests that fecal coliforms in water may not always indicate recent fecal contamination of that water, but rather resuspension of viable sediment-bound bacteria (LaLiberte and Grimes 1982).
- The practice of confining livestock in smaller areas to improve production efficiency concentrates animal waste loading with subsequent runoff to nearby streams. Concurrent removal of riparian vegetation to increase available acreage, as well as vegetation depletion by livestock grazing and loafing activities, has eliminated the buffer strip that formerly protected streams from direct pollution (Hammer et al. 1993).
- Buffers can be effective at controlling fecal coliform inputs into wetlands and stream surface waters. In a review of the literature, (Castelle et al. 1992) presented the results of a fecal coliform reduction model for dairy waste management developed by Grismer in 1981 and applied to the Tillamook basin in northwestern Oregon. The model considered the effects of precipitation, season, method of waste storage and application, die-off of the bacteria in storage, die-off of the bacteria on the land surface, infiltration of bacteria in the soil profile, soil characteristics, overland transport of bacteria through runoff, and buffer zones. Grismer's model suggested that a 98-foot “clean grass” strip would reduce the concentration of fecal coliform by 60 percent.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to reduce fecal coliform levels in rivers and estuaries.***

Objective 1: Target restoration efforts to watersheds having known or anticipated fecal coliform problems.

Strategy 1.1: Identify watersheds to be targeted for fecal coliform control efforts. Primary target watersheds are streams or stream reaches having fecal coliform levels which exceed state or local water quality standards. Secondary target watersheds are streams or stream reaches which do not exceed water quality standards for fecal coliform but have the greatest potential for future problems due to agricultural and residential development. Tertiary watersheds are all others.

Rationale: Restoration activities should focus on areas of greatest need.

Strategy 1.2: Identify locations of significant contributors of fecal coliform bacteria from county health departments, Washington State Department of Ecology, and other sources.

Rationale: Known sources of elevated fecal coliform bacteria should be targeted first.

Procedure:

1. Identify primary watersheds having known fecal coliform problems from a search of the technical literature and subsequent review by local technical experts.

2. Identify watersheds/drainages not having existing fecal coliform problems. Use landuse/landcover layer to calculate which of these watersheds/drainages have greater than 30 percent of their area in non-forest uses. Use knowledge gained from river basin characterization to identify additional watersheds or drainages which do not meet the 30 percent non-forest criteria but which have substantial landcover charge and geologic features that increase the risk of fecal coliform inputs to surface water.

3. Compile information from Steps 1 and 2 and establish a coverage highlighting primary and secondary watersheds for this function.

4. Finalize data layer which identifies primary and secondary watersheds/drainages for the fecal coliform control function.

Product:

A list of primary and secondary watersheds/drainages having the greatest need for fecal coliform control.

Objective 2: Identify wetlands which have the greatest potential to retain and destroy fecal coliform bacteria.

Strategy 2.1: Identify potential wetland restoration sites which have the greatest opportunity to receive bacteria inputs. Use the landuse/landcover coverage and aerial photography to identify potential wetland restoration sites whose dominant land use surrounding or upstream of the wetland is residential or agricultural.

Rationale: Sources of fecal coliform bacteria are primarily associated with residential development (septic system failures, sewage treatment, urban runoff) and agriculture (poor pasture/livestock waste management). For a wetland to have the potential to perform this function, elevated levels of fecal coliforms must be entering the site.

Strategy 2.2: Identify wetlands which maximize surface water retention times. Use aerial photography and soils data to identify historic water retention capability of the site compared to existing conditions. Key factors include: presence of a constricted outlet or the absence of a defined channel through the wetland.

Rationale: Native microfloral competition/antagonism (including bacterial predation) and protozoan predation are major biotic factors influencing fecal coliforms and fecal streptococci survivals (Marino and Gannon 1991). It is assumed that longer exposure times of bacterial predators to undesirable bacteria will result in better control of the bacteria.

Strategy 2.3: Identify wetlands having physical and chemical features which maximize effectiveness at destroying bacteria. Use soils, landuse/landcover, and other GIS data layers to identify favorable existing or potential conditions. Key factors include the presence of mineral soils and the lack of sediment disturbance.

Rationale: Increased organic matter content in a Histosol compared with a mineral soil resulted in an increased survival of the fecal coliforms (Tate 1978). Studies have shown that coliform bacteria can survive for several days in aquatic sediment and that a resuspension of sediments can mean a resuspension of viable sediment-bound bacteria (LaLiberte and Grimes 1982).

Strategy 2.4: Target wetland restoration sites which have an extended (minimum two day) retention time.

Rationale: Constructed wetlands operating at nominal retention times between two and seven days show considerable potential for the removal of fecal coliform levels from dairy farm wastewaters after pretreatment in oxidation ponds (Tanner et al. 1995).

Strategy 2.5: When possible, identify each site's fecal coliform bacteria source and evaluate if the restoration site is of adequate size to treat anticipated organic loading rates using equations established by Hammer (1992).

Rationale: On sites where dairy or other nonpoint pollution wastewater exists, it is important to determine the maximum expected mass loading of organics prior to wetland restoration or creation to ensure the site is large enough to treat anticipated waste flows (Hammer 1994).

Procedure:

1. *Select potential wetland sites classified as depressional open, depressional closed, riverine closed, and fringe wetlands within primary and secondary watersheds/drainages.*

2. *Overlay landuse/landcover data layer onto sites identified in Step 1. Use landuse/landcover data layer and aerial photography under magnification to select sites which lie adjacent to or down stream from agricultural or residential development. Code sites selected F2=2.*

3. *Using available soils data, identify organic and groundwater discharge soil mapping units within the river basin.*

4. *Select all sites coded F2=2. Overlay these sites with soils data which highlights organic and groundwater discharge soil mapping units. Use best professional judgment to delete sites having organic soils or minimal surface water inputs. Recode sites with these features F2=0.*

5. *Use best professional judgment to estimate water retention time and delete sites from consideration that have less than a two day retention time.*

6. *Use best professional judgment to estimate the minimum wetland size needed to handle maximum expected mass loading associated with animal waste management, and delete sites from consideration that do not meet the minimum size.*

Product:

A list of wetland restoration sites which have the greatest potential for retaining and destroying harmful bacteria.

Objective 3: Identify native riparian corridors which buffer streams from direct fecal coliform inputs.

Strategy 3.1: Identify stream reaches within primary and secondary watersheds which do not have a scrub-shrub or forested riparian corridor adjacent to agricultural or residential landuse.

Rationale: Undisturbed riparian vegetation serves as a filter/buffer strip to protect streams from direct fecal coliform inputs. Modeling indicates that a 98-foot “clean grass” strip would reduce the concentration of fecal coliform from dairy waste by 60 percent (Castelle et al. 1992).

Procedure:

1. *Using aerial photography under magnification, identify exposed stream reaches within primary and secondary watersheds/drainages.*

2. *Overlay landuse/landcover data layer onto sites identified in Step 1. Use landuse/landcover data layer and aerial photography under magnification to select sites which lie adjacent to agricultural or residential development. Code sites selected F2=3.*

Product:

A list of riparian reaches which have the greatest potential to buffer streams from direct fecal coliform inputs if restored.

Objective 4: Evaluate all sites for coding consistency.

Strategy 4.1: Ensure that all selected potential wetland and riparian restoration sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands and riparian areas are restored within primary and secondary watersheds/drainages.

Strategy 4.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F2>0. Highlight sites coded F2=2 and F2=3 by assigning each a different polygon/arc color. All sites coded F2=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F2 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products

- A list of watersheds/drainages having the greatest need for fecal coliform control.
- A list of potential wetland restoration sites which have the greatest potential for retaining and destroying harmful bacteria.
- A list of riparian reaches which have the greatest potential to buffer streams from direct fecal coliform inputs if restored.

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Function 3
Sediment Retention/Transformation

Introduction

Suspended sediments which exceed natural background levels can reduce stream channel capacity, serve as a transport mechanism for bacteria and pollutants, fill gravel spaces which smother eggs and juvenile fish, lower overall productivity by reducing algae growth, reduce fish feeding and growth, lower dissolved oxygen, and bury benthic organisms (Stockdale 1991). Human factors which have been shown to increase suspended sediments include timber harvest and related road development, construction-related clearing and grading, poor pasture management, dikes, and the loss of large organic debris which results in reduced in-channel sediment storage capacity.

Wetlands can play a role in reducing the amount of suspended sediments in streams. Some wetlands capture and retain sediments prior to reaching a stream while others capture sediments that have entered a stream system.

Goal

Restore wetlands which have the greatest potential to help capture and retain sediments adversely impacting natural stream functions.

Objectives

- Target restoration efforts to watersheds which have known sediment retention problems.
- Identify wetlands which capture sediments before they enter streams.
- Identify wetlands which remove suspended sediments in stream systems.
- Create wetlands which remove suspended sediments from surface sheet or stream flows.

Assumptions

- The principle factor affecting a wetland's ability to trap sediments is the change in the velocity or energy level of incoming water. Decreased water velocity results in sediment deposition (Marble 1990).
- The greatest opportunities to restore wetlands which help reduce sediment inputs to streams occur where degradation results from piece-meal activities over time rather than one or more large mass wasting events.
- Roads represent the greatest risk to riparian and aquatic systems when compared to timber harvest activities. Timber harvest has been shown to increase rates of mass

movement several fold, while road construction can increase the rates of landsliding from 30-350 fold (Forest Ecosystem Management Assessment Team 1993).

- Natural erosional processes, timber harvest and related road systems, construction-related clearing and grading, and poor pasture management are primary sources of stream sediments (Stillaguamish Implementation Review Committee, pers. comm.).
- Depressional closed and riverine closed wetland classes have physical features which reduce water velocity and maximize potential for sediment retention. Drainage converts closed wetlands to open systems and reduces the capture and retention capabilities of the wetland.
- The greatest potential for addressing increased sedimentation/turbidity occurs when closed systems are restored within non-forested areas experiencing increased sedimentation and overland flows.
- A wetland's ability to retain sediments and reduce turbidity over the long-term is greatly compromised by large mass wasting events where a huge volume of material is entering a stream system.
- Estuarine fringe, lacustrine fringe, depressional open and riverine open wetland classes have the physical features and opportunity to remove sediments that are being transported by a flowing stream.
- Watersheds having greater than 30 percent of area in non-timber uses are at increased risk of having elevated sediment/turbidity inputs in the future.
- A wetland's ability to retain water for long periods of time is determined by the following physical and biological factors: a) a constricted outlet or no outlet, b) a gentle wetland gradient, c) dense wetland vegetation which slows water velocity, forces water to flow through a longer course, retaining water longer, and discouraging resuspension of bottom sediments, d) a long duration and extent of seasonal flooding allowing for greater retention times, and e) shallow water depth (Marble 1990).
- Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff (Roth et al. 1993).
- A substantial portion of increases in sediment/turbidity are the result of soil disturbance from agricultural and residential development and timber harvest.
- Increased sediment/turbidity from timber harvest must be addressed at the source. These issues are being addressed in part through forest practice regulations.
- Minimal fetch or exposure to wind reduces the chance for resuspension. Estuarine (flocculation of clays), palustrine, and lacustrine (basin shaped) wetlands offer good sediment trapping capability. Riverine wetlands are more likely to carry more sediments and not serve as traps (Marble 1990).
- It is important for the water source of the wetland to be generated principally from surface runoff, the principle source of sediment laden water (Marble 1990). Wetland inputs must have a sediment source to function in this capacity.

Procedure For Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to help capture and retain sediments adversely impacting natural stream functions.***

Objective 1: Target restoration efforts to watersheds which have known sediment retention problems.

Strategy 1.1: Identify watersheds to be targeted for sediment retention. Primary target watersheds are streams or stream reaches which have recognized sediment/turbidity problems. Secondary target watersheds are streams or stream reaches which lack documentation of sediment/turbidity problems but have the greatest potential for problems in the future due to developmental impacts.

Rationale: Restoration activities should focus on areas of greatest need.

Strategy 1.2: Evaluate causes of sediment problems in each watershed and assess the ability of wetland restoration efforts to address those problems.

Rationale: In general, the greatest opportunities to restore wetlands which help reduce sediment inputs to streams occur where degradation results from piece-meal activities over time rather than one or more large mass wasting events. Large mass wasting events caused by timber harvest practices and unstable geologic formations introduce huge sediment inputs into streams. The result is a stream system that looks and functions differently for many years. Under these conditions, it is assumed that a wetland's ability to perform this function over the long-term is greatly compromised by the volume of material entering a stream system. For this reason, watersheds having substantial mass wasting are not considered areas in which wetland restoration can be an effective tool to manage sediments.

Procedure:

1. *Identify primary watersheds and drainages having known sediment/turbidity problems from a search of the technical literature and subsequent review by local technical experts.*

2. *Identify watersheds/drainages not having existing sediment/turbidity problems. Use landuse/landcover layer to calculate which of these watersheds/drainages have greater than 30 percent of their area in non-forest uses. Use knowledge gained from river basin characterization to identify additional watersheds or drainages which do not meet the 30 percent non-forest criteria, but have substantial landcover change and geologic features that increase the risk of sediment inputs to surface water.*

3. *Delete watersheds/drainages experiencing large mass wasting events resulting from timber harvest practices and natural catastrophic events.*

4. *Compile information from Steps 1, 2 and 3 and establish a coverage highlighting primary and secondary watersheds for this function. Finalize data layer which identifies primary and secondary watersheds/drainages for the sediment retention function.*

Product:

A list of watersheds where wetland restoration has the greatest potential to capture and retain suspended sediments.

Objective 2: Identify wetlands which capture sediments before they enter streams.

Strategy 2.1: Identify non-timber land uses which are known to generate increased overland flows and sediments capable of reaching streams.

Rationale: Wetland inputs must have a sediment source to function in this capacity. References indicate that natural erosional processes, timber harvest and related road systems, construction-related clearing and grading, and poor pasture management are sources of stream sediment.

Strategy 2.2: Identify potential wetland sites classified as depressional closed and riverine closed which have surface water runoff as the dominant water source and receive suspended sediments from non-forest areas.

Rationale: The principle transport mechanism of sediment laden water is surface water runoff (Marble 1990). The principle factor affecting a wetland's ability to trap sediments is the change in the velocity or energy level of incoming water. Decreased water velocity results in sediment deposition (Marble 1990). It is assumed that depressional closed and riverine closed wetland classes have physical features which reduce water velocity and maximize potential for sediment retention. Drainage converts closed wetland subclasses to open subclasses and reduces the capture and retention capabilities of the wetland. By restoring open systems back to their predisturbance closed subclass, sediments suspended within overland flows can be once again captured and retained. It is assumed that the greatest potential for addressing increased sedimentation/turbidity occurs when closed systems are restored within non-forested areas experiencing increased sedimentation and overland flows.

Strategy 2.3: Identify all potential restoration sites having organic peat and muck soils (histosols) and remove them from consideration for sediment retention.

Rationale: Wetland soils are an indication of a wetland’s opportunity to perform a sediment retention function. In general, wetlands which develop mineral soils perform this function to some degree while organic soils do not. In a predisturbance condition, wetlands developing histosol soils had a stable water source and limited sediment inputs. Using wetlands with histosol soils for sediment retention will most likely further reduce the ability of the site to perform other historic functions.

Procedure:

1. *Access landuse/landcover data for primary and secondary watersheds/drainages.*
2. *Overlay potential wetland restoration sites onto landuse/landcover data and highlight depressional closed and riverine closed wetlands. Select all restoration sites having direct or adjacent association with non-timber landuse. Code sites which meet this criteria F3=2. Use aerial photography and best professional judgment to identify additional sites having less recognizable sediment inputs via surface water runoff and code F3=2.*

Product:

A list of wetland restoration sites which have the greatest potential to capture sediments suspended in overland flows before reaching a stream system.

Objective 3: Identify wetlands which remove suspended sediments from stream systems.

Strategy 3.1: Identify areas of non-timber land uses known to generate sediments capable of reaching streams.

Rationale: Wetland inputs must have a sediment source to function in this capacity. Natural erosional processes, timber harvest and related road systems, construction-related clearing and grading, and poor pasture management are primary sources of stream sediments.

Strategy 3.2: Identify estuarine fringe, lacustrine fringe, depressional open, and riverine open wetlands which receive sediment laden stream water.

Rationale: It is assumed that estuarine fringe, lacustrine fringe, depressional open and riverine open wetland classes have the physical features necessary to remove sediments that are being transported by a flowing stream. Opportunity to retain sediments after they reach a stream can be maximized by identifying wetlands within these classes which occur adjacent to or down stream from disturbed areas that generate sediments.

Strategy 3.3: Identify riverine open wetlands having physical features which maximize potential for retaining sediments. Physical features to consider at a river basin scale include:

a) Presence of a constricted outlet or no outlet;

b) Extensive stands of woody and/or persistent emergent vegetation;

c) Wetland is 5 percent or greater of watershed feeding the wetland.

Rationale: The above physical site features are identified by Marble (1990) as features which promote sediment retention in a wetland. It is assumed that freshwater wetlands in a predisturbance condition consisted primarily of persistent emergent and woody vegetation.

Procedure:

1. *Access landuse/landcover data for primary and secondary watersheds/drainages.*

2. *Overlay potential wetland restoration sites onto landuse/landcover data and highlight wetlands classified as depressional open, riverine open, estuarine fringe and freshwater fringe. Select all restoration sites having direct or adjacent association with non-timber landuse or which occur down stream from a sediment source. Code sites which meet this criteria F3=3. Use aerial photography and best professional judgment to identify additional sites having less recognizable sediment inputs via surface water runoff and code F3=3.*

3. *Overlay F3=3 sites with soils data showing the location of peat and muck soils and groundwater discharge soil mapping units. Select F3=3 sites having greater than 50 percent of area in peat or muck soils or 50 percent of area in groundwater discharge soil mapping units and recode F3=0. Select sites classified estuarine fringe and delete mudflat areas from consideration by recoding F3=0.*

4. *Select all sites coded F3=3. Reselect riverine open wetlands. Examine the outlet of each site and use best professional judgment to delete sites from consideration which do not have a constricted outlet.*

5. *Finalize list of wetland restoration sites coded F3=3.*

Product:

A list of potential wetland restoration sites which provide the greatest potential for removing sediments from streams.

Objective 4: Create wetlands which remove suspended sediments from surface sheet or stream flows.

Strategy 4.1: When evaluating wetland restoration options with cooperating landowners who generate suspended sediments due to landuse practices, assess property for potential to create wetlands which capture and retain these suspended sediments.

Rationale: Landowners are most likely to consider wetland creation if elevated suspended sediments are being generated on that property. It is unlikely that individual landowners will be in favor of large public works projects which capture sediments generated over a large area. Opportunities must be addressed on an individual basis and customized to site-specific features and the landowners' desires.

Procedure:

1. When in the field, evaluate site potential for using wetland creation as a tool to capture and retain suspended sediments.

Objective 5: Evaluate all sites for coding consistency.

Strategy 5.1: Ensure that all selected potential wetland sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands are restored within primary and secondary watersheds/drainages.

Strategy 5.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F3>0. Highlight sites coded F3=2, F3=3, and F3=4 by assigning each a different polygon color. All sites coded F3=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites and delete any F3 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products

- A list of watersheds where wetland restoration has the greatest potential to capture and retain suspended sediments.

- A list of wetland restoration sites which have the greatest potential to capture sediments suspended in overland flows before reaching a stream system.
- A list of potential wetland restoration sites which provide the greatest potential for removing sediments from streams.

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Function 4
<u>Nutrient Removal/Transformation</u>

Introduction

Nitrogen and phosphorus are essential nutrients for any natural aquatic system. Ecosystem function is dependent, in part, on the natural nutrient inputs and outputs unique to each system. Human activities can substantially increase nutrient inputs to stream systems, altering natural ecosystem function. Increases in phosphorus have been linked to the use of agricultural and residential fertilizers, detergents and commercial cleaners, sewage and food residues, soil erosion, and decomposing vegetation. Elevated levels of phosphorous are known to accelerate lake eutrophication. Increases in nitrates have been linked to animal wastes, sewage, and fertilizers and can result in fish habitat degradation, excess vegetation, algae blooms, and reduced dissolved oxygen (Thornburgh 1993).

Wetlands can function to retain nutrients, transform inorganic nutrients to their organic forms, and transform nitrogen into its gaseous form (denitrification) for removal from the system. Wetlands capable of performing this function help maintain resident fish and anadromous fish runs, dissolved oxygen levels, and nitrogen balance, while reducing algae blooms.

Goal

Restore wetlands and riparian areas which have the greatest potential to help retain and transform excessive nutrient inputs resulting from human development.

Objectives

- Target restoration efforts to watersheds having known nutrient problems.
- Identify wetlands capable of retaining nutrients before reaching streams.
- Identify wetlands capable of removing/retaining nutrients from stream systems.
- Identify native riparian buffers which remove/retain nutrients prior to entering wetlands or streams.

Assumptions

- Phosphorus is readily immobilized by calcium, aluminum, and iron by absorption and precipitation reactions. Because fine mineral soils usually have higher concentrations of these ions, they typically have higher capacities to retain phosphorus than organic soils (Marble 1990).
- Wetlands capable of physically detaining nutrients have: a) low gradients to allow for sedimentation, b) long detention time of surface water, c) woody stemmed plants which

slow water and increase sedimentation result in enhanced nutrient retention by burial, d) dense vegetation which helps to remove and take up nutrients, e) permanently saturated or flooded wetland soils which favor phosphorus retention, f) anaerobic and aerobic conditions at the surface of saturated sediments and rapid fluctuation between anaerobic and aerobic conditions favor nitrogen removal (Marble 1990).

- Sphagnum bogs are characterized as nutrient poor systems that will be irrevocably altered if nutrient inputs are increased.
- Only denitrification and the long-term storage of immobilized phosphorous in wetland soils are considered true nutrient removal in a wetland. While many wetlands are capable of nutrient uptake and storage in plant material, this is considered only a temporary storage function.
- Watersheds having greater than 30 percent of area in non-timber uses are at substantial risk of increased nutrient levels in the future.
- Sources of phosphates include agricultural and residential fertilizers, detergents and commercial cleaners, sewage and food residues, soil erosion, and decomposing vegetation in groundwater. Sources of nitrates are known to include animal wastes, sewage, and fertilizers.
- Depressional closed, depressional open, and riverine closed wetlands have physical features which maximize effectiveness to capture and retain nutrients prior to their reaching a stream.
- Lacustrine fringe, depressional open, and riverine open wetlands have physical features which provide the opportunity to remove and retain nutrients from streams.
- To have the opportunity to retain nutrients, a wetland must be adjacent to or downslope from a nutrient source.
- Wetlands which receive a substantial portion of their water budget from groundwater maintain water temperatures above biological zero through most, if not all, of the year.
- Wetlands which remain above biological zero through most, if not all, of the year have the greatest opportunity to retain nutrients during the winter months when overland runoff and nutrient inputs to aquatic systems are highest.
- Buffers can be effective at controlling nutrient inputs into wetlands and stream surface waters. In a review of the literature, Castelle et al. (1992) presented the results of a number of studies which documented nutrient uptake within buffer strips. Buffer widths which were shown to be effective at reducing nutrient (nitrogen, phosphorus, and potassium) inputs ranged from 12.5 feet to over 300 feet. One study evaluated the utility of vegetated buffers in reducing soluble nutrient levels in runoff from logging operations and found that a 98-foot buffer reduced nutrient levels in the water to “far below drinking water standards.”

Procedures for Characterizing Site Function

Goal: ***Restore wetlands and riparian areas which have the greatest potential to help retain and transform excessive nutrient inputs resulting from human development.***

Objective 1: Target restoration efforts to watersheds having known nutrient problems.

Strategy 1.1: Identify watersheds to be targeted for nutrient removal efforts. Primary target watersheds are streams or stream reaches having documented high nutrient levels. Secondary target watersheds are streams or stream reaches which lack documentation of nutrient problems but have the greatest potential for problems due to agricultural and residential development. Tertiary watersheds are all others.

Rationale: Restoration activities should focus on areas of greatest need.

Procedure:

1. *Identify primary watersheds and drainages having known nutrient problems from a search of the technical literature and subsequent review by local technical experts.*

2. *Identify watersheds/drainages not having existing nutrient problems. Use landuse/landcover layer to calculate which of these watersheds/drainages have greater than 30 percent of their area in non-forest uses. Use knowledge gained from river basin characterization to identify additional watersheds or drainages which do not meet the 30 percent non-forest criteria, but have substantial landcover change and geologic features that increase the risk of nutrient inputs via surface water.*

3. *Compile information from Steps 1 and 2 and establish a coverage highlighting primary and secondary watersheds for this function.*

Product:

A map identifying primary and secondary watersheds used to target nutrient retention efforts.

Objective 2: Identify wetlands capable of retaining nutrients before reaching streams.

Strategy 2.1: Identify areas within primary and secondary watersheds which are predominantly residential or agricultural lands.

Rationale: Sources of phosphates include agricultural and residential fertilizers, detergents and commercial cleaners, sewage and food residues, soil erosion, and decomposing vegetation in groundwater. Sources of nitrates are known to include animal wastes, sewage, and fertilizers.

Strategy 2.2: Identify predisturbance depressional closed and riverine closed wetlands which receive surface water runoff from predominantly residential, agricultural, or other non-forest landuses.

Rationale: Depressional closed and riverine closed wetlands have physical features which maximize effectiveness to capture and retail nutrients prior to their reaching a stream. For a wetland to have the opportunity to perform this function, the wetland must be adjacent to or downslope from a nutrient source.

Procedure:

1. *Access landuse/landcover data for primary and secondary watersheds/drainages.*

2. *Overlay potential wetland restoration sites onto landuse/landcover data and highlight depressional closed and riverine closed wetlands. Select all restoration sites having direct or adjacent association with non-timber landuse. Code sites which meet this criteria F4=2. Use aerial photographs and best professional judgment to identify additional sites having less recognizable nutrient inputs via surface water runoff and code F4=2.*

3. *Review each site for appropriateness and finalize list of sites coded F4=2.*

Product:

A list of wetlands which have the potential to capture and retain nutrients before they reach a stream.

Objective 3: Identify wetlands capable of removing/retaining nutrients from stream systems.

Strategy 3.1: Identify sources of nutrients within primary and secondary watersheds.

Rationale: Sources of phosphates include agricultural and residential fertilizers, detergents and commercial cleaners, sewage and food residues, soil erosion, and decomposing vegetation in groundwater. Sources of nitrates are known to include animal wastes, sewage, and fertilizers.

Strategy 3.2: Identify predisturbance lacustrine fringe, depressional open, and riverine open wetlands being fed by stream flow within primary and secondary watersheds.

Rationale: Lacustrine fringe, depressional open, and riverine open wetlands have physical features which maximize opportunities to remove and retain nutrients from streams.

Strategy 3.3: Identify wetlands which have physical features which increase effectiveness or opportunity to retain nutrients. Criteria which can be evaluated at a river basin scale include:

a) Fine mineral soils to immobilize phosphorous;

b) Permanently flooded or saturated soils to retain phosphorous;

c) Rapid fluctuation between anaerobic and aerobic conditions at the surface favors nitrogen removal/transformation; and

d) Wetland possesses a constricted outlet to increase retention time.

Rationale: Criterion noted above are identified by Marble (1990) as key features of wetlands providing a nutrient removal/transformation function.

Procedure:

1. *Overlay landuse/landcover data onto primary and secondary watersheds/drainages.*

2. *Identify potential restoration sites classified as lacustrine fringe, depressional open, and riverine open. Using landuse/landcover layer and aerial photos, select sites which are adjacent to, or down slope from non-timber landuses capable of generating nutrients. Code selected sites F4=3.*

3. *Overlay soils data onto F4=3 sites and identify potential wetlands having organic soils (peats and mucks). Further identify which of these sites have soils characteristic of <u>Sphagnum</u> bogs. Recode bogs F4=0. Use best professional judgment to determine which organic soil sites have potential to remove nutrients. As a rule of thumb, consider sites having 50 percent or more organic soils as having reduced potential and recode F4=0.*

4. *Select F4=3 sites classified as riverine open. Identify fine mineral hydric soils and overlay onto selected riverine open sites. Identify sites having less than 50 percent of area in fine mineral soils and recode F4=0.*

5. *Highlight F4=3 sites. Use configuration of each potential wetland polygon and best professional judgment to identify sites which do not have a constricted outlet and record F4=0.*

6. *Highlight sites coded F4=3 and use best professional judgment to review and evaluate appropriateness of each site. Finalize site selection and coding.*

Product:

A list of wetlands which have the potential to remove or transform nutrients in streams.

Objective 4: Identify native riparian buffers which remove/retain nutrients prior to entering wetlands or streams.

Strategy 4.1: Identify stream reaches not having a riparian buffer consisting of predominant scrub-shrub or forested vegetation and target for restoration.

Rationale: Buffers can be effective at controlling nutrient inputs into wetlands and stream surface waters. In a review of the literature, Castelle et al. (1992) presented the results of a number of studies which documented nutrient uptake within buffer strips. Buffer widths which were shown to be effective at reducing nutrient (nitrogen, phosphorus, and potassium) inputs ranged from 12.5 feet to over 300 feet.

Procedure:

1. *Identify the location of primary and secondary watersheds/drainages. Use aerial photography under magnification and other available data to identify exposed stream reaches which are being used for, or occur adjacent to, non-timber landuses capable of generating increased nutrients.*

2. *Digitize riparian stream reaches identified and code each reach F4=4.*

Product:

A list of riparian restoration sites having the greatest potential to reduce nutrient inputs to a stream.

Objective 5: Evaluate all sites for coding consistency.

Strategy 5.1: Ensure that all selected potential wetland and riparian restoration sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands and riparian areas are restored within primary and secondary watersheds/drainages.

Strategy 5.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F4>0. Highlight sites coded F4=2, F4=3, and F4=4 by assigning each a different polygon/arc color. All sites coded F4=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F4 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products:

- A map identifying primary and secondary watersheds used to target nutrient retention efforts.
- A list of wetlands which have the potential to capture and retain nutrients before they reach a stream.
- A list of potential wetland sites which have the greatest potential to remove or transform nutrients in streams.
- A list of riparian restoration sites having the greatest potential to reduce nutrient inputs to a stream.

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Function 5
Groundwater Nutrient Retention

Introduction

Within many areas, domestic water supplies come from groundwater. Human activities within groundwater recharge areas can substantially impact groundwater quality and quantity. The greatest potential for groundwater recharge occurs within alluvial and glacial outwash surficial geology deposits. Threats to groundwater quality increase with increased commercial and industrial development, concentrated dairy farming, and the use of agricultural chemicals on these recharge areas (Messman et al. 1994). Elevated levels of nitrates in groundwater used for domestic uses can cause infant sickness or, in extreme cases, death.

Wetlands are capable of retaining nutrients from surface water. Where wetlands occur within groundwater recharge areas, wetlands can serve to capture and retain nutrients from overland flows before these nutrients percolate downward into groundwater aquifers. Key considerations to effectiveness are the length of nutrient retention time and the level of denitrification. Wetlands can store and release nutrients seasonally, or store and retain nutrients for long periods of time.

Goal

Restore wetlands which have the greatest potential to capture and retain or remove nutrients destined for groundwater aquifers.

Objectives

- Identify pre-development wetlands which recharge groundwater aquifers of importance to humans.
- Identify groundwater recharge wetlands having altered physical features which reduce the site's ability to efficiently capture and retain, or remove nutrients.

Assumptions

- The interface between bedrock or till, and outwash or alluvium is a location where substantial groundwater recharge occurs. While the high potential for groundwater recharge occurs in wetlands which occur on the interface between bedrock or till and outwash or alluvium, recharge can and does occur throughout outwash and alluvial deposits.
- Custer-Norma soil units occur on nearly flat areas that are underlain by stratum more permeable than basal till (Dinicola 1990).
- Undisturbed outwash soil units are highly permeable soils where groundwater flow is the predominant runoff mechanism (Dinicola 1990).

- Disturbance of outwash soil units increases the chance of Horton overland flow occurring (Dinicola 1990).
- Subsurface flow is the predominant runoff mechanism from undisturbed glacial till on hillslopes (Dinicola 1990).
- Direct recharge potential to shallow groundwater aquifers is generally moderate to high on alluvium and recessional outwash units except at river outlets where the silty and clayey sediments prevent infiltration of rainwater (Economic and Engineering Services, Inc. 1991).
- The Vashon till typically forms a low permeability barrier to downward water percolation. Recharge of rain water to the unweathered Vashon till is slow. Shallow groundwater may occur within weathered till perched on top of unweathered till or within thin discontinuous lenses of sand and gravel in some till. Topographic depressions in the upper surface of the unweathered till will trap groundwater that will slowly infiltrate into underlying geologic units and aquifers (Economic and Engineering Services, Inc. 1991).
- The likelihood that water will infiltrate and pass through the surface materials to recharge the underlying aquifer system in dependent on a number of relatively static physical conditions which include: soil permeability, surficial geologic materials, depth to water, and topography (Economic and Engineering Services, Inc. 1991).
- To provide groundwater recharge, the wetland's water source must come from surface water (channel flow or overland flow). Once the water reaches the wetland, it must be detained in the wetland basin. One of the most critical criteria relating to groundwater recharge is site selection (Marble 1990).
- Generally, conditions suitable for groundwater recharge can only exist in palustrine, lacustrine, and riverine systems. Tidal, marine, and estuarine systems have little recharge potential because the elevation head is so low (Marble 1990).
- The porosity of the underlying soil and bedrock conditions determine the potential hydraulic conductivity of a wetland (Marble 1990).
- Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff (Roth et al. 1993).
- To have the opportunity to retain substantial nutrient inputs, a wetland must be located adjacent to or downslope from a nutrient source.
- Depressional closed and riverine closed wetlands have physical features which maximize the potential to capture and retail nutrients prior to reaching a stream. Depressional open, lacustrine fringe, and riverine open wetlands have physical features which maximize the opportunity to capture and retain nutrients from streams.
- Wetlands which receive a substantial portion of their water budget from groundwater maintain water temperatures above biological zero through most, if not all, of the year. Plant uptake of nutrients occurs when water temperatures exceed biological zero. Wetlands having this physical feature have the greatest opportunity to perform this

function during the winter months when overland runoff and nutrient inputs to aquatic systems are highest.

- Within the floodplain, it is assumed that wetlands located away from the channel are more effective at recharging alluvial soils than wetlands directly associated with the river channel.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to retain nutrients destined for groundwater aquifers.***

Objective 1: Identify potential wetland sites which can recharge groundwater aquifers of importance to humans.

Strategy 1.1: Identify geographic areas which function to recharge underground aquifers of importance for human use.

Rationale: Efforts to protect groundwater quality should focus on important aquifer recharge areas based on available technical data.

Strategy 1.2: Identify potential wetlands occurring on groundwater recharge areas.

Rationale: Not all wetlands are capable of recharging groundwater. The greatest potential for wetlands to recharge groundwater exists when wetlands occur on surficial geology formations which allow the rapid downward movement of water to aquifers. Because bedrock and glacial till are generalized as having predominantly shallow subsurface flows, the interface between bedrock or till and outwash or alluvium is a location where substantial groundwater recharge occurs. While high potential for groundwater recharge occurs in wetlands which are at the interface between bedrock or till and outwash or alluvium, recharge can and does occur within wetland and upland areas throughout outwash and alluvial deposits.

Strategy 1.3: Delete alluvial areas at river outlets where silty and clayey sediments prevent infiltration of rainwater.

Rationale: Direct recharge potential to shallow groundwater aquifers is generally moderate to high on alluvium and recessional outwash units except at river outlets where the silty and clayey sediments prevent infiltration of rain water (Economic and Engineering Services, Inc. 1991).

Strategy 1.4: Evaluate which potential restoration sites within recharge areas have the greatest potential to recharge groundwater aquifers when restored. Consider the following features which increase opportunity or effectiveness to provide this function:

a) A high proportion of the wetlands water budget comes from channel flow, overland runoff, and precipitation;

b) Extended water retention times;

c) Presence of a constricted surface water outlet or no outlet; and

d) Landscape position within floodplain but away from the stream channel.

Rationale: To provide groundwater recharge, the wetland's water source must come from surface water (channel flow or overland flow). Once the water reaches the wetland, it must be detained in the wetland basin. One of the most important criteria relating to groundwater recharge is site selection (Marble 1990). Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff (Roth et al. 1993). Within the floodplain, it is assumed that wetlands located away from the channel are more effective at recharging alluvial soils than wetlands directly associated with the river channel.

Procedure:

1. *Use existing technical information and surficial geology data to identify areas of high surficial recharge. If technical reports are not available which identify the areas of high surficial recharge, use surficial geology coverage, and highlight mapping units found to have high surficial recharge potential (alluvium, advanced and recessional outwash).*

2. *Overlay potential wetland site data onto the areas of high surficial recharge. Select all potential wetlands occurring within recharge areas and code F5=1. Identify potential wetland sites located within the tidally influenced floodplain area and recode F5=0.*

4. *Select all potential wetlands coded F5=1. Examine the outlet of each selected site and use best professional judgment to delete sites from consideration which do not have a constricted outlet. Overlay soil mapping units characteristic of groundwater discharge soils. Use best professional judgment to identify sites which have >75 percent of area in groundwater discharge soils and recode F5=0. Overlay stream data onto surficial geology and floodplain data. Use aerial photos and best professional judgment to identify riverine open sites on floodplain alluvial soils that have a direct association to the river or stream and record F5=0. Examples of areas recoded F5=0 include gravel bars and riparian wetlands adjacent and parallel to the stream.*

5. *Finalize list of sites which have potential to recharge groundwater.*

Product:

A list of wetland restoration sites having the greatest potential for recharging groundwater aquifers used by humans.

Objective 2: Identify groundwater recharge wetlands having the greatest opportunity to retain nutrients prior to recharge.

Strategy 2.1: From groundwater recharge wetlands, identify sites which are adjacent to or down slope from non-timber land uses.

Rationale: To have the opportunity to retain substantial nutrient inputs, a wetland must be located adjacent to, or downslope from a nutrient source. Sources of phosphates include agricultural and residential fertilizers, detergents and commercial cleaners, sewage and food residues, soil erosion, and decomposing vegetation in groundwater. Sources of nitrates are known to include animal wastes, sewage, and fertilizers.

Strategy 2.2: From sites identified in Strategy 2.1, identify depressional closed and riverine closed sites which are capable of removing/retaining nutrients before reaching a stream.

Rationale: Depressional closed and riverine closed wetlands have physical features which maximize potential to capture and retain nutrients prior to reaching a stream.

Strategy 2.3: From sites identified in Strategy 2.1, identify depressional open, lacustrine fringe, and riverine open sites which are capable of removing/retaining nutrients from stream systems.

Rationale: Depressional open, lacustrine fringe, and riverine open wetlands have physical features which maximize the opportunity to capture and retain nutrients from streams.

Strategy 2.4: From the sites identified in Strategy 2.2 and 2.3, identify wetlands having physical features which maximize potential for retaining nutrients. Criteria which can be evaluated at a river basin scale include:

a) Presence of fine mineral soils to immobilize phosphorous;

b) Permanently flooded or saturated conditions to retain phosphorous;

c) Rapid fluctuation between anaerobic and aerobic conditions at the surface favor nitrogen removal/transformation; and

d) Wetland possesses a constricted outlet to increase retention time.

Rationale: Criterion noted above are identified by Marble (1990) as key features of wetlands providing a nutrient removal/transformation function.

Procedure:

1. *Overlay landuse/landcover and topography coverages onto groundwater recharge sites identified in Objective 1.*

2. *Select all depressional closed and riverine closed wetlands within areas of high groundwater recharge. Use landuse/landcover data, topography, and aerial photography under magnification to identify sites which receive surface water inputs from non-timber landuses. Sites should be on, adjacent to, or down stream from nutrient inputs. Code sites which meet this criteria F5=2. Use aerial photos and best professional judgment to identify additional sites having less recognizable nutrient inputs via surface water runoff and code F5=2.*

3. *Select all lacustrine fringe, depressional open, and riverine open wetlands located within areas of high groundwater recharge. Use landuse/landcover data, topography data, and aerial photography under magnification to identify sites which receive surface water inputs from non-timber landuses. Sites should be on, adjacent to, or down stream from nutrient inputs. Code sites which meet this criteria F5=2. Use aerial photos and best professional judgment to identify additional sites having less recognizable nutrient inputs via surface water runoff and code F5=2. Overlay soils data onto sites selected and identify potential wetlands having organic soils (peats and mucks). Further identify which of these sites have soils characteristic of Sphagnum bogs. Recode bogs F5=0. Use best professional judgment to determine which other organic soil sites have potential to remove nutrients. As a rule of thumb, consider sites having 50 percent or more organic soils as having reduced potential and recode F5=0. Select sites classified as riverine open. Identify fine mineral hydric soils and overlay onto selected riverine open sites. Identify sites having less than 50 percent of area in fine mineral soils and recode F5=0. Select F5=2 sites and use best professional judgment to delete sites from consideration which do not have a constricted outlet.*

Product:

A list of restoration sites having the greatest potential for retaining nutrients from surface water prior to recharge.

Objective 3: Evaluate all sites for coding consistency.

Strategy 3.1: Ensure that all selected potential wetland sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands are restored within primary and secondary watersheds/drainages.

Strategy 3.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F5>0. Highlight sites coded F5=1 and F5=2 by assigning each a different polygon color. All sites coded F5=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F5 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products:

- A list of wetland restoration sites having the greatest potential for recharging groundwater aquifers used by humans.

- A list of restoration sites having the greatest potential for retaining nutrients from surface water prior to recharge.

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Function 6
Flood Flow Storage and Desynchronization

Introduction

Runoff volume is directly related to the level of development in the watershed (Roth et al. 1993). Increases in impervious area, changes in soil structure and texture due to disturbance or land use change have decreased surface detention/retention times, rainfall interception, and plant transpiration (Dinicola 1990). Further, road ditches and other shallow excavation intercepts subsurface interflow on till and converts it to surface runoff. Development, soil disturbance, timberland conversion, timber harvest, and slope within the watershed are all factors which increase the intensity of flood events. Increased flooding can result in property damage, soil erosion, increased bedload movement, loss of fish reeds and stream habitat, increased sediment inputs, an increase in non-native invasive plants, and stream channel erosion.

Wetlands can function to store flood flows that would otherwise intensify flooding further down stream. In concert with other floodplain management activities, wetland restoration can reduce property/crop damage and soil erosion while buffering increases in flood hazard and soil erosion due to future development impacts.

Goal

Restore wetlands which have the greatest potential to store and desynchronize flood flows.

Objectives

- Target wetland restoration efforts to watersheds which have known flooding problems.
- Identify wetlands which capture and desynchronize surface flows from rain-on-snow areas before flows reach forks or tributaries of the river system.
- Identify wetlands which capture and desynchronize surface flows within the floodplain.
- Identify wetlands which capture and desynchronize stormwater runoff from residential, agricultural, and disturbed lands.

Assumptions

- Drainage of an area can affect wetlands downstream. Drainage results in increased delivery of water to lowlands, streams, and lakes (Winter 1988).
- Wetland location influences a wetland’s effectiveness at desynchronizing flows. Greatest opportunity for desynchronizing flows exist when wetland restoration retains runoff within the floodplain (Roth et al. 1993).

- Rain-on-snow areas have potential to produce substantial runoff which contributes to the risk of flooding downstream. Opportunity for desynchronizing flood flows exists in wetlands which occur within or directly below rain-on-snow areas.
- Watersheds with a relatively small portion of their upslope area occupied by wetlands will benefit most in terms of effective floodflow alteration. A watershed with greater than ten percent of its acreage in wetlands may not realize an incrementally significant floodflow alteration benefit from additional wetland acreage (Marble 1990).
- Wetlands along floodplains near the mouth of a basin are in a position to control flooding, while those at the headwaters can only control a small volume of the basin's floodwaters. Ogawa and Male refined these concepts by numerically modeling the flood storage characteristics of wetlands with respect to location and size. Consider a wetland lying downstream along a major river. The volume of water that may flood from the channel onto the wetland is far greater than the runoff that can be produced from the wetland. Consequently, the runoff-producing and runoff-conveying function of the wetland is overridden and storage capacity becomes the dominant function, leading to a reduction in the flood peak. Where a small tributary stream originates in a wetland, there is no major volume of water flowing overland to be stored on the wetland. In this setting all runoff is generated in the wetland and the immediate environs, and will flow away as rapidly as channel conditions allow. For wetland-flanked streams that are between these extremes, the wetland function may depend on the magnitude of the flood, with the runoff function dominant for the higher frequency storms, and the storage function dominant for lower frequency storms (i.e., major flood events) (O'Brien 1988).
- Water marks are valid indicators of seasonal and episodic stage fluctuations in wetlands and are strong indicators of storage function (Roth et al. 1993).
- Generally, the larger the wetland, the greater its ability to store and attenuate flood flows (Roth et al. 1993).
- Wetlands with no outlets, or with restricted or controlled outlets generally will store greater amounts of water than wetlands with unrestricted flow outlets. Also, the wetland can store water for slower release into the water system (Roth et al. 1993).
- Rain-on-snow areas are known to produce substantial overland flow during major storm events during the winter flood season in Puget Sound. Rain-on-snow runoff on steep slopes reach small stream systems quickly. Riverine open, depressional open and extensive peat open wetlands which receive this runoff prior to reaching major rivers or tributaries have increased opportunity to store and dysnchronize flows.
- Closed wetland systems capture and hold all runoff entering them and thus are most effective at desynchronizing flood flows. When closed systems are drained, water is transported directly to streams. Increased flood flows occur as this additional water reaches the floodplain.
- Densely vegetated wetlands with vegetation greater than six feet are better able to control flood flows than wetlands dominated by open water or low growing vegetation, which generally offers little resistance (Roth et al. 1993).

- If the wetland is upstream from an urban area, its ability to control floods becomes more important (Roth et al. 1993).
- Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff. The value of flood control and flow conservation to a community is higher where runoff is greater (Roth et al. 1993).
- In undisturbed forested areas, subsurface flow, sometimes combined with exfiltration, is the predominant runoff mechanism on hillslopes mantled with glacial till. Within the soil profile, transmission of water is greatly retarded, but once the water is exfiltrated, this mechanism can contribute substantially to storm runoff. The rate of runoff by the mechanism is proportional to the angle of the hillslope (Dinicola 1990).
- In undisturbed forested areas, classical Horton overland flow is not an important runoff mechanism over most, if not all, areas (Dinicola 1990).
- In undisturbed forested areas, groundwater flow is the predominant runoff mechanism on glacial outwash deposits. Runoff rates from this mechanism are slow and attenuated (Dinicola 1990).
- In undisturbed forested areas, saturation overland flow is the predominant runoff mechanism in depressions, stream bottoms, and till-capped hilltops. Runoff comes quickly and frequently from depressions and stream bottoms, but it comes only during prolonged wet periods from the till-capped hilltops (Dinicola 1990).
- In disturbed nonforested areas, rapid, direct overland flow is the runoff mechanism on impervious areas (Dinicola 1990).
- In disturbed nonforested areas, Horton overland flow, perhaps in combination with some of the mechanisms from undeveloped areas, is an important runoff mechanism from disturbed pervious areas. This is due primarily to changes in soil structure and texture, and to increased moisture supply from nearby impervious surfaces (Dinicola 1990).
- In disturbed nonforested areas, there is decreased surface detention and retention storage available, decreased rainfall interception, and decreased plant transpiration in the pervious parcels within disturbed areas (Dinicola 1990).
- Within a floodplain, wetlands having no constricted outlet can provide a flood storage function if the site provides a substantial area of live storage for flood water.
- The importance of a wetland in altering floodflows depends to a great extent on its position in the watershed and its outlet characteristics. Wetlands located in the upper portion of the watershed are most effective if the total acreage of wetlands and other surface waters above them in the watershed is less than about seven percent of the watershed. Wetlands low in the watershed can be effective regardless of the available upstream storage (Marble 1990).
- A watershed which produces high volumes of runoff will benefit most from the addition of wetland areas. Impervious surfaces, including soils with slow infiltration rates, steep slopes, and developed areas covered by asphalt or concrete, will generate more runoff than undeveloped land with vegetation cover (Marble 1990).

- Flood water storage is most significant in palustrine, lacustrine, and upper riverine wetland systems (Marble 1990).
- A 60 percent level of impervious area in a one-square mile drainage area can increase the mean annual peak discharge by a factor of three (Stockdale 1991).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to store and desynchronize flood flows.***

Objective 1: Target wetland restoration efforts to watersheds which have known flooding problems.

Strategy 1.1: Identify individual watersheds to be targeted for wetland restoration which desynchronize flood flows.

Rationale: Restoration activities should focus on areas of greatest need.

Procedure:

1. *Identify watersheds/drainages with increasing flooding problems and develop a GIS map which highlights them as primary target areas. If the mainstream river has known flooding problems, the entire basin should be addressed as a primary area to maximize flood desynchronization potential.*

Product:

A map identifying watersheds with known flooding problems.

Objective 2: Identify wetlands which capture and desynchronize surface flows from rain-on-snow areas before flows reach forks or tributaries of the river system.

Strategy 2.1: Identify predisturbance depressional open, riverine open, and extensive peat open wetlands which occur between rain-on-snow areas and major tributary streams.

Rationale: Rain-on-snow areas have well defined drainage pathways which transport high flows during rain-on-snow events. Rain-on-snow runoff is slowed as it passes through riverine open, depressional open and extensive peat open systems prior to reaching large rivers. Drainage of these sites accelerate water transport to collector streams or rivers.

Strategy 2.2: From the sites identified in Strategy 2.1, highlight those having drainage areas with less than seven percent of area in other wetlands and have a constricted outlet.

Rationale: The importance of a wetland in altering floodflows depends to a great extent on its position in the watershed and its outlet characteristics. Wetlands located in the upper portion of the watershed are most effective if the total acreage of wetlands and other surface waters above them in the watershed is less than about seven percent of the watershed (Marble 1990).

Procedure:

1. *Overlay the rain-on-snow layer onto potential wetland site data. Select and highlight depressional open and extensive peat open sites one color. Select and highlight riverine open wetlands another color. Add stream data to help clarify stream-wetland associations.*

2. *Identify and select all highlighted sites connected to a stream drainage system and lying between a rain-on-snow area and a major tributary stream. Code all sites which meet this criteria F6=2.*

3. *Select all F6=2. Use stream coverage to identify sites that have an outlet but no inlet. Recode F6=0. Use potential wetland site polygons and best professional judgment to identify sites which lack a constricted outlet and recode F6=0.*

4. *Overlay potential wetland site coverage onto digital elevation and stream coverages. Select all F6=2 and use best professional judgment to identify sites which have >7 percent of their upstream drainage in wetlands. Recode F6=0.*

Product:

A list of riverine open, depressional open, and extensive peat open wetlands which have potential to provide improved flood flow alteration by intercepting and retaining rain-on-snow runoff before it reaches large rivers.

Objective 3: Identify wetlands which capture and desynchronize surface flows within the floodplain.

Strategy 3.1: Identify diked areas which constrict the floodplain and/or reduce flood flow access to wetlands.

Rationale: Dikes which are not designed to be overtopped regularly reduce and at times eliminate the opportunity for wetlands and riparian areas to store and desynchronize flood flows.

Strategy 3.2: Identify riverine open potential restoration sites within the floodplain having a constricted outlet.

Rationale: A constricted outlet increases a site's effectiveness at providing floodflow attenuation.

Strategy 3.3: Identify riverine open restoration sites which occur near the river channel and provide live storage for flood flows.

Rationale: Within a floodplain, wetlands having no constricted outlet can provide a flood storage function if the site provides a substantial area of live storage for flood water.

Strategy 3.4: Identify potential sites classified as riverine closed.

Rationale: Riverine closed wetlands have physical features which maximize retention time.

Procedure:

1. *Use soil survey maps, maps produced by Bortleson et al. (1980), and other sources to identify dikes, railroad grades, and roads which divert flood flows or restrict over-bank flood access to floodplain wetlands. Overlay this information onto potential wetland site data and identify sites which have reduced opportunity to store flood flows within the floodplain due to dikes or other diversion structures. Code sites selected F6=3.*

2. *Select all riverine open wetlands within the floodplain boundary. Use best professional judgment to identify sites having a constricted outlet and code F6=3. Code sites without a constricted outlet F6=0.*

3. *Reselect all riverine open wetlands within the floodplain boundary which do not have a constricted outlet and coded F6=0. Use best professional judgment to identify sites which occur near or adjacent to the channel of the river and have potential for regular flooding (i.e., live storage), and recode F6=3.*

4. *Select all riverine closed wetlands and code F6=3.*

Product:

A list of potential wetland restoration sites which can store and desynchronize flood flows within the floodplain.

Objective 4: Identify wetlands which capture and desynchronize stormwater runoff from residential, agricultural, and disturbed lands.

Strategy 4.1: Identify sources of stormwater runoff.

Rationale: Runoff volume is directly related to the level of development in the watershed (i.e., the more development, the more runoff). The value of flood control and flow conservation to a community is higher where runoff is greater (Roth et al. 1993).

Strategy 4.2: Identify wetland restoration sites which are located between the floodplain and development areas.

Rationale: Opportunity to store runoff from altered landscapes exists if the potential restoration site lies between the source of runoff and a major stream or river.

Strategy 4.3: Identify potential restoration sites having a constricted outlet or no outlet receiving surface runoff from non-timber areas.

Rationale: A constricted outlet or no outlet increases a site's effectiveness at providing floodflow attenuation.

Strategy 4.4: Identify uplands sites where wetlands can be created with the physical features noted above to capture and store stormwater runoff before reaching a stream.

Rationale: Stormwater runoff from altered drainages results in substantially different flow hydrographs (Stockdale 1991). These alterations in flow pattern can have major impacts to the plant communities of existing wetlands. The use of created wetlands to capture and store increases in stormwater runoff before they reach existing wetlands is desirable if the functions being provided by existing wetlands are to be maintained.

Procedure:

1. *Select sites coded F6=2 and F6=3 and highlight. Then select potential wetland sites classified as depressional open, riverine open, extensive peat open, and depressional closed and not having an F6=2 or F6=3 coding. Overlay landuse/landcover, topography, and stream coverages onto these potential sites. Use aerial photos, and best professional judgment to identify sites which occur adjacent to or down slope from residential, agricultural, or other non-forest uses and have potential to receive stormwater runoff. Code sites F6=4*

2. *Identify wetland creation sites on a site-specific basis when working with individual landowners.*

Product:

A list of wetland restoration and creation sites which are capable of reducing flood flows resulting from residential, agricultural, and disturbed lands outside the floodplain.

Objective 5: Evaluate all sites for coding consistency.

Strategy 5.1: Ensure that all selected potential wetland sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands are restored within primary and secondary watersheds/drainages.

Strategy 5.2: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F6>0. Highlight sites coded F6=2, F6=3, and F6=4 by assigning each a different polygon color. All sites coded F6=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F6 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site data layer and visually search for inconsistencies. Use surficial geology, landuse/landcover, topography, and soils to assist in this quality assurance step.*

Products

- A map identifying watersheds with known flooding problems.
- A list of riverine open, depressional open, and extensive peat open wetlands which can provide improved flood flow alteration by intercepting and retaining rain-on-snow runoff before it reaches large rivers.
- A list of potential wetland restoration sites which can store and desynchronize flood flows within the floodplain.
- A list of wetland restoration and creation sites which are capable of reducing flood flows resulting from residential, agricultural, and disturbed lands outside the floodplain.

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Function 7
Base Flow Maintenance

Introduction

A minimum stream base flow is required to support many of the functions a stream is capable of providing. When flows drop below a minimum flow rate, the stream is more susceptible to rises in temperature and a higher degree of pollution from industrial, municipal, and agricultural wastes (Hidaka 1973). Low flows can reduce or obstruct fish passage to available habitat. Factors known to reduce stream base flows include the draining of bottomland and depressional areas with seasonally high water tables, drainage of Custer-Norma soil units, shallow excavations on till (i.e., road ditches) which intercept subsurface flows and convert them to overland flows, groundwater withdrawals, increased surface water runoff resulting from forest conversion to agricultural or residential landuse, and the increase of hard surface areas. These alterations result in decreased groundwater recharge, increased overland flow to streams, and a pirating of subsurface flows on glacial till.

Since the last ice age, native fish and wildlife have adapted to the dynamic natural base flow conditions of each stream system. Human disturbance has substantially altered both the timing and extent of surface and groundwater inputs to many streams. Where base flows have been declining, wetland restoration can help maintain anadromous fish runs and resident fish habitat by naturally regulating the release of groundwater discharge into streams and by recharging aquifers which discharge groundwater to streams.

Goal

Restore wetlands which have the greatest potential to help maintain adequate stream base flow for natural stream function.

Objectives

- Target wetland restoration efforts to watersheds which have known or anticipated base flow problems.
- Identify wetlands which receive groundwater discharge and release it to a stream through either surface or subsurface flows.
- Identify wetlands which recharge aquifers discharging water to a stream.
- Identify headwater wetlands which maintain base flows during summer low flows.

Assumptions

- Bottomland and depressional areas with seasonally high water tables can generate substantial amounts of saturated overland flow (Dinicola 1990).

- Custer-Norma soil units occur on nearly flat areas and have high water tables that can generate saturated overland flow (Dinicola 1990).
- Watersheds having greater than 30 percent of area in non-forest uses are at substantial risk of water temperature increases in the future.
- In undisturbed forested areas, subsurface flow, sometimes combined with exfiltration, is the predominant runoff mechanism on hillslopes mantled with glacial till. Within the soil profile, transmission of water is greatly retarded, but once the water is exfiltrated, this mechanism can contribute substantially to storm runoff. The rate of runoff by the mechanism is proportional to the angle of the hillslope (Dinicola 1990).
- The largest base-flow indexes were obtained for streams draining permeable unconsolidated glacial and alluvial sediments in parts of the lowlands adjacent to Puget Sound (Hidaka 1973).
- The smallest indexes were computed for streams draining areas underlain by relatively impermeable igneous, sedimentary, and metamorphic rocks or by relatively impermeable glacial till (Hidaka 1973).
- Periods of low stream flow are usually the most critical factor in relation to instream water use, such as fish propagation. During low flows, the stream is more susceptible to rises in temperature and to a higher degree of pollution from industrial, municipal, and agricultural wastes (Hidaka 1973).
- Low flows of low-altitude streams occur during late summer. Minimum flows of these streams are dependent largely upon ground-water discharge as almost all the winter precipitation falls as rain and no snow or ice is stored for summer runoff. The extent to which groundwater supports streamflow is a function of the amount of groundwater in storage and the rate of movement toward surface streams. High altitude may cause low flow periods to occur both during the summer and winter depending on the amount of runoff coming from snow melt. Streams with winter low-flow periods drain basins sustained by melt water from glaciers and perennial snowfields (Hidaka 1973).
- The lack of glaciers in some basins provides little melt water during low flow season. Larger low flow indexes recorded in some watersheds can be attributed to their fairly large areas of highly permeable recessional outwash and the abundance of precipitation over the basins. The small low-flow index for one watershed may be due to the smaller amount of precipitation and the low permeability of the consolidated sedimentary rocks that underlie most of the basin. Creeks which drain lowlands underlain by glacial till can be expected to have smaller low-flow yield indexes (Hidaka 1973).
- The extent to which groundwater supports streamflow is a function of the amount of groundwater in storage and the rate of movement toward surface streams.
- Precipitation that falls on the land surface will flow over it, remain ponded in depressions, and/or infiltrate into the subsurface. The relative distribution of water involved in each of these processes depends on the slope and permeability of the land surface. In areas of steep uniform slope and high permeability, the water that does

infiltrate and that is not transpired will move downgradient in the subsurface and discharge in the lowlands near streams or lakes (Winter 1988).

- In most environments, only minimal quantities of water percolate through the unsaturated zone to recharge groundwater during the growing season. Large quantities of water will percolate past the root zone if the water uptake capacities of the plants are met during extended rainy periods, or during the nongrowing season. In areas with high precipitation and where soil water does not freeze, such as the Pacific Northwest, groundwater recharge is high beginning in the fall after plants become dormant (Winter 1988).
- One principle conclusion from numerical modeling of generalized settings is that recharge commonly is localized where thickness of the unsaturated zone is small relative to contiguous points of the landscape. Assuming the water table is relatively flat and the land surface is hummocky, the areas of minimal thickness of the unsaturated zone occur directly adjacent to surface water or at depressions in the landscape [e.g., wetlands]. The actual volume of recharge at a depression will be variable in space, depending on the size of the depression, permeability of the soil, and amount and type of vegetation that may transpire the water before it percolates past the root zone (Winter 1988).
- Detrimental effects of altering recharge are caused by removal of water. Increasing the efficiency of water removal from areas of flat slope by ditching reduces recharge to groundwater. Not only is less water available because of drainage, but the resulting lowered water table reduces the hydraulic head that provides the driving force for recharge. If a depressional wetland that recharges groundwater is drained, the recharge function is lost. If a recharge wetland is adjacent to a groundwater flow-through or groundwater discharge wetland, these adjacent wetlands will receive less groundwater inflow (Winter 1988).
- The impact of wetland drainage on regional flow systems is not as great as it is for local flow systems. For upland areas, some of the water that seeps from recharge wetlands serves as recharge to regional flow systems. Whether or not the recharge point shifts from one local depression to another in uplands makes little difference to the total regional recharge process (Winter 1988).
- Wetlands on till tend to occupy higher elevations, and as a result are often linked to the headwaters of streams. This juxtaposition of wetlands with streams and permeable materials associates them with aquifers and raises the potential for moderating streamflow (O'Brien 1988).
- Freeze and Witherspoon have indicated that in small aquifers where the water table is near the surface, the recharge area tends to be large in proportion to the discharge area. Therefore, a wetland that overlies a discharge area is in a position to exercise considerable control over groundwater discharge (O'Brien 1988).
- Groundwater discharge has been shown to be important to streamflow in several studies. Groundwater levels may be particularly critical to streamflow in some areas as researchers have shown that a small decline in groundwater level can lead to a cessation of streamflow (O'Brien 1988).

- The alteration of wetlands can have a direct effect on groundwater (O'Brien 1988).
- Wetlands perched above the main zone of saturation are commonly in a position to recharge the regional aquifer, whereas those in contact with the major groundwater zone generally serve as a discharge area for the regional aquifer (O'Brien 1988).
- A wetland which has an organic mat containing a highly permeable upper peat layer might contribute significantly to streamflow but is highly sensitive to changes in groundwater levels, whereas an organic mat with an overall low hydraulic conductivity (common with muck) might have very different effects on streamflow (O'Brien 1988).

Procedure For Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to help maintain adequate stream base flow for natural stream function.***

Objective 1: Target wetland restoration efforts to watersheds which have known or anticipated base flow problems.

Strategy 1.1: Identify watersheds and drainages to be targeted for base flow improvement. Primary target watersheds are streams or stream reaches having documented low stream flows. Secondary target watersheds are streams or stream reaches which lack documented base flow problems but have the greatest potential for problems in the future due to developmental pressures. Tertiary target watersheds are all others.

Rationale: Restoration activities should focus on areas of greatest need.

Procedure:

1. *Identify primary watersheds having known base flow problems from a search of the technical literature and subsequent review of local technical experts.*

2. *Identify watersheds/drainages not having existing base flow problems. Use landuse/landcover coverage to calculate which of these watersheds/drainages have greater than 30 percent of their area in non-forest uses. Use knowledge gained from river basin characterization to identify watersheds and drainages which do not meet the 30 percent non-forest criteria but have substantial landcover change and geologic features which increase the areas vulnerable to decreasing stream base flows.*

3. *Compile information from Steps 1 and 2 and establish a coverage highlighting primary and secondary watersheds for this function.*

Product:

A map identifying the location of primary and secondary target areas for improving stream base flows.

Objective 2: Identify wetlands which receive groundwater discharge and release it to a stream through either surface or subsurface flows.

Strategy 2.1: Identify predisturbance wetlands having significant groundwater inputs to their water budget, based on the following criteria:

a) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and having hydric soil mapping units known to occur at groundwater discharge sites;

b) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and occurring on alluvium at the toe of escarpments which border outwash areas or within alluvial plains having escarpments; and

c) Identify potential wetland sites classified as riverine open, depressional open, or extensive peat open and having evidence of spring/seep areas where groundwater discharge is occurring.

Rationale: Riverine open, depressional open, and extensive open wetlands have a direct hydrologic connection to streams. In a predisturbance condition, many of these wetlands stored groundwater discharge under a forested canopy and slowly released it to streams throughout the summer months. Many riverine open, depresssional open, and extensive peat open wetlands adjacent to streams have been drained. Drainage facilitates the rapid removal of surface water and reduces water storage for release during the warm, dry late summer/fall months when low flows can be a problem. Custer-Norma soil units occur on nearly flat areas and have high water tables that can generate saturated overland flow. (Dinicola 1990). Field work in the Stillaguamish Basin indicates that groundwater discharge regularly occurs at the toe of escarpments on both younger and older alluvium. Physical evidence of groundwater discharge is needed where other criteria are not met.

Procedure:

1. *Review county soil survey data and identify hydric soils areas which result from groundwater discharge.*

2. *Select and highlight potential wetlands classified as riverine open, depressional open, and extensive peat open within primary and secondary watersheds/drainages.*

3. *Overlay soil mapping units identified in Step 1 onto polygons selected in Step 2. Identify the polygons having soil mapping units characteristic of groundwater discharge areas.*

4. *Use best professional judgment to select those sites having an adequate groundwater discharge area to support this function. Code sites selected F7=2. All other sites remain F7=0.*

5. *Select sites coded F7=0 and overlay digital elevation model data, surficial geology, and potential wetland site data. Identify escarpments which border alluvium or outwash. Then select potential wetland sites which lie below and adjacent to these escarpments and code F7=2.*

6. *Select sites coded F7=0. Use field work, local experts, and other available information to identify potential wetland sites which are known to receive groundwater from springs and seeps. Code these sites F7=2.*

Product:

A list of wetland restoration sites which have the greatest potential for contributing to stream base flows.

Objective 3: Identify wetlands which recharge aquifers discharging water to a stream.

Strategy 3.1: Identify areas of highest surficial recharge potential. Then identify areas on outwash and alluvium adjacent to target streams which discharge groundwater as springs and seeps into the stream (F7=2). Finally, identify potential wetland sites within areas of highest recharge potential which have an opportunity to support groundwater discharge wetlands that help maintain stream base flows.

Rationale: The extent to which groundwater supports streamflow is a function of the amount of groundwater in storage and the rate of movement toward surface streams. Wetlands occurring on or adjacent to groundwater recharge areas retain water for extended periods of time, allowing maximum groundwater recharge potential. Conversely, drained wetlands which historically recharged groundwater aquifers have greatly diminished retention time and reduced recharge potential.

Strategy 3.2: Use the following criteria to evaluate which wetlands or potential restoration sites within the surface water recharge area noted above have the greatest potential to recharge groundwater aquifers:

a) A high proportion of the wetland's water budget comes from channel flow, overland runoff, or precipitation;

b) Extended water retention times;

c) Wetland is located near an escarpment where both the topography and groundwater table slope sharply downward from the wetland; and

d) Presence of a constricted surface water outlet or no outlet.

Rationale: Selected groundwater recharge criterion were taken from Marble (1990). Wetlands which retain water for extended periods of time allow for maximum groundwater recharge potential. Conversely, drained wetlands which historically recharged groundwater aquifers have greatly diminished retention time and reduced recharge potential.

Procedure:

1. *Compile existing groundwater resource data for the river basin and identify areas of highest surficial recharge potential. If specific data is not available for the river basin, use surficial geology and digital elevation model data to identify areas of non-tidally influenced alluvium, recessional outwash, and advance outwash.*

2. *Select all sites which are coded F7=0. Identify areas of greatest groundwater recharge potential within primary and secondary watersheds/drainages. Overlay potential wetland site data onto information compiled in Step 1 and select all sites which occur on areas of high groundwater recharge potential. Code these sites F7=3.*

3. *Select sites coded F7=3. Overlay hydric soil layer which highlights soils characteristic of groundwater discharge. Identify potential sites having groundwater discharge soils and recode F7=0. In cases where the site has groundwater discharge soils over only a portion of the site, use best professional judgment to determine potential for groundwater recharge and code accordingly.*

4. *Select sites coded F7=3. Reselect riverine open wetlands and examine the wetland polygon coverage for evidence of a constricted outlet. Use best professional judgment to select riverine open sites having no constricted outlet and recode F7=0.*

Product:

A list of restoration sites which have the greatest potential for recharging groundwater aquifers that support stream base flows through groundwater discharge via springs and seeps.

Objective 4: Identify headwater wetlands which maintain base flows during summer low flows.

Strategy 4.1: Identify depressional open and extensive peat open potential wetland sites located at or near the headwaters of streams that are capable of storing water for release during summer low flows.

Rationale: Headwater wetlands are characterized as water source areas having potential to support stream base flows when retention time is maximized via landscape topography or beaver dams. Information from field-based fisheries biologists in the Stillaguamish Basin support this characterization.

Procedure:

1. *Select depressional open and extensive peat open potential wetland sites occurring within primary and secondary watersheds/drainages. Overlay onto DNR stream data layer and select sites having an outflow but no inflow and having a headwater landscape position. Code these sites F7=4.*

2. *Identify depressional open and extensive peat sites having an inlet and outlet and use aerial photos and best professional judgment to identify sites having the greatest potential to store and release water during base flow conditions. Evaluation criteria should include the location of wetland in relation to stream initiation, water source using surficial geology and soils, and water permanence. Code sites selected F7=4.*

Product:

A list of potential wetland restoration sites having the greatest potential to increase stream base flows during low flow periods.

Objective 5: Evaluate all sites for coding consistency.

Strategy 5.1: Ensure that all selected potential wetland and riparian restoration sites are in primary or secondary watersheds/drainages.

Rationale: It is assumed that the greatest opportunities to help solve problems in a river basin exist when wetlands and riparian areas are restored within primary and secondary watersheds/drainages.

Strategy 5.2: Evaluate each site’s code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a “big picture” view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F7>0. Highlight sites coded F7=2, F7=3, and F7=4 by assigning each a different polygon color. All sites coded F7=0 should be a more neutral color but remain visible.*

2. *Overlay watershed/drainage boundary data onto the colored sites data and delete any F7 coded sites falling outside primary and secondary boundaries. Note any exceptions.*

3. *Overlay DNR stream data and digital elevation model data onto the colored site coverage and visually search for inconsistencies. Use surficial geology, landuse/landcover, and soils to assist in this quality assurance step.*

Products

- A map identifying the location of primary and secondary target areas for improving stream base flows.
- A list of wetland restoration sites which have the greatest potential for contributing to stream base flows.
- A list of restoration sites which have the greatest potential for recharging groundwater aquifers that support stream base flows through groundwater discharge via springs and seeps.
- A list of potential wetland restoration sites having the greatest potential to increase stream base flows during low flow periods.

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Function 8
Groundwater Recharge

Introduction

Groundwater aquifers are used as an important water source for domestic use. The opportunity for surface water to recharge an underlying aquifer system is dependent on a number of relatively static physical conditions which include: soil permeability, surficial geologic materials, depth to water, and topography (Economic and Engineering Services, Inc. 1991). However, human-caused alterations to these physical conditions can impact the proportion of surface water which recharges aquifers. Wetland drainage, forest clearing, soil compaction from agricultural and residential activities, road cuts which intercept groundwater and bring it to the surface, and hard surface barriers (i.e., roads, parking lots, roofs) all reduce recharge potential while increasing surface water runoff.

Wetland restoration can help maintain existing quantities of groundwater for domestic use. Within groundwater recharge areas, the restoration of drained wetlands increases retention time promoting the downward movement of surface water to groundwater aquifers.

Goal

Restore wetlands which have the greatest potential to help recharge groundwater aquifers of importance for human use.

Objective

- Identify potential wetland sites which can recharge groundwater aquifers of importance to humans.

Assumptions

- Not all wetlands are capable of recharging groundwater. The potential for wetlands to recharge groundwater exists when wetlands occur on surficial geology formations which allow the rapid downward movement of water to aquifers.
- High potential for wetland groundwater recharge occurs at the interface between bedrock or till and outwash or alluvium. However, recharge does occur throughout outwash and alluvial deposits.
- Undisturbed outwash soil units are highly permeable soils where groundwater flow is the predominant runoff mechanism (Dinicola 1990).
- Disturbance of outwash soil units increases the chance of Horton overland flow occurring (Dinicola 1990).
- Subsurface flow is the predominant runoff mechanism from undisturbed glacial till on hillslopes (Dinicola 1990).

- Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff (Roth et al. 1993).
- Direct recharge potential to shallow groundwater aquifers is generally moderate to high on alluvium and recessional outwash units except at river outlets where the silty and clayey sediments prevent infiltration of rainwater (Economic and Engineering Services, Inc. 1991).
- The Vashon till typically forms a low permeability barrier to downward water percolation. Recharge of rainwater to the unweathered Vashon till is slow. Shallow groundwater may occur within weathered till perched on top of unweathered till or within thin discontinuous lenses of sand and gravel in some till. Topographic depressions in the upper surface of the unweathered till will trap groundwater that will slowly infiltrate into underlying geologic units and aquifers (Economic and Engineering Services, Inc. 1991).
- The likelihood that water will infiltrate and pass through the surface materials to recharge the underlying aquifer system in dependent on a number of relatively static physical conditions which include: soil permeability, surficial geologic materials, depth to water, and topography (Economic and Engineering Services, Inc. 1991).
- To provide groundwater recharge, the wetland's water source must come from surface water (channel flow or overland flow). Once the water reaches the wetland, it must be detained in the wetland basin. One of the most critical criteria relating to groundwater recharge is site selection (Marble 1990).
- Generally, conditions suitable for groundwater recharge can only exist in palustrine, lacustrine, and riverine systems. Tidal, marine, and estuarine systems have little recharge potential because the elevation head is so low (Marble 1990).
- The porosity of the underlying soil and bedrock conditions determine the potential hydraulic conductivity of a wetland (Marble 1990).
- Precipitation that falls on the land surface will flow over it, remain ponded in depressions, and/or infiltrate into the subsurface. The relative distribution of water involved in each of these processes depends on the slope and permeability of the land surface. In areas of steep uniform slope and high permeability, the water that does infiltrate, and that is not transpired, will move downgradient in the subsurface and discharge in the lowlands near streams or lakes (Winter 1988).
- In most environments, only minimal quantities of water percolate through the unsaturated zone to recharge groundwater during the growing season. Large quantities of water will percolate past the root zone if the water uptake capacities of the plants are met during extended rainy periods, or during the nongrowing season. In areas with high precipitation and where soil water does not freeze, such as the Pacific Northwest, groundwater recharge is high beginning in the fall after plants become dormant (Winter 1988).
- One principle conclusion from numerical modeling of generalized settings is that recharge commonly is localized where thickness of the unsaturated zone is small relative to contiguous points of the landscape. Assuming the water table is relatively flat and the land surface is hummocky, the areas of minimal thickness of the unsaturated zone occur

directly adjacent to surface water or at depressions in the landscape [e.g., wetlands]. The actual volume of recharge at a depression will be variable in space, depending on the size of the depression, permeability of the soil, and amount and type of vegetation that may transpire the water before it percolates past the root zone (Winter 1988).

- Detrimental effects of altering recharge are caused by removal of water. Increasing the efficiency of water removal from areas of flat slope by ditching reduces recharge to groundwater. Not only is less water available because of drainage, but the resulting lowered water table reduces the hydraulic head that provides the driving force for recharge. If a depressional wetland that recharges groundwater is drained, the recharge function is lost. If a recharge wetland is adjacent to a groundwater follow-through or groundwater discharge wetland, these adjacent wetlands will receive less groundwater inflow (Winter 1988).
- The impact of wetland drainage on regional flow systems is not as great as it is for local flow systems. For upland areas, some of the water that seeps from recharge wetlands serves as recharge to regional flow systems. Whether or not the recharge point shifts from one local depression to another in uplands makes little difference to the total regional recharge process (Winter 1988).
- Wetlands on till tend to occupy higher elevations, and as a result are often linked to the headwaters of streams. This juxtaposition of wetlands with streams and permeable materials associates them with aquifers and raises the potential for moderating streamflow (O'Brien 1988).
- Freeze and Witherspoon have indicated that in small aquifers where the water table is near the surface, the recharge area tends to be large in proportion to the discharge area. Therefore, a wetland that overlies a discharge area is in a position to exercise considerable control over groundwater discharge (O'Brien 1988).
- Groundwater discharge has been shown to be important to streamflow in several studies. Groundwater levels may be particularly critical to streamflow in some areas as researchers have shown that a small decline in groundwater level can lead to a cessation of streamflow (O'Brien 1988).
- The alteration of wetlands can have a direct effect on groundwater (O'Brien 1988).
- Wetlands perched above the main zone of saturation are commonly in a position to recharge the regional aquifer, whereas those in contact with the major groundwater zone generally serve as a discharge area for the regional aquifer (O'Brien 1988).
- A wetland which has an organic mat containing a highly permeable upper peat layer might contribute significantly to streamflow but be highly sensitive to changes in groundwater levels, whereas an organic mat with an overall low hydraulic conductivity (common with muck) might have very different effects on streamflow (O'Brien 1988).
- Within the floodplain, it is assumed that wetlands located away from the channel are more effective at recharging alluvial soils than wetlands directly associated with the river channel.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to help recharge groundwater aquifers of importance for human use.***

Objective 1: ***Identify potential wetland sites which can recharge groundwater aquifers of importance to humans.***

Strategy 1.1: Identify geographic areas which function to recharge underground aquifers of importance for human use.

Rationale: Efforts to protect groundwater quality should focus on important aquifer recharge areas based on available technical data.

Strategy 1.2: Identify potential wetlands occurring on groundwater recharge areas.

Rationale: Not all wetlands are capable of recharging groundwater. The greatest potential for wetlands to recharge groundwater exists when wetlands occur on surficial geology formations which allow the rapid downward movement of water to aquifers. Because bedrock and glacial till are generalized as having predominantly shallow subsurface flows, the interface between bedrock or till and outwash or alluvium is a location where substantial groundwater recharge occurs. While high potential for groundwater recharge occurs in wetlands which are at the interface between bedrock or till and outwash or alluvium, recharge can and does occur within wetland and upland areas throughout outwash and alluvial deposits.

Strategy 1.3: Delete alluvial areas at river outlets where silty and clayey sediments prevent infiltration of rainwater.

Rationale: Direct recharge potential to shallow groundwater aquifers is generally moderate to high on alluvium and recessional outwash units except at river outlets where the silty and clayey sediments prevent infiltration of rain water (Economic and Engineering Services, Inc. 1991).

Strategy 1.4: Evaluate which potential restoration sites within recharge areas have the greatest potential to recharge groundwater aquifers when restored. Consider the following features which increase opportunity or effectiveness to provide this function:

a) A high proportion of the wetland’s water budget comes from channel flow, overland runoff, and precipitation;

b) Extended water retention times;

c) Presence of a constricted surface water outlet or no outlet; and

d) landscape position within floodplain but away from the stream channel.

Rationale: To provide groundwater recharge, the wetland's water source must come from surface water (channel flow or overland flow). Once the water reaches the wetland, it must be detained in the wetland basin. One of the most important criteria relating to groundwater recharge is site selection (Marble 1990). Runoff volume is directly related to the level of development in the watershed: the more development, the more runoff (Roth et al. 1993). Within the floodplain, it is assumed that wetlands located away from the channel are more effective at recharging alluvial soils than wetlands directly associated with the river channel.

Procedure:

1. *Use existing technical information and surficial geology data to identify areas of high surficial recharge. If technical reports are not available which identify the areas of high surficial recharge, use surficial geology layer, and highlight mapping units found to have high surficial recharge potential (alluvium, advanced and recessional outwash).*

2. *Overlay potential wetland site data onto the areas of high surficial recharge. Select all potential wetlands occurring within recharge areas and code F8=1. Identify potential wetland sites located within the tidally influenced floodplain area and recode F8=0.*

4. *Select all potential wetlands coded F8=1. Examine the outlet of each selected site and use best professional judgment to delete sites from consideration which do not have a constricted outlet. Overlay soil mapping units characteristic of groundwater discharge soils and use best professional judgment to delete sites from consideration which have >75 percent of area in groundwater discharge soils. Overlay stream data onto surficial geology and floodplain data. Use aerial photos and best professional judgment to identify riverine open sites coded F8=1 on floodplain alluvial soils having a direct association to the river or stream, and delete from consideration. Examples of areas deleted and recoded F8=0 include gravel bars and riparian wetlands adjacent and parallel to the stream.*

5. *Finalize list of sites coded F8=1 having potential to recharge groundwater.*

6. *Overlay surficial geology onto potential wetland restoration sites and highlight sites coded F8=1. Review sites coded F8=1 in relation to sites coded F8=0 and assess appropriateness. Sites in question should be re-evaluated using the above procedures and recoded if necessary.*

Product:

A list of wetland restoration sites having the greatest potential for recharging groundwater aquifers used by humans.

Product

- A list of wetland restoration sites having the greatest potential for recharging groundwater aquifers used for human consumption.

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Function 9
Shoreline Stabilization

Introduction

Shoreline stabilization is the binding of soil at the shoreline or water's edge by wetland plants and the resulting physical dissipation of erosive energy caused by waves, currents, tides, or ice in a basin or channel. Erosional forces can cause substantial shoreline property damage, loss of fish and wildlife habitat, and increased turbidity.

Wetlands serve as a buffer between open water and upland areas and can function to dissipate erosional forces and minimize detrimental impacts to beaches, property, and ecosystems.

Goal

Restore wetlands which have the greatest potential to stabilize shorelines of importance to public/private property and fish and wildlife habitat.

Objective

- Identify wetland restoration sites which function to stabilize shorelines of importance to public/private property and fish and wildlife habitat.

Assumptions

- Fringe wetlands, by definition, are located between open water and dry land. Because of this location, opportunity exists for selected fringe wetlands to buffer the effects of tides and waves.
- Gradient associated scour factors connected with many streams reduce the effectiveness of wetlands to buffer shoreline erosion related to current.
- Rip-rap placed on hydric soils indicate that shoreline stability is required and that at some point in time, a wetland may have performed this function.
- The frictional resistance a wetland offers to erosive energy depends on the vegetated width of the wetland, the density of vegetation, and the height of the vegetation relative to incoming waves and currents. Persistent emergent and woody vegetation are preferred because they offer frictional resistance throughout the year (Marble 1990).
- For a wetland to be valued as a shoreline stabilizer, potentially erosive conditions must be present (i.e., flowing water, long fetch adjacent to eroding areas, and water with low turbidity) (Marble 1990).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to stabilize shorelines of importance to public/private property and fish and wildlife habitat.***

Objective 1: Identify wetland restoration sites which function to stabilize shorelines of importance to public/private property and fish and wildlife habitat.

Strategy 1.1: Identify wetland areas and hydric soil areas which are susceptible to erosional forces. Sites having evidence of erosive forces include:

a) Open water expanses of 100 feet or greater;

b) Boat wakes; and

c) Unstable slopes exceeding 10 percent immediately adjacent to the site.

Rationale: By definition, fringe wetlands are located between open water and dry land and provide the greatest opportunity to buffer the effects of tides and waves. Wave size and energy increases with increased fetch and boat activity. Toe-of-slope erosion increases the instability of the entire slope.

Strategy 1.2: Evaluate the restoration potential of each site by assessing present shoreline stabilization potential compared to the following preferred physical features:

a) Wetland has sheet flow rather than channel flow;

b) Forested, scrub/shrub, and persistent emergent vegetation types should be capable of dominating; high density vegetation conditions are preferred with rigid, persistent plants tall enough to penetrate the entire water column during seasonal flooding; and

c) The average width of vegetation should be greater than 30 feet total, perpendicular to flow to maximize stabilization effectiveness.

Rationale: Selected shoreline stabilization criterion were taken from Marble (1990).

Procedure:

1. *Select all restoration sites classified as estuarine or lacustrine fringe and highlight each by assigning a unique polygon color.*

2. *Review hydrologic investigations data developed by Bortleson et al. (1980) identifying the extent of pre-development estuarine fringe wetlands. Using the coverage which displays the location of known dikes and levees, use aerial photos*

and best professional judgment to identify estuarine fringe restoration sites which can serve to stabilize shorelines and code F9=1.

3. *Select sites classified as lacustrine fringe. Using available aerial photography, overlay available landuse information and topography data onto lacustrine fringe wetlands. Use best professional judgment to identify wetland restoration sites having potential to stabilize shoreline areas used for residential, agricultural, or recreational purposes or having importance as wildlife habitat. Code sites selected F9=1.*

4. *Select sites coded F9=1 and highlight. Determine appropriateness of present coding by scanning all potential restoration sites as well as highlighted sites for opportunity and effectiveness to stabilize shoreline.*

Product

- A list of potential wetland restoration sites which can function to stabilize shorelines if restored.

Reference

Marble, A.D. 1990. A guide to wetland functional design. US Department of Transportation, Federal Highway Administration. Report No. FHWA-IP-90-010

Function 10
Anadromous and Resident Fish Diversity and Abundance

Introduction

Development pressures and associated landuse change have had a significant negative impact on the habitat of anadromous and resident fish in the Pacific Northwest. While each river system is unique in the type and magnitude of habitat loss, fish habitat degradation has occurred throughout the Pacific Northwest from timber harvest, agricultural activities, and residential development. Wetland, riparian, and floodplain alteration have all contributed to a loss of food, spawning gravel cover, and refuge for anadromous and resident fish. Limiting factors for critical stocks of anadromous fishes in North Puget Sound include: lowland flow regime, loss of channel structure from logging, sedimentation of upper watershed, loss of riparian cover and large organic debris, high stream temperatures and low water quality, blocked access to wetland habitats, sediment impact to the estuary, flooding, loss of estuarine wetlands, tide gate and culvert passage problems, summer low flows, loss of winter cover, excessive bedload, degradation of nearshore habitat, scouring of spawning habitat, and water withdrawals (Washington State Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1994).

Landuse practices which impact wetlands have major impacts to fish migration and spawning, incubation, freshwater rearing, and estuarine/saltwater rearing. The loss of wetland and riparian habitat, coupled with other degradation factors, have resulted in increased flood flows, decreased stream base flows, increased sediment inputs, increased water temperature, barriers to fish passage, and reduced stream habitat diversity which all adversely impact fish. Along with these broad watershed-level impacts to fish habitat, evidence is mounting that the loss of wetlands which provide off-channel winter rearing habitat for juvenile coho salmon and sea-run cutthroat trout is a specific limiting factor under certain stream conditions. Cedarholm and Scarlett (1981) believe that on the north coast of Washington, significant increases in natural coho smolt production are possible during winters of extremely high stream flows by increasing the opportunity for coho to find and use small tributary wetlands as winter habitat. Further, work by Beechie et al. (1994) in the Skagit River system indicate that the largest benefits to coho salmon smolt production can be gained by restoring side-channel and distributory slough habitats (i.e., wetlands).

Wetland restoration can contribute to the recovery of anadromous fish runs and the improvement of resident fish habitat. Wetlands are known to help maintain cool water temperatures, retain sediments, store and desynchronize flood flows, maintain stream base flows, and provide food and cover for fish. The restoration or creation of wetlands which provide juvenile coho salmon off-channel winter rearing and cutthroat trout with year-round habitat can improve habitat conditions.

Goal

Restore wetlands which have the greatest potential to increase the diversity and abundance of resident and anadromous fish.

Objectives

- Identify wetland restoration sites recognized by professional fish habitat biologists as having the greatest potential to provide fish habitat considered limiting within the watershed.
- Identify additional wetland restoration sites which have some potential to provide fish habitat considered limiting within the watershed.
- Target the restoration of degraded estuarine wetlands.
- Target the restoration of riparian habitat on stream reaches which support resident and/or anadromous fish.

Assumptions

- Significant increases in natural coho smolt production are possible during winters of extremely high stream flows by increasing the opportunity for coho to find and use small tributary wetlands as winter habitat (Cedarholm and Scarlett 1981).
- Large benefits to coho salmon smolt production can be gained by restoring wetlands which provide side-channel and distributory slough habitats (Beechie et al. 1994).
- Professional fisheries biologists who have worked in, surveyed, and walked individual stream drainages have the best on-the-ground knowledge and understanding of where wetland restoration can be used to improve fish habitat.
- Because of the variability in habitat needs across drainages, experienced fisheries biologists that have a working knowledge of each drainage, have the best technical perspective to make priority judgments.
- Estuarine wetlands provide important habitat for both anadromous fish smolts and adults.
- A lack of large organic debris recruitment from riparian areas can result in a loss of cover and in-stream habitat diversity.
- Unvegetated river bars provide limited opportunity for habitat restoration.
- It is assumed that headwater wetlands have adequate opportunity to provide off-channel rearing habitat for juvenile coho salmon in most cases. Experience in the Stillaguamish Basin indicates that coho salmon are spawning in small unmapped feeder streams which

flow into these headwater wetlands providing adequate opportunity for juvenile fish to move downstream into them.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to increase the diversity and abundance of resident and anadromous fish.***

Objective 1: Identify wetland restoration sites recognized by professional fish habitat biologists as having the greatest potential to provide fish habitat considered limiting within the watershed.

Strategy 1.1: Compile existing fish habitat literature which identifies wetland restoration sites capable of providing improved fish habitat. Supplement this information by using fisheries professionals familiar with each drainage to summarize drainage habitat needs and identify wetland restoration sites capable of addressing these needs.

Rationale: Restoration activities should focus on areas of greatest need based on local professional fisheries biologists.

Procedure:

1. *Develop a map of each watershed highlighting the location of each stream and its name or tributary number, the extent of anadromous fish runs, and the location of potential wetland restoration sites.*

2. *If available, use information in existing reports to highlight wetland sites which have potential to improve fish habitat if restored. Select local fish habitat biologists who have field knowledge of each watershed, provide them with customized wetland maps developed in Step 1, and have them use their best professional judgment to identify restoration sites which have the greatest potential for fish habitat improvement. Circle sites on maps provided.*

3. *Using information compiled in Step 2, code sites selected in reports and by fisheries biologists F10=1.*

Product:

A list of potential wetland restoration sites recognized by local fisheries biologists as having the greatest potential to meet fish habitat needs within each stream system.

Objective 2: Identify additional wetland restoration sites which have potential to provide fish habitat considered limiting within the watershed.

Strategy 2.1: Use GIS-based fish habitat data and aerial photos to identify additional wetland restoration sites not identified by reports or local fisheries biologists, but which have potential to provide habitat for cutthroat trout and/or juvenile coho salmon if restored.

Rationale: While it is anticipated that a majority of wetland restoration sites capable of providing important fish habitat have been identified by local fisheries biologists, it is not realistic to assume that all sites will be identified by local biologists.

Strategy 2.2: Identify unvegetated river bars and delete from further consideration. Within sites coded F10=2, identify headwater wetlands accessible to coho salmon and having an outlet but no inlet on the DNR stream data layer. Maintain F10=2 site coding unless it is known that no coho spawning habitat exists above the wetland.

Rationale: While classified as a wetland, unvegetated river bars provide limited opportunity for habitat restoration. It is assumed that headwater wetlands have adequate opportunity to provide off-channel rearing habitat for juvenile coho salmon in most cases. Experience in the Stillaguamish Basin indicates that coho salmon are spawning in small unmapped feeder streams which flow into these headwater wetlands providing adequate opportunity for juvenile fish to move downstream into them.

Procedure:

1. *Select all restoration sites classified as riverine open, depressional open, or extensive peat open and highlight. Reselect sites coded F10=1 and remove highlight. Onto remaining highlighted sites, overlay stream access data for cutthroat trout and coho salmon.*

2. *Using published fish access data and unpublished information from local biologists when available, identify restoration sites which have potential to be accessed by either cutthroat trout or coho salmon and code F10=2. Use aerial photography under magnification to identify unvegetated river bars coded F10=2, and recode F10=0.*

Product:

A list of additional wetland restoration sites which have some potential to address known fish habitat needs within each stream system.

Objective 3: Target the restoration of degraded estuarine wetlands.

Strategy 3.1: Identify historic estuarine fish habitats that have been degraded by dikes other human alterations.

Rationale: Substantial literature documents the important value of estuarine wetlands to both anadromous fish smolts and adults.

Procedure:

1. *Review local information on the historic location and extent of estuarine habitat. Then review hydrologic investigations data developed by Bortleson et al. (1980) identifying the extent of pre-development estuarine fringe wetlands. Locate dikes and use best professional judgment to identify estuarine fringe restoration sites which can serve as anadromous fish habitat if restored. Code sites selected F10=3.*

Product:

A list of estuarine wetland restoration sites which have potential to provide habitat for anadromous fish.

Objective 4: Target the restoration of riparian habitat on stream reaches which support resident and/or anadromous fish.

Strategy 4.1: Identify stream reaches not having a predominant scrub-shrub/forested vegetation class but supporting resident or anadromous fish.

Rationale: A lack of large organic debris recruitment from riparian areas can result in a loss of cover and in-stream habitat diversity.

Strategy 4.2: Remove riparian reaches from consideration if they occur within timber harvest areas.

Rationale: Timber harvest of riparian areas is regulated by Timber-Fish-Wildlife guidelines designed to minimize impacts to fish habitat.

Procedure:

1. *Using the exposed riparian reach data layer developed earlier, overlay stream fish access data. Identify exposed stream reaches which are accessed by one or more anadromous or resident fish species and code F10=4.*

2. *Select all sites coded F10=4 and overlay the landuse/landcover coverage. Using aerial photography under magnification and land use data, select all exposed reaches being managed for timber harvest and recode F10=0.*

Product:

A list of stream reaches in need of riparian restoration to improve fish habitat.

Objective 5: Evaluate all sites for coding consistency.

Strategy 5.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F10>0. Highlight sites coded F10=1, F10=2, F10=3, and F1=4, and assign each a different polygon/arc color. All sites coded F1=0 should be a more neutral color but remain visible.*

2. *Overlay stream fish access data and DNR stream data onto the colored site data layer and visually search for inconsistencies. Sites having questionable determinations should be referred to local fisheries biologists for a determination.*

Products

- A list of potential wetland restoration sites recognized by local fisheries biologists as having the greatest potential to meet fish habitat needs within each stream system.
- A list of additional wetland restoration sites which have some potential to address known fish habitat needs within each stream system.
- A list of estuarine wetland restoration sites which have potential to provide habitat for anadromous fish.
- A list of stream reaches in need of riparian restoration to improve fish habitat.

References

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Function 11
Migratory Water Bird Diversity and Abundance

Introduction

Migratory water birds represent a diverse group of wildlife species of recreational and economic importance to humans. Extensive agricultural, industrial, and residential development within estuaries and river floodplains have resulted in a significant loss of, or disturbance to, water bird wintering and migration habitat in western Washington. This loss of habitat forces birds to seek alternative habitats which can increase competition for food and space, expose birds to greater risk of predation or weather related mortality, and increase the risk of disease outbreaks.

Restoring wetlands that once provided important migration and wintering habitat within Puget Sound can help stabilize and, in some cases, increase populations where critical habitat is limiting or where new habitat has been created through landuse change. The conversion of forested wetlands to emergent/open water wetlands has created new wintering, migration, and production habitat for some migratory water bird species while degrading habitat for others.

Due to the diversity and geographic extent of habitat used by water birds, the identification of limiting factors is often unclear and generally over simplified. Many times, limiting factors are identified based solely on the loss of predisturbance habitat types. One exception is the dramatic population declines of black brandt in Puget Sound which were attributed to concurrent declines in eelgrass beds (Bob Zeigler pers. com.). Many waterfowl species, in particular, have demonstrated the ability to adapt to new habitat opportunities as they become available. For example, some waterfowl species that traditionally wintered in the central valley of California are now wintering in more northern coastal states, like Washington, where lower floodplain farming practices (i.e., Skagit Valley) provide an abundant, readily available winter food source that limited wintering habitat prior to clearing and floodplain agriculture. However, many migratory shorebirds and wading birds have demonstrated less adaptive abilities when confronted with a loss or alteration to their habitat.

Goal

Restore wetlands which have the greatest potential to increase the diversity and abundance of migratory water birds.

Objectives

- Identify degraded wetlands which currently provide important habitat for water birds.
- Identify wetlands that are part of a larger non-floodplain wetland complex known to support migratory water bird concentrations.

- Identify wetlands that currently provide limited habitat for water birds but have the greatest potential to provide important habitat if restored.

Assumptions

- In general, as wetland size increases, so does its habitat diversity and stability. Wetland size limits the number of water birds capable of using an individual wetland and generally limits species richness (Adamus et al. 1991).
- Small wetlands occupy a critical link in the breeding biology of such common ducks as the mallard, pintail, blue-winged teal, gadwall, and shoveler. Because breeding ducks are territorial, ten one-acre wetlands provide habitat for many more duck pairs than does one ten-acre wetland (Wildlife Management Institute 1995).
- Interspersion of vegetation and water and the length of shoreline correlate directly with bird species diversity (Marble 1990).
- Increases in vegetative structural diversity and in the number of plant communities, correlate with increased bird species diversity (Marble 1990).
- Providing special habitat needs for migratory birds which use wetlands (i.e. tree cavities for cavity nesting ducks) increases the opportunity for use by a particular species.
- Estuarine and tidally influenced freshwater wetlands have substantial potential to provide habitat for water birds (Mitsch and Gosselink 1993).
- Wetlands that are near wetlands of a different type are more likely to support notable on-site diversity and/or abundance of wetland-dependent birds (Adamus et al. 1991).
- Wetland complexes consisting of a diversity of wetland sizes and habitat types in close proximity are more likely to provide migratory water birds with all necessary food, cover, and security requirements than individual wetlands (Gersib et al. 1989).
- Wetlands located close to tidal waters or a major river are more likely to support a notable on-site diversity of wetland-dependent birds than are those not located near such a body of water (Adamus et al. 1991). Freshwater wetlands located within five miles of estuarine or freshwater tidal wetlands larger than five acres are expected to maximize water bird support opportunities (Marble 1990).
- Wetlands supporting moderate to large-sized mudflats with good visibility and adjoined by emergent marsh are more likely to support a diversity and/or abundance of migratory water birds (Marble 1990).
- Wetlands without major, frequent disturbances are more likely to support a notably great on-site diversity and/or abundance of wetland-dependent birds (Adamus et al. 1991). Wetlands capable of providing security from disturbance must have either a visual barrier or adequate distance from the sources of disturbance.
- Waterfowl are known to use wetlands having an open water component or emergent vegetation which allows access during migration and wintering seasons.

- Wintering habitat use by water birds is restricted to ice free conditions. Wetlands having substantial groundwater inputs are capable of maintaining some open water when other wetlands are covered with ice.
- For dabbling ducks within the Puget Sound region, it appears that farmland adjacent to intertidal areas is an essential component of coastal habitat complexes. (Baldwin and Lovvorn in draft).
- Regarding farmland adjacent to intertidal areas, three aspects seem especially pertinent: crop or forage type, flooding of fields, and refuge from human disturbance (Baldwin and Lovvorn in draft).
- Surface water appears to serve antipredator functions and declines in importance if adequate refuges from disturbance are provided (Baldwin and Lovvorn in draft).
- Telemetry data indicate that the dispersion of widgeon and pintails feeding at night was strongly influenced by the location of refuges and other human disturbance. Refuges from hunting and other human disturbance are important to the attractiveness of coastal habitat complexes and influence the dispersion of ducks in feeding fields (Baldwin and Lovvorn in draft).
- When migratory water bird concentrations occur, wetlands in close proximity to the concentration area have increased opportunity to provide habitat.
- It is assumed that *Sphagnum* bogs and slope wetlands have limited potential to provide important migratory water bird habitat.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to increase the diversity and abundance of migratory water birds.***

Objective 1: Identify degraded wetlands which currently provide important habitat for water birds.

Strategy 1.1: Identify wetland restoration sites which currently support waterfowl concentrations.

Rationale: The PHS database and other available state and local data sources represent the best available information on the subject.

Procedure:

1. *Using Washington State Department of Fish and Wildlife Priority Habitat Species coverage, identify the recorded locations of wood ducks, cavity nesting ducks, and waterfowl concentrations. When available, identify additional locations of migratory bird concentration areas using other information sources. Overlay this*

migratory water bird data onto potential wetland site information. Select all potential sites which fall within the concentration areas and code F11=1.

Product:

A list of restoration sites which currently provides important habitat for migrating and wintering water birds.

Objective 2: Identify wetlands which are part of a larger non-floodplain wetland complex known to support migratory water bird concentrations.

Strategy 2.1: Identify wetland restoration sites five acres or greater in size which occur within a 2.5 mile radius of a known water bird concentration area based on PHS or other migratory bird data. Delete sites from consideration which are classified as slope wetlands or known to be *Sphagnum* bogs.

Rationale: Migratory birds are highly mobile and can, at some energetic expense, move many miles to meet their daily needs. To maximize energetic efficiency during both migration and wintering, habitat which meets all life requisites must be in close proximity and provide adequate security to minimize disturbance. Wetland complexes consisting of a diversity of wetland sizes and habitat types meet this criteria. Likewise, wetland complexes provide the diverse habitat required for water bird production. Although traditional water bird production habitat was limited due to the predominance of forested wetlands in a predisturbance condition, considerable potential for water bird production habitat now exists due to clearing and agricultural use.

When migratory water bird concentrations occur, wetlands within close proximity to the concentration area have increased opportunity to provide a habitat function. Marble (1990) notes that freshwater wetlands larger than five acres, located within five miles of estuarine or freshwater tidal wetlands, are expected to maximize water bird support opportunities. Experience in the Stillaguamish Basin indicates that when a five mile radius was drawn around known water bird concentration areas, nearly the entire lower basin fell within at least one radius arc. To avoid the “blanket” coding of nearly all lower wetlands, a 2.5 mile radius was used to discern habitat potential. Finally, it is assumed that *Sphagnum* bogs and slope wetlands have limited potential to provide important migratory water bird habitat.

Strategy 2.2: If site specific information is available, evaluate each wetland restoration site for potential to reestablish one or more of the following physical features:

a) An open water component within an emergent wetland which allows water bird access during migration and wintering seasons and provides security and brood rearing habitat;

b) A diversity of wetland plant species or one wetland plant community that is limited within the complex;

c) An increase in seasonal ponding in the spring/early summer (to July 15 for brood rearing) and fall;

d) Groundwater inputs capable of maintaining some open water during most of the winter; and

e) Disturbance minimal or site has large area of unobstructed views or a visual barrier.

Rationale: The opportunity for water birds to use a restoration site increases if it is near a wetland or wetlands used by large numbers of water birds. Factors which can effect use include physical access, available food, and security.

Procedure:

1. *Select and highlight sites coded F11=1. Overlay floodplain data onto these water bird concentration areas and delete sites from consideration which fall within the floodplain area.*

2. *Establish a shaded 2.5 mile radius around each concentration area identified in Step 1. Overlay this information with potential wetland site data. Select all potential wetland sites five acres or larger in size. Then reselect those sites which fall within each shaded 2.5 mile radius and code F11=2.*

3. *Select all sites coded F11=2. Reselect sites classified as slope wetlands or known to be Sphagnum bogs and recode F11=0.*

4. *Use aerial photos and site specific information when available to evaluate each site for potential to support physical features noted in Strategy 2.2 and delete sites having limited potential to provide one or more of these physical features.*

5. *Select all sites coded F11=2. Reselect sites classified as slope wetlands and sites of known Sphagnum bogs and recode F11=0.*

Product:

A list of wetland restoration sites which are part of a non-floodplain wetland complex, and have potential to provide important migratory water bird habitat.

Objective 3: Identify wetlands which currently provide limited habitat for water birds but have the greatest potential to provide important habitat if restored.

Strategy 3.1: Identify wetland restoration sites which have the greatest potential for providing migratory water bird habitat when restored. Potential migratory water bird habitat should include:

a) tidally influenced estuarine and freshwater wetlands;

b) freshwater wetlands five acres or greater in size within 2.5 miles of tidally influenced wetlands;

c) wetlands five acres or greater in size within one mile of agricultural areas in the floodplain or along coastlines;

d) wetlands five acres or greater in size within a one mile radius of agricultural areas outside of the floodplain; and

e) no *Sphagnum* bogs or slope wetlands.

Rationale: Tidally influenced wetlands provide regionally important shorebird habitat in and around Puget Sound. Wetlands located close to tidal waters or a major river are more likely to support a notable on-site diversity of wetland-dependent birds than are those not located near such a body of water (Adamus et al. 1991). Marble (1990) notes that freshwater wetlands located within five miles of estuarine or freshwater tidal wetlands larger than five acres are expected to maximize water bird support opportunities. Experience in the Stillaguamish Basin indicated that when a five mile radius was drawn around known water bird concentration areas, nearly the entire lower basin fell within at least one radius arc. To avoid the "blanket" coding of nearly all lower wetlands, a 2.5 mile radius was used to discern habitat potential. The one mile radius chosen for floodplain wetlands is arbitrary and based on best professional judgment. It is assumed that *Sphagnum* bogs and slope wetlands have limited potential to provide important migratory water bird habitat.

Procedure:

1. *Select potential wetland sites classified as estuarine fringe and code F11=3.*

2. *Establish a shaded 2.5 mile radius around all existing estuarine fringe wetlands. Overlay this information with potential wetland site data. Select all potential wetland sites five acres or larger in size. Then reselect those sites which fall within each shaded 2.5 mile radius and code F11=3.*

3. *Overlay floodplain boundary and landuse/landcover data onto potential wetland site data. Select all potential wetlands within the floodplain boundary which are five acres or greater in size. Using the landuse/landcover data, use best*

professional judgment to reselect potential wetland sites which are in, or within one mile of agricultural landuses, and code F11=3.

4. *Select all wetlands within one mile of the coastline that are five acres or greater in size and code F11=3.*

5. *Use landuse/landcover data to identify agricultural areas outside of the floodplain boundary. Use aerial photos and best professional judgment to determine potential of these agricultural areas to provide habitat for migratory water birds. When agricultural areas appear suitable, select all potential wetlands within the agricultural area which are five acres or greater in size and code F11=3. Use best professional judgment to select sites which are within one mile of agricultural areas, and five acres or greater in size, and code F11=3.*

6. *Select all sites coded F11=3. Reselect sites classified as slope wetlands and sites of known Sphagnum bogs, and recode F11=0.*

Product:

A list of wetland restoration sites within floodplains and agricultural areas having the greatest potential to provide migratory water bird habitat if restored.

Objective 4: Evaluate all sites for coding consistency.

Strategy 4.1: Evaluate each site's code designation in relation to all other potential wetland sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F11>0. Highlight sites coded F11=1, F11=2, and F11=3 by assigning each a different polygon color. All sites coded F11=0 should be a more neutral color but remain visible.*

2. *Overlay landuse/landcover, 2.5 mile radius circles, and floodplain data onto the colored site data layer and visually search for inconsistencies.*

Products

- A list of restoration sites which currently provide important habitat for migrating and wintering water birds.

- A list of wetland restoration sites which are part of a non-floodplain wetland complex and have potential to provide important migratory water bird habitat.

- A list of wetland restoration sites within floodplains and agricultural areas having the greatest potential to provide migratory water bird habitat if restored.

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Function 12
<u>Aquatic Diversity and Abundance</u>

Introduction

Aquatic diversity encompasses the ability of a wetland to support a characteristic group of native plants and animals during all or part of their life cycle. Both direct and indirect wetland impacts such as hydrologic alteration, landuse change, and habitat fragmentation adversely affect the diversity and abundance of native plant and animal communities that use a wetland. In general, as disturbance increases, species diversity may increase or decline, but complexity decreases as non-native species tend to invade and dominate. The restoration of wetlands can serve as a tool for reestablishing and maintaining native plant and animal communities within wetland systems.

Wetland restoration can be used to reestablish near-natural hydrologic conditions which once supported predisturbance native species richness and abundance. Once natural hydrologic inputs are reestablished, time will be required to create the predisturbance conditions most suited for native plant and animal species.

Goal

Restore wetlands which have the greatest potential to increase native aquatic diversity and abundance.

Objectives

- Identify wetlands having functioning ditches, tile, canals, levees, or similar artificial features that change the retention time of water or alterations such as tilling, filling, excavation, addition of inlets, or blockage of outlets.

- Identify wetlands which support or once supported rare or unique aquatic plant communities.

Assumptions

- Wetlands without functioning ditches, canals, levees, or similar artificial features that cause water to leave faster than would occur under natural conditions are more likely to have great on-site diversity and/or abundance of fish and invertebrates than those with such structures (Adamus et al. 1991).
- Unaltered wetlands are more likely to exhibit a notably great on-site diversity and/or abundance of fish and invertebrates than those that have been altered by tilling, filling, excavation, addition of inlets, or blockage of outlets (Adamus et al. 1991).

- Wetlands that are tidally influenced, located near large water bodies, or within large drainages are more likely to provide a notably great on-site diversity and/or abundance of fish and invertebrates (Adamus et al. 1991).
- Critical habitat factors affecting aquatic diversity and abundance are salinity, temperature, substrate, current velocity, dissolved oxygen, vegetative composition, and the interspersion of vegetation and water. Stagnation is a negative along with acidic moss wetlands, hypersaline wetlands, and very shallow wetlands (Marble 1990).
- Wetland vegetation provides a source of nutrients, protective cover, and temperature moderation by providing shade. Vegetation in the form of detritus is critical to the fishery food chain in most riverine systems. Factors to be evaluated include water quality, water quantity, cover, substrate, interspersion, and food. Assume that a diversity of site conditions will in turn create a diversity of organisms (Marble 1990).
- Peat wetlands are unique aquatic systems which are limited in distribution and have no potential for replacement in one human lifetime.
- Wetlands or wetland plant communities which are locally recognized by river basin residents as important to aquatic diversity must be identified and ranked as high priority for restoration.
- In general, wetland restoration sites less than five acres in size have diminished potential to provide a substantial increase in aquatic diversity and abundance. However, there are exceptions to this general rule within selected species guilds (e.g., amphibians).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to increase native aquatic diversity and abundance.***

Objective 1: ***Identify wetlands having functioning ditches, tile, canals, levees, or similar artificial features that change the retention time of water or alterations such as tilling, filling, excavation, addition of inlets, or blockage of outlets.***

Strategy 1.1: Identify predisturbance estuarine and tidally influenced freshwater wetlands that have been altered by diking and drainage.

Rationale: Wetlands that are tidally influenced are more likely to provide on-site diversity and/or abundance of fish and invertebrates (Adamus et al. 1991). Extensive wetland alteration has occurred within Puget Sound estuaries. Data compiled by Bortleson et al. (1980) indicates that extensive diking and bank stabilization projects (beginning in the early 1870's) have reduced habitat abundance as estuarine wetlands were converted to agricultural land.

Strategy 1.2: Identify freshwater wetlands that have been altered by the construction of ditches, canals, dikes or through tilling, filling, or outlet alteration and are located near or down stream from large water bodies or in the lower reaches of major rivers.

Rationale: Undisturbed wetlands are more likely to provide a notably greater on-site diversity and/or abundance of native fish, wildlife, plants, and invertebrates than disturbed wetlands. Wetlands located near large water bodies or within large drainages are more likely to provide a notably great on-site diversity and/or abundance of fish and invertebrates (Adamus et al. 1991).

Strategy 1.3: Identify extensive wetland areas of reed canarygrass (*Phalaris arundinacea*).

Rationale: Field observations within Puget Sound watersheds indicate that reed canarygrass has invaded many wetland areas, resulting in reduced native plants species diversity and abundance. Extensive work is currently underway by others to identify and control non-native cordgrasses (*Spartina* sp.). For this reason, *Spartina* control will not be addressed here.

Procedure:

1. *Select sites classified as estuarine fringe. Review local estuary plans and hydrologic investigations data developed by Bortleson et al. (1980) identifying the extent of potential sites classified as estuarine fringe. Locate dikes and reselect the estuarine fringe restoration sites which through restoration have the potential to increase aquatic diversity and abundance. Code F12=1.*

2. *Use best professional judgment to delineate the lowland area associated with large water bodies and river systems which have substantial landuse/landcover change due to human development. Using NWI data, aerial photography under magnification, and site information, select wetlands within the established lowland area which are altered by drainage, tiling, diking, tillage, or other alteration. Code sites selected F12=1. Select sites coded F12=1 and reselect all sites which are less than five acres in size and recode F12=0.*

3. *Use site specific information and aerial photos to identify potential wetland restoration sites dominated by reed canarygrass and code F12=1. Work to control the size and extent of reed canarygrass at all restoration sites.*

Product:

A list of potential wetland restoration sites which have the greatest potential to provide aquatic diversity and abundance.

Objective 2: Identify wetlands which support or once supported rare or unique aquatic plant communities.

Strategy 2.1: Identify the location of *Sphagnum* peat bogs.

Rationale: Peat wetlands are unique systems which are limited in distribution and have no potential for replacement in one human lifetime.

Strategy 2.2: Work with local wetlands ecologists/botanists to identify wetlands or wetland plant communities which are recognized within the river basin as important to the aquatic diversity of the area.

Rationale: Wetlands or wetland plant communities which are recognized by river basin residents as important to aquatic diversity must be identified and ranked as high priority for restoration.

Procedure:

1. *Using soil survey data, Peat Resources of Washington by Rigg (1958), and local experts, identify Sphagnum peat wetlands/soil areas. Overlay this information onto potential wetland sites data and select sites which lie within identified areas. Code selected sites F12=2.*

2. *Contact natural resource managers in river basin to identify wetland plant communities which have been recognized as providing important aquatic diversity. Use available data sets and local experts to identify sites which meet established criteria and code F12=2.*

Product: A list of potential wetland restoration sites which have the greatest potential to support rare or unique aquatic plant communities.

Objective 3: Evaluate all sites for coding consistency.

Strategy 3.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F12>0. Highlight sites coded F12=1 and F12=2 by assigning each a different polygon color. Select sites coded F12=0 and five acres or more in size, and color a more neutral but visible color.*

2. *Overlay stream and landuse data onto the colored site data layer and visually search for inconsistencies. Use peat soils data to assist in this quality assurance step.*

Products

- A list of potential wetland restoration sites which have the greatest potential to provide aquatic diversity and abundance.

- A list of potential wetland restoration sites which have the greatest potential to support rare or unique aquatic plant communities.

References

Adamus, P.R., L. Stockwell, E. Clairain, Jr., M. Morrow, L. Rozad, and R. Smith. 1991. Wetland Evaluation Technique (WET) Volume I: Literature review and evaluation rationale. US Army Corps of Engineers, Wetlands Research Program Technical Report WRP-DE-2. 287 pp.

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Function 13
Rare, Threatened, and Endangered Species Diversity and Abundance

Introduction

Species declines, extirpation, or extinction have resulted from both human impacts (i.e., destruction of habitat, poisoning from pesticide/herbicide use, competition from introduced non-native invasives, indiscriminate killing/over harvest) or climatic change. Unfortunately, the causes of species declines are complex and not fully understood. Natural systems are in a dynamic interdependent state of equilibrium. The loss of species diversity and abundance alters this equilibrium and the food chain which it supports. As species are lost, opportunities to find solutions to medical, agricultural, and industrial problems decrease. Species that have been adversely impacted by humans also serve as biological indicators of our level of environmental stewardship.

Wetland restoration can help maintain or increase species diversity and abundance of rare, threatened, or endangered plants and animals dependent on wetland habitat. The restoration of wetlands within close proximity to existing rare, threatened, or endangered species populations can provide new opportunities for relocation or expansion that were not available prior to restoration. However, our lack of understanding inhibits our ability to clearly define and allow individual species limiting factors.

Goal

Restore wetlands which have the greatest potential to provide habitat for rare, threatened, or endangered species.

Objective

- Identify wetland restoration sites having the greatest opportunity to provide habitat for rare, threatened, and endangered species.

Assumptions

- The closer a wetland restoration site is located to the occurrence of a rare, threatened, or endangered species the greater the likelihood of use.
- The life requisites of individual rare, threatened, or endangered birds, amphibians, reptiles, plants, or animals must be understood and replicated at the restoration site to have the greatest opportunity for use by a target species.
- Targeting restoration efforts to wetlands existing within a home range or immediate proximity to a listed species occurrence provides the greatest potential for habitat utilization.

- It is assumed that sites within species occurrence circles high in a watershed and away from non-timber human disturbance have little if any potential for restoration.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to provide habitat for rare, threatened, or endangered species.***

Objective 1: ***Identify wetland restoration sites having the greatest opportunity to provide habitat for rare, threatened, and endangered species.***

Strategy 1.1: Identify the location of each rare, threatened, and endangered species within the river basin which require wetlands for one or more life requisites.

Rationale: Before restoration sites can be selected, locations of rare, threatened, or endangered species must identified.

Strategy 1.2: Identify potential restoration sites existing within species occurrence circles and having pre-development biological or chemical parameters which have the greatest potential to satisfy individual life requisites of listed species. Radius circles should be established using best professional judgment. For example, a plant species occurring at one riverine wetland should have an elongated circle that extends upstream and downstream of the existing site. Amphibians using small depressional closed wetlands may have a 0.25 mile or 0.50 mile radius around the occurrence record.

Rationale: Targeting restoration efforts to wetlands existing within a home range or immediate proximity to a listed species occurrence provides the greatest potential for habitat utilization.

Strategy 1.3: Delete species occurrence circles from consideration which occur high in watersheds and away from non-timber human disturbance.

Rationale: It is assumed that sites within species occurrence circles high in a watershed and away from non-timber human disturbance have little if any potential for restoration.

Procedure:

1. *Acquire lists of rare, threatened, or endangered species known to occur in the basin. At a minimum use Washington State Department of Fish and Wildlife Priority Habitats and Species (PHS), information from local jurisdictions and tribes, Washington Rivers Information System (WARIS), and Washington State Department of Natural Resources Heritage data sets. Identify and list species that use wetlands for one or more life requisites. For rare, threatened, or endangered*

plant species, compare these listed species to a list of hydrophytic plants and delete non-hydrophytic plants from consideration.

2. *When occurrence records are identified as point data, establish a shaded radius circle around each point occurrence. Radius circles should be established using best professional judgment. For example, a plant species occurring at one riverine wetland should have an elongated circle that extends upstream and downstream of the existing site. Amphibians using small depressional closed wetlands may have a 0.25 mile or 0.50 mile radius around the occurrence record. Occurrence data presented as polygons should be used as is. Develop a data coverage of all rare, threatened, and endangered species that use wetlands for at least one life requisite. Overlay stream data and landuse data and use best professional judgment to determine which occurrences are within areas which have been impacted by direct human disturbance. Submit for review by local experts. Delete sites from consideration which occur high in watersheds and away from non-timber human disturbance.*

3. *Overlay the species occurrence data layer developed in Step 2 onto potential wetland restoration site data, and select all potential wetland restoration sites occurring within 0.25 mile occurrence circles or polygons. Code selected sites F13=1. When large potential wetland restoration sites occur outside, but very near, occurrence circles or polygons, use best professional judgment to determine if site should be coded F13=1.*

4. *When site specific data is available for sites coded F13=1, evaluate if each site can reestablish conditions suitable for meeting target species life requisites. If needed habitat conditions can not be reestablished through restoration, delete site from further consideration.*

Objective 2: Evaluate all sites for coding consistency.

Strategy 2.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites coded F13=1 and assign a distinct polygon color. All sites coded F13=0 should be a more neutral color but remain visible.*

2. *Using the coverage which highlights the occurrence points and polygons of wetland dependent rare, threatened, and endangered species, overlay potential*

wetland site and stream data onto this layer and visually search for inconsistencies.

Product

- A list of wetland restoration sites which have the greatest potential to provide habitat for rare, threatened, and endangered species.

Function 14
Food Chain Support

Introduction

Food chain support is the production of organic material and its subsequent physical transport out of a wetland to areas down stream (Marble 1990). Within a watershed or basin, a food web exists consisting of producers and consumers. Organic matter which reaches a stream system is consumed by fish and aquatic invertebrates which, in turn are consumed by higher level predators. Areas which produce large amounts of organic matter provide essential food for many fish and wildlife species of importance to humans. The loss of wetland areas which provide food chain support adversely impact fish and wildlife which depend on these food sources.

Wetlands are highly productive biological systems capable of providing a food chain support function by exporting large amounts of organic matter when hydrologically linked to other surface water systems.

Goal

Restore wetlands which have the greatest potential to provide food chain support.

Objective

- Identify wetland restoration sites which have the greatest potential to provide food chain support.

Assumptions

- There are three principal aspects of a wetland which establish its ability to produce and export organic material: a) plant productivity; b) nitrogen fixing ability from nitrogen fixing bacteria and some blue-green algae; and c) capacity for physical dispersal of food sources (Marble 1990).
- The gravitational movement of materials in drainage waters from terrestrial to aquatic ecosystems is the major link between land and water in the biological world. The tremendous plant biomass produced in Northwest forests and in riparian zones play a major role in this linkage. Primarily, this involves the transfer of dissolved organic matter and particulate matter (detritus) from riparian zones and the entire watershed to the stream system. This transfer of organic matter to streams is the major source of energy for most coastal streams and accounts for as much as 99 percent of the energy input in small forest streams. The remaining energy contribution is derived from photosynthesis within these streams by mosses, algae, and aquatic vascular plants (Albright et al. 1980).

- The transport of organic materials is the most critical element in a wetland's production export capability. To transport organic materials, the wetland must be linked hydrologically to downstream wetlands via an outlet, or operate as an adjacent fringe wetland in an existing basin. Major export occurs during flood events. Contact between surface water and macrophytes should be maximized. Generally surface water must flow (high velocities are a negative) through a wetland rather than stagnate. The balance between vegetation and open water is important, as the vegetation must not be so dense as to impede circulation, but have a density high enough to be productive. Optimum is high density of macrophytes in small patches throughout the wetland (Marble 1990).
- Selected studies from the literature show that mean net primary productivity values were as follows: sedge-dominated marshes produced 10.4 metric tons per hectare per year ±0.94 (standard deviation); cattail and reed marshes produced 27.4 ±6.7 and 21.0 ±5.8 metric tons per hectare per year, respectively; freshwater tidal marshes produced 16.2 ±3 metric tons per hectare per year; bogs, fens and muskegs produced 9.3 ±4.6 metric tons per hectare per year; swamp forests produced (above ground NPP only) 10.5 ±3.3 metric tons per hectare per year; and grassland produced 5.1 ±1.5 metric tons per hectare per year (Richardson 1978).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to provide food chain support.***

Objective 1: ***Identify wetland restoration sites which have the greatest potential to provide food chain support.***

Strategy 1.1: Identify restoration sites having physical features capable of transporting organic matter to a stream system.

Rationale: Food chain support requires the production of organic material and its subsequent physical transport out of a wetland to areas downstream or to deeper waters within the same basin (Marble 1990). Riverine open, depressional open and all fringe wetlands are hydrogeomorphic subclasses having the physical features needed to transport materials.

Strategy 1.2: Identify restoration sites capable of flooding regularly.

Rationale: Major export occurs during flood events, since the energy produced by these events picks up and carries organic matter which has accumulated on wetland substrates.

Strategy 1.3: Identify restoration sites which meet one or more of the following conditions:

a) Site supports a diversity of wetland plant communities (i.e. emergent, aquatic bed, scrub/shrub, and forested) when restored;

b) Site has macrophytes in constant contact with water; and

c) Site supports a high interspersion of vegetation and open water.

Rationale: Although scrub/shrub and forested macrophytes produce less organic material than emergent and aquatic bed macrophytes, the larger macrophytes produce materials during periods when the smaller macrophytes are in a less productive state, therefore contributing seasonal stability to the food export supply (Marble 1990). Wetlands which are permanently flooded may also function well in production export, as long as the contact between surface water and macrophytes is maximized (Marble 1990). The balance between vegetation and open water is important to a wetland's ability to provide food chain support. The optimum condition is a high density of macrophytes in small patches throughout the wetland (Marble 1990).

Procedure:

1. *Select potential wetland sites classified as riverine open, depressional open, estuarine fringe, and lacustrine fringe, code F14=1, and highlight selected sites.*

2. *Delete open water lakes from consideration. From highlighted sites, reselect lacustrine fringe wetlands and delete the open water, depressional open portion of the system. Using DNR hydro data, select all highlighted sites coded as water body type 421 (lake). Use aerial photography under magnification, and best professional judgment to identify open water lake systems, and recode F14=0.*

3. *Delete river bars from consideration. Use soils coverage to identify the location of "riverwash" hydric soil mapping units. Use aerial photography under magnification, and best professional judgment to identify unvegetated river bars, and recode F14=0.*

4. *Delete coniferous forest wetland sites from consideration. Using the landuse/landcover coverage, identify highlighted potential wetland sites located within the area of coniferous forest landcover. Use aerial photography under magnification, and best professional judgment, to identify coniferous forest wetlands, and recode F14=0.*

5. *Delete Sphagnum bogs from consideration. From highlighted sites, select extensive peat open wetlands. Use soil survey data to identify soil mapping units which have developed from Sphagnum moss. Overlay these soil mapping units onto sites coded F14=1, and recode Sphagnum bogs F14=0.*

6. *Identify potential wetland sites classified as riverine closed and highlight. Overlay the soil data, highlighting soil mapping units which flood frequently, and use best professional judgment to select sites having these soil mapping units. Aerial photography under magnification should be used to assist in this determination. Code sites selected F14=1.*

Product:

1. A list of wetland restoration sites having the greatest potential to provide food chain support.

Objective 2: Evaluate all sites for coding consistency.

Strategy 2.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F14=1 and highlight using a distinct polygon color. All sites coded F1=0 should be a more neutral color but remain visible.*

2. *Overlay the stream and frequently flooded soil mapping unit coverages onto the colored site data layer and visually search for inconsistencies. Use aerial photography under magnification to assist in this quality assurance step.*

Product

- A list of wetland restoration sites having the greatest potential to provide food chain support.

Reference

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Function 15
Active and Passive Recreation

Introduction

Fishing, hunting, shellfish gathering, swimming, kayaking, boating, sightseeing, birdwatching, and nature photography are just some of the recreational opportunities that wetlands are capable of providing for our use. As our population grows and prospers, interest in outdoor activities increases. Unfortunately, nature-centered recreational opportunities continue to be pushed farther from city centers as development pressures are brought to bear on “undeveloped” land. Pollution and a lack of public access to areas capable of functioning in this manner further increase the need for areas which provide both active and passive recreation opportunities. The restoration of wetlands and the acquisition of public access provides new opportunities for active and passive recreation.

Goal

Restore wetlands which have the greatest potential to provide opportunities for active and passive recreation.

Objective

- Identify wetland restoration sites having the greatest potential to provide recreation opportunities.

Assumptions

- Public access to a wetland is needed to maximize long-term recreation potential.
- To maximize opportunities for birdwatching and nature photography, the site should be capable of supporting a diversity of habitats when restored.
- To maximize potential to support migratory birds and game species for wildlife viewing and hunting, a five acre minimum wetland size is recommended.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to provide opportunities for active and passive recreation.***

Objective 1: ***Identify wetland restoration sites having the greatest potential to provide recreation opportunities.***

Strategy 1.1: Identify restoration sites which have public access for recreational purposes.

Rationale: Public access to a wetland is needed to maximize long-term recreation potential.

Strategy 1.2: Identify restoration sites having a diversity of habitats for wildlife and a minimum size of five acres to maximize potential for migratory bird and other wildlife use.

Rationale: To maximize opportunities for birdwatching and nature photography, the site should be capable of supporting a diversity of habitats for wildlife when restored. To maximize potential to support migratory birds for birdwatching and game species for hunting, a five acre minimum wetland size is recommended.

Procedure:

1. *Identify the location of local, state, and federal public lands using the major public lands and local public ownership coverages. Overlay these coverages onto potential wetland restoration site data and select sites located on public lands. Reselect sites five acres or larger in size, and code F15=1.*

2. *Using the coverage for major public lands and available data on local public ownership, identify location of public trails through otherwise private lands. Establish a 200-foot buffer on both sides of the trail, and select potential wetland sites within the buffer area. Reselect sites five acres or larger in size, and code F15=1.*

3. *Identify migratory bird concentration areas from the PHS coverage and overlay this with public access roads. Identify those sites having public road access to the area for birdwatching, and code F15=1.*

Objective 2: Evaluate all sites for coding consistency.

Strategy 2.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites coded F15=1 and highlight by assigning a distinct polygon color. All sites coded F15=0 should be a more neutral color but remain visible.*

2. *Overlay the major public lands coverage with local public ownership data onto the colored sites data, and visually search for inconsistencies.*

Product

- A list of wetland restoration sites which have the greatest potential for providing recreational opportunities.

Function 16
Outdoor Education

Introduction

The use of outdoor classroom settings has increased substantially as educators recognize the benefits of allowing students to explore and test concepts learned in the classroom. Opportunities to use an outdoor classroom setting are dependent upon distance from school, ease of access, and diversity and condition of habitats found there.

Wetlands function as excellent outdoor education classrooms because of the diversity of plant communities associated with wetlands and wetland buffers, the diversity of wildlife species which use wetlands, and the combination of aquatic, transitional, and terrestrial environments found there.

Goal

Restore wetlands which have the greatest potential to be used for outdoor education.

Objective

- Identify wetland restoration sites which can provide outdoor education opportunities.

Assumptions

- Potential use of a wetland site for outdoor education is dependent on distance from school, ease of access, and diversity and condition of habitats found there.
- To maximize educational potential, a site should be convenient for educators to get to and access.
- A field trip that can be taken in two class periods is easier to schedule than a half day or full day trip. Distances greater than ten miles from a school may require round-trip travel times in excess of one class period alone.
- Sites which expose students to health risks should not be used for educational purposes.
- Restoration sites which can support a diversity of plant communities and habitat types have the greatest opportunity to serve as an outdoor classroom for a variety of purposes throughout the year.
- Repeated visits by classes of students to study and monitor a wetland can have an adverse affect on sensitive species.
- It is assumed that public lands will allow public access for educational purposes. This will not be true in all situations (e.g., security areas within Naval Reserves).

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to be used for outdoor education.***

Objective 1: ***Identify wetland restoration sites which can provide outdoor education opportunities within the basin.***

Strategy 1.1: Identify restoration sites which have public access and are located within a five mile and ten mile radius of each school.

Rationale: To maximize educational potential, a site should be convenient for educators to get to and access. A field trip that can be taken in two class periods is easier to schedule than a half day or full day trip. Distances greater than ten miles from a school may require round-trip travel times in excess of one class period alone.

Strategy 1.2: Delete sites from consideration which pose a safety hazard to students and teachers.

Rationale: Sites which expose people to health risks (i.e. overflow areas from waste treatment facilities, areas on or adjacent to old landfills, contaminated soil areas) should not be used for educational purposes.

Strategy 1.3: Identify restoration sites which can support a diversity of native plant communities, and fish and wildlife habitats.

Rationale: While any wetland area can serve an important educational function at a certain time or under certain conditions, restoration sites which can support a diversity of plant communities and habitat types have the greatest opportunity to serve as an outdoor classroom for a variety of purposes throughout the year.

Strategy 1.4: Delete sites from consideration which support rare, threatened, or sensitive species.

Rationale: Repeated visits by classes of students to study and monitor a wetland can have an adverse affect on sensitive species.

Procedure:

1. *Use USGS GNIS point coverage to identify the location of schools within the river basin and within a ten mile radius of the river basin boundary. Use local expertise to verify completeness of school coverage. Establish a shaded five and ten mile radius around each school location. Add to this coverage the potential wetland restoration site, major public lands (including local recreation lands), and transportation data.*

2. *From the coverage developed in Step 1, select all potential wetland sites occurring on public land within the five mile radius and code F16=1. Use the transportation coverage and best professional judgment to identify sites coded F16=1 which do not have reasonable vehicle assess. Recode sites with inadequate vehicle access F16=0.*

4. *From the coverage developed in Step 1, select potential wetland restoration sites occurring on public lands between the five and ten mile radii and highlight. Using the transportation coverage and best professional judgment, identify sites which are located adjacent to maintained state or county roads, and code F16=1.*

5. *Select sites coded F16=1. Use aerial photography under magnification and best professional judgment to delete sites from consideration which support a monotypic plant community. Use same aerial photography and best professional judgment to identify selected sites which have potential to expose students to health risks. At a minimum, selected potential wetland sites should be evaluated in regard to the location of wastewater treatment facilities and landfill areas.*

6. *Select sites coded F16=1. Identify potential wetland sites which provide or have the potential to provide habitat for rare, threatened, and sensitive species by reselecting sites coded F13=1. Recode sites F16=0 that have an F13=1 coding.*

Objective 2: Evaluate all sites for coding consistency.

Strategy 2.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F16=1 and highlight. All sites coded F16=0 should be a more neutral color but remain visible.*

2. *Overlay the custom coverage developed in Objective 1 and visually search for inconsistencies.*

Product

- A list of restoration sites having the greatest potential to provide outdoor education functions within the basin.

Function 17
Cultural Significance/Unique Qualities

INTRODUCTION

Cultural significance/uniqueness comprise a group of often intangible uses which are dependent on individual cultural, philosophical, and theological perspective (Adamus et al. 1991). Wetlands which provide this function exhibit features which maintain activities of cultural importance, provide aesthetic enjoyment, open space, and landscape diversity, or protect archaeologically or geologically unique features.

Goal

Restore wetlands which have the greatest potential to contribute to culturally significant activities/sites or reestablish and maintain unique or irreplaceable habitats.

Objectives

- Identify wetlands of cultural significance to basin residents.
- Identify wetlands which support, or once supported, unique or irreplaceable habitats or plant communities.

Assumptions

- Shellfish gathering represents a culturally significant activity for native American tribes.
- Wild native salmon runs are a culturally significant resource to native American tribes.
- Peat systems, particularly ombrotrophic bogs, support plants, animals, and microbes that have adapted to the harsh physical and chemical environment of these wetlands. The result is a unique specialized flora and fauna which have evolved in this wetland habitat. (Mitsch and Gosselink 1993)
- The intentional creation of peat systems by humans is speculative at best and not cost or time effective. Peat systems require specific hydrogeomorphic conditions for development. Within suitable sites, extensive time is required to develop the water chemistry parameters needed for peat development.

Procedure for Characterizing Site Function

Goal: ***Restore wetlands which have the greatest potential to contribute to culturally significant activities/sites or reestablish and maintain unique or irreplaceable habitats.***
Objective 1: ***Identify wetlands of cultural significance to basin residents.***

Strategy 1.1: Identify wetlands documented by the Department of Community Development, Office of Archaeology and Historic Preservation as being historic or archaeological sites.

Rationale: Washington State Department of Community Development maintains records of historic and archaeological sites.

Strategy 1.2: Identify wetlands which are capable of supporting wetland plants of cultural significance to Native Americans for food gathering or medicinal purposes.

Rationale: Many of the medicinal and food plants used by Native Americans grow in wetlands. Tribal members have indicated that some of the plants used for medicinal purposes are becoming harder to find as lowland wetlands are degraded by human activities. The restoration of these wetlands has the greatest potential to increase opportunities for the gathering of wetland plants for cultural purposes.

Strategy 1.3. Identify wetlands which contribute to water quality improvement via fecal coliform control necessary to open currently restricted shellfish beds.

Rationale: Shellfish gathering represents a culturally significant activity for native American tribes.

Strategy 1.4: Identify wetlands which contribute to improving anadromous fish habitat.

Rationale: Wild native salmon runs are a culturally significant resource to Native American tribes.

Procedure:

1. *Access data compiled by W`shington Departlent of Community Development, Office of Archaeology and Historic Preservation and identify potential wetland restoration sites which have cultural significance. Code sites selected F17=1.*

2. *Compile local tribal information on wetland sites used by Native Americans in the river basin for food and medicinal plant gathering. Compile information on wetland plants collected by Native Americans and use best professional judgment of tribal members and wetland ecologists to identify potential wetland sites which, if restored, could support these plants. Code sites selected F17=1.*

3. *Identify wetland restoration sites which have the greatest opportunity to control fecal coliform inputs to shellfish beds. Select F2>0 and code F17=1.*

4. *Identify wetland restoration sites which have the greatest potential to provide habitat for anadromous fish. Select F10>0 and code F17=1.*

Products:

A list of wetland restoration sites documented to have archaeological or historic significance.

A list of restoration sites which maintain or improve culturally significant activities of native American tribes.

Objective 2: Identify wetlands which support, or once supported, unique or irreplaceable habitats or plant communities.

Strategy 2.1: Identify restoration sites which support, or have supported *Sphagnum* bog extensive peat wetlands.

Rationale: Sphagnum bogs require very specific landscape features which can not be replicated in one human lifetime.

Procedure:

1. *Select potential wetland sites classified as extensive peat open and extensive peat closed. Using soil survey data, identify soil mapping units which developed from Sphagnum mosses and code F17=2. Use local experts to assist in identifying additional Sphagnum bogs and code F17=2.*

4. *Using aerial photography under magnification, local expertise, and an evaluation of existing vs. potential wetland acreage of each site, identify high quality sites worthy of preservation. Remaining degraded sites will be targeted for restoration.*

Products:

A list of undisturbed peat systems suitable for preservation.

A list of sites which have potential for the restoration of peat wetlands.

Objective 3: Evaluate all sites for coding consistency.

Strategy 3.1: Evaluate each site's code designation in relation to all other sites.

Rationale: Opportunities for detecting coding errors increase when the analyst takes a "big picture" view and evaluates the coding of each potential wetland restoration site in relation to all other sites.

Procedure:

1. *Select all sites with a coding F17>0. Highlight sites coded F17=1 and F17=2 by assigning each a different polygon color. All sites coded F17=0 should be a more neutral color but remain visible.*

2. *Using the Digital Elevation Model coverage, overlay the potential wetland site data from Step 1 and visually search for inconsistencies.*

Products

- A list of wetland restoration sites documented to have archaeological or historic significance.
- A list of restoration sites which maintain or improve culturally significant activities of Native American tribes.
- A list of undisturbed peat systems suitable for preservation.
- A list of sites which have potential for the restoration of peat wetlands.

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