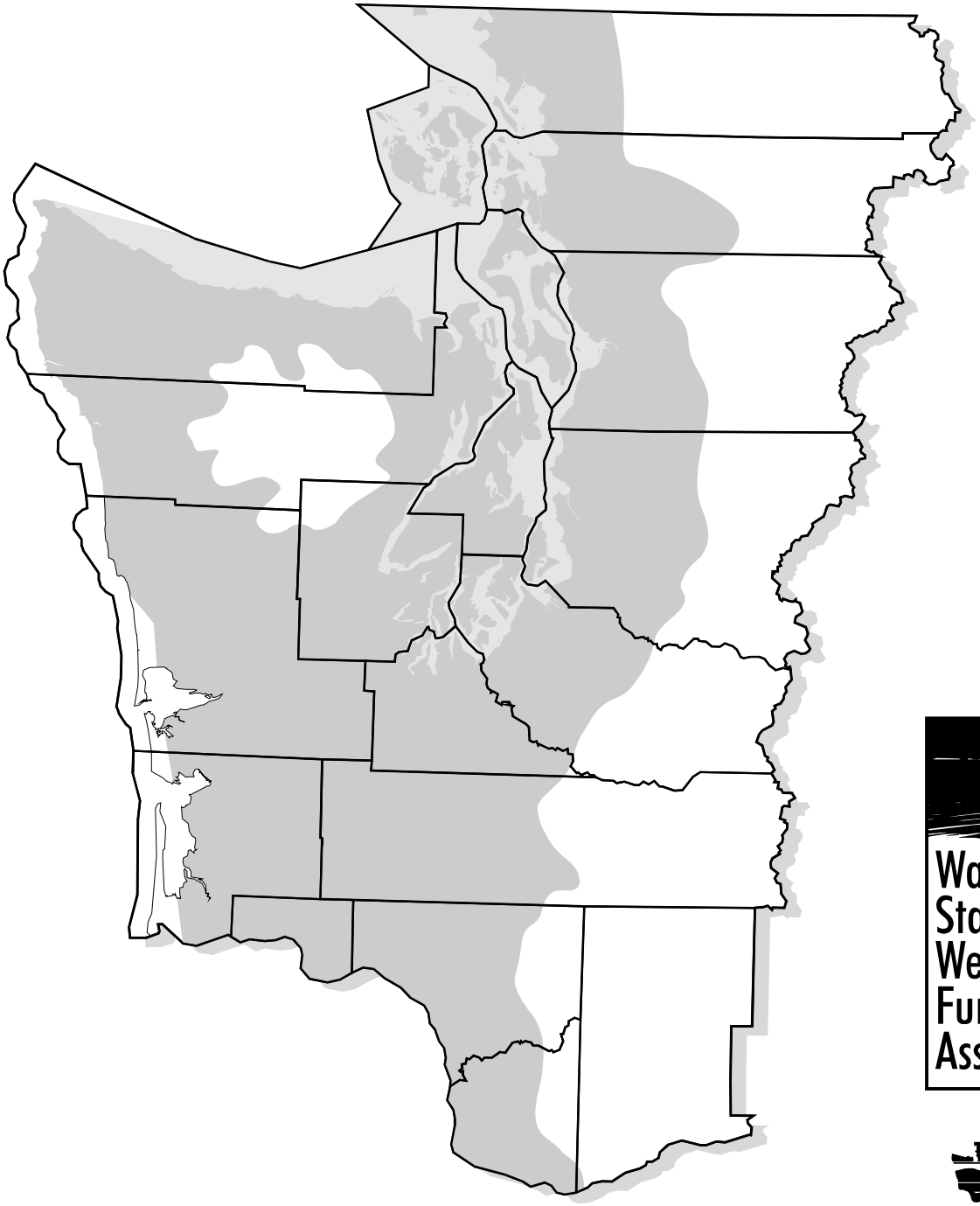
# Methods for Assessing Wetland Functions



**Volume I**
Riverine and Depressional Wetlands in the Lowlands of Western Washington

**Part I**
Assessment Methods

Washington State Wetland Function Assessment Project

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Ecology Publication #99-115

# Methods for Assessing Wetland Functions

## Volume I: Riverine and Depressional Wetlands in the Lowlands of Western Washington

## Part 1: Assessment Methods

### Ecology Publication #99-115

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# *Overview of the Document*

This document is the first volume of several describing methods for assessing wetland functions in Washington. This volume is divided into two parts. The first part contains background information and four methods, one each for four wetland types (subclasses) occurring in the lowlands of western Washington. The second part contains procedures and field forms for collecting and recording the data needed to apply the methods.

## Part 1

**Chapter 1** — Chapter 1 is a brief description of the project, enough to provide a context for the assessment methods. It also includes a summary of the process followed, the wetland classification system used, and how reference wetlands were used in method development.

**Chapter 2** — Chapter 2 describes the type of methods that were developed and the technical aspects of model building, such as calibration and normalization of the equations. The chapter ends with a summary of what the numeric results of the models represent.

A companion document **"An Approach to Developing Methods to Assess the Performance of Washington's Wetlands,"** will be written to provide additional details regarding the project, the process used, and the decisions made regarding the assumptions upon which the methods are based.

**Chapter 3** — Chapter 3 is an introduction to applying the methods in the field using photos, maps, and field data. The issue of dividing a wetland into smaller units to be assessed individually (called assessment units or AUs) is also introduced in this chapter. As described below, detailed procedures regarding completing fieldwork at the site to be assessed are provided in Part 2.

**Chapter 4** — Chapter 4 describes how to apply the results of the methods in the context of wetland management. The chapter covers some of the applications for which the results can be used, how to interpret the results, other information that should be incorporated in decision-making, and tips for the decision-maker.

**Chapter 5** — The functions that are being assessed are discussed in Chapter 5. The logic behind choice of functions and generalized definitions for each function are provided. The functions specific to each subclass are described in the chapters containing the methods.

**Chapters 6 through 9** — Chapters 6 through 9 contain the actual subclass methods for depressional outflow, depressional closed, riverine flow through, and riverine impounding wetlands in the lowlands of western Washington. Each method includes models for up to 17

individual functions. Within these chapters, each function model is described in its own section, and includes the following:

- Definition and description of the function
- Description of how the function is assessed for that subclass
- Summary of the model ("Model at a Glance")
- Description and scaling of variables

**"Model at a Glance"** displays the environmental processes or characteristics that are assessed for that function, the variables chosen to model that process, and any indicators of the variable if needed. Variables are defined at the bottom of the table and listed in alphabetical order. "Model at a Glance" tables also give the equations that are used to calculate the potential of the function being performed.

The **summary of the calculations** is presented in table format. These provide the scaling of the variables needed to compute the equations. A description of the scaling, any calculations needed to determine the scaling, and the resulting score for each variable is displayed. The field data for each variable or, where needed, the indicators used in the calculations for scaling are numbered to correspond to the field data sheets. The equation for the model is repeated here so that the scores can be inserted in the equation and the numeric index of performance or habitat suitability can be computed.

**Miscellaneous** — Part 1 ends with a glossary, cited references, and appendices.

# Part 2

Part 2 contains the detailed procedures for collecting the data to complete the assessments. It describes how to gather information including maps and photographs, organizing the field equipment needed, and previewing information prior to visiting the site. Part 2 also provides guidance for determining if multiple assessment units are needed within a contiguous wetland boundary.

The bulk of the volume consists of the detailed procedures for collecting each datum for the assessment. Data sheets for each subclass are provided in the appendices, along with other tools.

This volume includes a diskette with spreadsheets for entering the field data and automatically calculating the numeric results.

# 1. Introduction to the Project

The Washington State Wetland Function Assessment Project is a statewide partnership of government bodies and the private sector born out of the need for better information about wetlands. Managers and scientists need better technical tools to provide site-specific assessments of how well wetlands perform their functions. They also need consistency in how functions are assessed across the state. The lack of consistently used methods leads to confusion, conflict, duplication of effort, and increased permitting times and costs.

## 1.1 The Goal and Objectives of the Project

The goal of the project is to develop relatively rapid, scientifically acceptable methods for assessing functions at individual wetlands to meet regulatory and non-regulatory needs within our existing management framework.

Use of the assessment methods is not mandated in any current regulation or policy. The methods may be endorsed by some agencies and used consistently because they provide uniform, reliable, and accurate assessments of wetland functions.

### 1.1.1 Potential Uses

The following are examples of potential applications of the methods:

- Assessing project impacts to wetlands
- Assessing the adequacy of compensatory mitigation proposals, the success of mitigation projects, and the success of mitigation banks
- Calculating credits and debits for mitigation banking
- Assessing restoration potential and success
- Assessing the suitability of different wetland management or conservation activities such as enhancement at wildlife preserves
- Assessing the benefits of site-specific wetland acquisition
- Assessing the relative level of performance of several or all wetlands in a watershed

### 1.1.2 Objectives of the Assessment Methods

The following are objectives were established to help guide the development of these methods. Fulfilling all equally well was not possible, as some are mutually exclusive.

The methods are intended to do the following:

- Assess the level at which a wetland area performs a function (level of performance), not its value
- Be scientifically acceptable (based on the best available scientific information)
- Be practical, relatively rapid, and cost effective
- Be numerically based (quantitative)
- Be useful for assessing individual wetlands in making wetland management decisions
- Be sensitive to differences between regions and wetland types
- Be easy to revise in light of new knowledge
- Allow for assessments at different levels of data collection and detail
- Be "transparent" in that users can backtrack through the equations to determine how results are determined
- Be user friendly for trained people
- Generate reproducible results
- Be insensitive to small changes in input so slight variations in input will not cause significant changes in output

### 1.1.3 Time to Apply the Methods

The length of time needed to apply the methods will vary with size and complexity of the area being assessed; from a couple of hours for smaller wetlands to a few days for the largest and most complex sites. In most cases, "relatively" rapid and "cost effective" were intended to mean not more than one day to collect data in the field and calculate the results. The methods are meant to be applicable during a one-time visit at any time of year.

### 1.1.4 Expertise Needed to Apply Methods

The level of expertise needed to apply the methods is similar to that needed to delineate wetlands.

The methods are designed to be applied by technical wetland experts and those with a strong background in wetland science. Expertise is required to make accurate and consistent observations of the variables and indicators that are included in the models. At the time of printing of these methods, Ecology had two 5-day training sessions planned for future users of the methods. Continuation of the training sessions by Ecology, or by a private training company, is dependent upon demand. **Completion of the 5-day course is strongly recommended to help ensure appropriate and accurate application of the methods.** Experience has shown that untrained users may generate index scores that vary significantly from those obtained by the assessment teams.

## 1.2 Who was Involved

Broad participation is one of the project's strengths. Most assessment methods are developed by individuals or small groups and therefore, reflect the biases or limitations of the authors. This project protects against such biases through broad participation and review. Involvement of wetland scientists, managers, and the general public also helps ensure the methods are both scientifically acceptable and practical.

Broad participation also fosters support and acceptance of the methods, thereby increasing the likelihood that the methods will be used consistently. The breadth of interest and participation in the project is demonstrated by the diversity of the more than 900 individuals and organizations on the project mailing list.

The list includes scientists, policy-makers, planners, representatives of a wide range of interest groups, and members of the general public. To help keep everyone informed about the project, periodic updates about the project are sent out to those on the mailing list and draft documents are distributed to encourage comments. The draft approach to developing methods was the first document distributed for broad review in June of 1996.

Broad participation has also been demonstrated by the organizations and parties that were involved with the various committees and teams consulting on the project. Members of these committees and teams are listed in Appendix A (Part 1). The Technical Committees were chosen for their expertise in wetland function assessment. The Assessment Teams were chosen for their expertise in specific disciplines. The committees and teams are listed below.

- Statewide Technical Committee (SWTC) that guides the technical components of the project statewide
- Eastern Washington Technical Committee that helps guide our efforts east of the Cascade Mountains
- Implementation Committee (formerly composed of the Interagency Wetlands Review Board - IWRB) that provides guidance on the policy components of the project
- Riverine Assessment Team and Depressional Assessment Team, interdisciplinary teams that helped develop methods for the lowlands of western Washington
- Depressional Assessment Team – Columbia Basin, also an interdisciplinary team, that is developing assessment methods for a portion of eastern Washington
- Eight field teams that collected data at reference wetlands and suggested improvements to the data collection procedure

Selected technical experts from specific disciplines, at the national as well as regional and state levels, reviewed the models of the functions before they were calibrated. Comments were provided in writing or during a four-day technical review workshop. This initial review was important to ensure that the appropriate field data were collected. The workshop was followed by several more iterations of revision, review, and field-testing.

## 1.3 The Approach Used to Develop the Methods

The following section briefly describes the process, the wetland classification, and the technical assumptions used to develop the methods. These and other elements of the approach will be described in more detail in a separate document, along with the analysis and options that were considered for each of these topics.

The SWTC analyzed several options for adapting existing, or developing new, methods to assess functions. With concurrence from the IWRB, they determined that new methods should be developed for different wetlands and different regions of the state.

They also determined that the approach should be based on the Hydrogeomorphic (HGM) Approach (Smith et al. 1995) with modifications that include some new elements added by the committee and the Assessment Teams. In addition, the committee directed the Assessment Teams to include the useful technical components of other existing methods as a foundation on which to build the new methods. For example, many of the functions that wetlands perform and the variables that represent performance of those functions have been defined in existing methods. These variables and the basic equations of the existing methods, as in the Wetland Evaluation Technique (WET) (Adamus et al. 1987), were used as a starting point.

The **Hydrogeomorphic Approach** is a process for developing methods that assess selected wetland functions of different wetland classes and subclasses in each region of the country. It has three major elements:

- Procedural steps used to develop the function assessment methods
- A wetland classification system based on landscape position and hydrologic characteristics
- Specific technical assumptions, including the use of reference wetlands

For a detailed description of the HGM Approach, refer to Brinson et al. (1995, 1996) and Smith et al. (1995).

A similar process is being used to develop methods for the Columbia Basin in eastern Washington, and is expected to be used for other methods that may be developed in the future. Differences will be described in the documentation for each effort.

### 1.3.1 Process Used to Develop the Methods

The SWTC determined that the process for developing methods for Washington should be based on that outlined in the HGM Approach. Washington's approach, however, has had added oversight by technical committees and a policy board, and more extensive outside involvement, including testing of the calibrated methods before they are released.

The following flow chart briefly outlines the process used to develop methods.

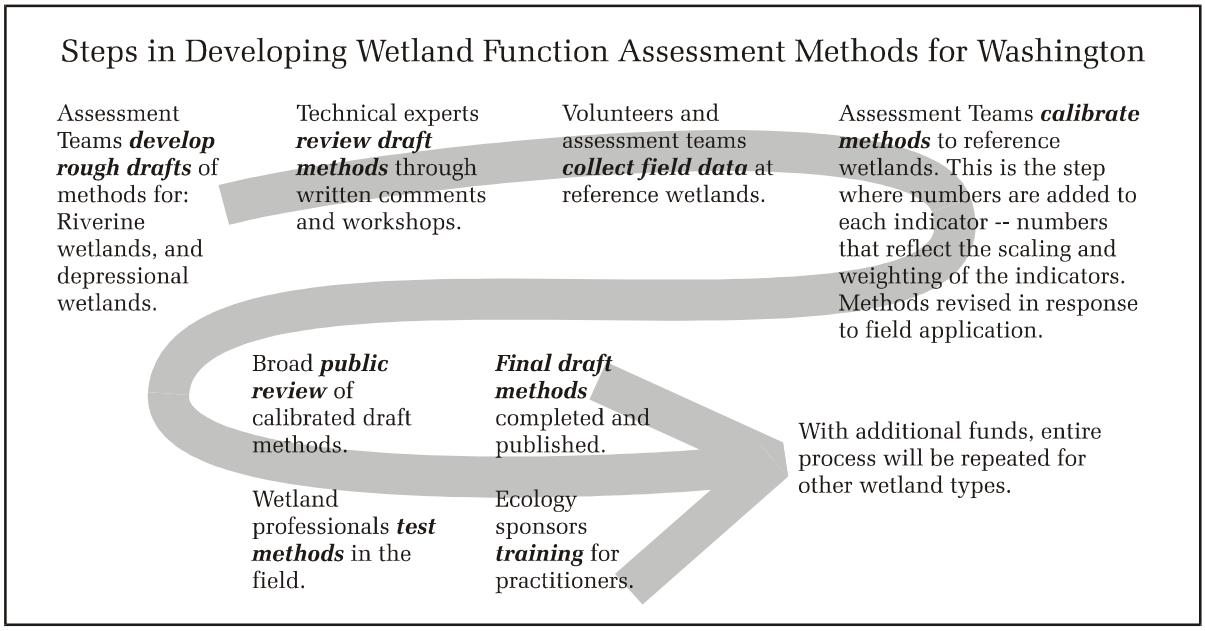


**Figure 1: Steps in Developing Wetland Function Assessment Methods for Washington**

## Developing and Revising the First Draft

Prior to developing the first draft models, the Assessment Teams visited selected reference wetlands in the field, refined the regional classification developed by the technical committee, identified the key criteria used to differentiate between wetland subclasses, and determined the functions that are performed by each subclass.

Each team developed an initial set of models during a four-day work session and subsequent meetings. Each team then worked with Ecology staff to produce a review document containing the initial models. The draft document was distributed to selected regional and national experts from specific disciplines for review and comment. These experts provided comments in writing or during an interactive technical workshop. The purpose of this review was to revise the models and variables as needed in order to ensure that the appropriate data were collected in the field.

## Calibrating and Reviewing Draft Models

The Assessment Teams revised the draft models and provided guidance to Washington State Department of Ecology (Ecology) staff for procedures to use when collecting field data. Ecology staff developed the data collection procedures and trained field teams to collect data at reference wetlands. The Assessment Teams also judged the alteration and the level of performance of each function for a subset of reference wetlands; field teams judged the remainder.

Using field data, the Assessment Teams refined the classification, the functions assessed, and addressed any problems with variables, indicators, or procedural issues that were uncovered during the data collection and analysis process. They calibrated the models by choosing reference standards wetlands for each function, developing the numeric scaling of each variable for each function, and developing the equation used to calculate each index of performance.

### Testing the Calibrated Methods

Calibrated methods were then reviewed by the general public and tested by wetland experts. The purpose of testing was to determine the efficiency, ease of understanding, reproducibility, and accuracy of the methods.

### Finalizing the Methods

The Assessment Teams reviewed the comments provided by reviewers and testers, as well as the results of field-testing. This information was used to make any necessary revisions, completing the methods development process. Ecology staff then prepared the final methods for publication.

### Training in the Methods

At the time of this printing, Ecology is planning to conduct at least two 5-day training sessions for those with a strong technical background in wetlands. These are intensive courses involving a field component, geared towards those that will be applying the methods in the field. Ecology is also planning to conduct several ½-day training sessions for wetland decision-makers; those that will be reviewing the result of assessments done with these methods. These trainings will focus on guidance on how to understand, interpret, and use the results.

### Updating the Methods

Project staff plan to periodically work with the Assessment Teams and the SWTC to review and incorporate new research findings and address suggestions offered by users of the methods.

Pending future funding, project staff will also solicit field data collected during the routine application of the methods. These data would be used to enhance the current database for regional reference wetlands. Assessment Teams may also be reconvened to periodically review the new data to determine if the calibration of the models should be refined.

## 1.3.2 The HGM Classification System

The SWTC decided that the classification system used in the HGM Approach (called the Hydrogeomorphic (HGM) Classification) is a sound one for developing methods. The HGM classification is hierarchical, and is designed to categorize wetlands into groups that function in similar ways (Brinson 1993, and Brinson et al. 1995).

The highest categories (i.e. classes) for wetlands in a region are defined nationally (Table 1). Subclasses for each of these classes are defined regionally by experts within that area. The wetland experts in each region can, therefore, tailor the subclasses to address differences in the performance of functions by different wetland types in their region.

In Washington, both technical committees created regions to reflect the differences in wetland functions, or differences in how functions are performed. The committees suggested that Assessment Teams revise the classification, including the draft regions, based on comments and field data collected during method development. The extent of the lowlands of western Washington is described in Appendix B (Part 1).

**Regions in Washington**

- Montane (statewide)
- Lowlands of Western Washington
- Columbia Basin
- Lowlands of Eastern Washington

The reference domain of the HGM classes for western Washington is defined on the north and south by state boundaries. However, we realize the methods may be applicable to similar areas of northwestern Oregon and southwestern British Columbia.

The highest category (i.e. classes) of wetlands in the classification for the lowlands of western Washington is based on geomorphic setting such as riverine, depressional, and slope. See Table 1 for a full list of the classes. These characteristics, however, are not always dramatic features on the landscape. The topographic valleys of small streams may be relatively narrow and have "valley" walls that are only a few feet high. Depressions may be very shallow with only inches of topographic relief creating the depression and the angle of slope wetlands may be slight.

Northwestern Oregon and southwestern British Columbia were not included in the scope of the project because of monetary and staffing constraints. Those with wetland expertise in those locales are encouraged to review and test these methods for applicability to these areas.

The second level of classification is based on hydrologic characteristics such as surface water connection to other water bodies and the duration of inundation. The hydrologic characteristics used as criteria to separate subclasses are different for each subclass and depend on conditions specific to that subclass.

| Table 1. Classes and Subclasses in the Lowlands of Western Washington [1] | |
|---|---|
| **Class** | **Subclass** |
| Riverine | Flow-through |
| | Impounding |
| Depressional | Outflow |
| | Closed |
| | Interdunal |
| Slope | [2] |
| Lacustrine Fringe | [2] |
| Estuarine Fringe | Tidal Fresh Water<br>Tidal Salt Water |
| Flats[3] | [2] |

[1] *The classes and subclasses are described in the profiles included in Appendix C (Part 1).*

[2] *At present, there are no subclasses for slope, flats and lacustrine fringe. Subclasses will be added if, during future model development, differences in function are determined to exist between wetlands within these classes.*

[3] *The SWTC decided to combine two national HGM classes, mineral flats, and organic flats, into a single "flats" class.*

## Clarification Regarding the Wetlands Assessed

*Only Vegetated Wetlands Are Classified and Assessed*

> The methods are not designed to assess the functions of other parts of the aquatic system or adjacent upland areas.

It is presumed that any areas classified and assessed for performance of functions are wetlands that meet the three criteria for jurisdictional wetlands: hydrology, plants and soils (WDOE 1997). There may, however, be areas within a vegetated wetland that are not vegetated. For example, wetlands may contain areas of open water that are unvegetated. If these areas are less than 2 meters (6.6 feet) deep and less than 8 hectares (20 acres) in size, and therefore not lacustrine, they are included as part of the assessment unit. However, in cases where the area is predominantly not vegetated (there is less than 30% cover of plants), the methods should not be used. An example is an unvegetated river bar.

The open-water portions of a river or stream are not to be included as part of the wetland unit being assessed unless it meets the criteria described in Part 2. Other methods for assessing streams and rivers may be needed in cases where the river is not part of the assessment unit.

*A Wetland's Current Condition Determines Classification*

In the case of altered wetlands, the current condition of the wetland is used to determine its classification. For example, diked wetlands that were once riverine flow-through, might now be either riverine impounding (if they experience overbank flooding frequently), or depressional closed (if they are flooded infrequently).

*Boundaries Between Subclasses*

The Assessment Teams developed models for wetlands within a particular class and subclass. Wetlands, however, occur along a continuous gradient of geomorphic and hydrologic conditions. Some wetlands are difficult to classify, and some may contain areas that can be classified into two or more subclasses. An example is a wetland located in a valley at the base of the valley wall ("wall-based" wetlands.) If it is not frequently flooded, even if it is located in a floodplain, it would be classified as a depressional wetland. Wall-based wetlands function more like depressional wetlands than riverine wetlands even though they are in the floodplain. The Assessment Team decided that such wetlands should be classified as depressional wetlands rather than riverine.

## 1.3.3 Using Reference Wetlands to Develop Methods

The SWTC reviewed many of the technical assumptions used in the HGM Approach and determined that many should also be used in developing Washington methods. Some of these assumptions, described in Chapter Two, are also common to other assessment methods.

One of the major steps in the development of this method, not commonly used in other methods, involves use of reference wetlands to calibrate the models. The technical committee agreed that reference wetlands should be used. The committee was uncertain, however, how to choose reference standard wetlands. They made their final decisions regarding which wetlands to use as reference standard sites once field data were analyzed using different assumptions for choosing the standard sites.

***Reference domain*** includes all wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass.

***Reference wetlands*** are a group of wetlands within the reference domain that encompass the known variation of a hydrogeomorphic subclass.

***Reference standard wetlands*** are sites within the reference data set, which establish the characteristics that must be present in a wetland for it to score the highest for a function.

Reference wetlands are a group of wetlands within the reference domain (region) that encompass the known variation of a hydrogeomorphic subclass. They are used to establish the range of performance of functioning within the subclass. Data collected at reference wetlands are needed so the models reflect regional conditions.

Once a group of reference sites is identified, an Assessment Team determines which will serve as reference standard wetlands. Reference standard wetlands are a subset of reference wetlands that establish what characteristics must be present in a wetland for it to score the highest for a function. The characteristics of the reference standard wetlands are those against which other wetlands being assessed are compared.

The HGM Approach suggests that the major criterion for choosing reference standard sites should be their relative lack of human disturbance or alteration. These reference standard wetlands are called "least altered" wetlands. The objective is to determine the optimum levels of performance in sites that are as undisturbed as possible (Davis et al. 1995). "The approach assumes that highest, sustainable functional capacity (i.e. level of performance) is achieved in wetland ecosystems and landscapes that have not been subject to long term anthropogenic disturbance" (Smith et al. 1995 p.28). Brinson (1995) adds the concept of "self-sustaining" to reference standard sites because reference standards are to be determined from "characteristics measured in the field on wetlands that are self-sustaining...".

Another critical presumption used in the HGM Approach is that the highest sustainable levels of performance (functional capacity) for the entire suite of functions performed by wetlands in a subclass are found in the relatively undisturbed wetlands. The reference standard wetlands (those that are least altered in the least altered watersheds), by definition, have a level of performance equal to [10] for all functions (D. Smith personal communication).

With the HGM Approach, the index for "functional capacity" represents deviation from the performance of wetlands that are judged to be the least altered sites in that subclass and domain.

> Simply put, using the HGM assumption, the functional capacity assessed represents the deviation from least altered conditions.

The Washington State Function Assessment Project explored another assumption to establish the characteristics against which other wetlands in that subclasses are compared. *The alternative assumption is that the highest level of performance of wetland functions will occur when a specific set of optimal environmental conditions are met, regardless of whether or not the wetland has been subject to human disturbance*. Using this assumption, one group of wetlands may not necessarily be the reference standards for all functions.

Using this assumption, the index for "performance of function" represents the deviation of performance from those wetlands judged to be the highest performers for each individual function in

> Using the Washington State assumption, the index of performance represents the deviation from the highest performing sites for individual functions, regardless of level of alteration.

that subclass and domain. The models compare the characteristics (variables and their indicators) present in the area being assessed to those occurring in the highest performing wetlands.

To analyze both assumptions, the Assessment Teams identified reference wetlands that they judged to be least altered and those that they judged to be the highest performers for each function. Several draft models were then calibrated in two ways, based on each approach. The comparison showed that both least altered and more significantly altered wetlands can perform functions at low to high levels. The Assessment Teams did not consistently judge least altered wetlands as the highest performers for all functions.

The Assessment Teams also found that it is difficult to predict "sustainability" in wetland functions, especially since this concept has not been defined in any documentation of the HGM Approach. Most of the watersheds in the lowlands of western Washington, as well as the state, are experiencing ongoing disturbances, and it is difficult to predict if any wetland, including those that are least altered, can sustain a particular level of performance over time.

The SWTC and Assessment Teams jointly reviewed the results of the comparison and discussed the results of both approaches in the context of wetland management. They decided that reference standard wetlands should be those reference wetlands within a subclass and domain that are judged by an Assessment Team to perform at the highest level for individual functions, regardless of level of alteration.

**Reference standard wetlands used to calibrate the Washington models** are those reference wetlands within a subclass and domain that are judged by an Assessment Team to perform at the highest level for individual functions, regardless of level of alteration. The highest level of performance of a wetland function will occur when a specific set of environmental conditions is met.

A detailed comparison of the two approaches to choosing reference standard wetlands and the technical and management implications is provided in Appendix D (Part 1).

# 2. Introduction to the Models

## 2.1 Understanding Wetland Assessment Methods

There is often much confusion about assessment methods. This confusion is the result of incorrect terms being used to describe methods. Methods for organizing our knowledge about a wetland have been referred to as: classifications, categorizations, characterizations, ratings, assessments, and evaluations. Each of these terms is meant to indicate the type of information a method provides, but often methods provide information that is not consistent with their name. The methods described in this document are called assessments because they provide a numeric estimate a relative level of performance for a function.

The ways in which data are analyzed within a method are called "models" or “algorithms” because most rely on equations or other mathematical rules for achieving a result. Here, the term “models” is used to represent the individual equations, and “methods” to represent a collection of models. Generally, a method has a separate model for each wetland function assessed, and there is a separate method for each wetland hydrogeomorphic subclass in a region.

| **Model** | **vs.** | **Method** |
|---|---|---|
| Equation used to estimate the relative level of performance for a specific function of a specific subclass | | Collection of models for a specific subclass |

There are two types of computational approaches commonly used - logic and mechanistic. A model using a “logic” approach has a qualitative, verbal, description that produces a result. In a logic model, the characteristics found in a wetland (variables) are combined by “logic” statements such as "and," "or," and "if...then" to establish a characterization or rating. Logic models have also been called “rule-based” models (Starfield et al. 1989) and “descriptive” models (Terrell et al. 1982). Probably the best known method using logic models is the Wetland Evaluation Technique (Adamus et al. 1987).

Wetland methods based on a mathematical aggregation of numeric data can be called mechanistic because they follow the “mechanistic” approach to model development described by the USFWS(1981) for Habitat Evaluation Procedure (HEP) models. In mechanistic models, environmental characteristics found in a wetland are treated as variables in an equation. Different “conditions” of these variables are assigned numbers and combined mathematically to generate an index or score. Examples of wetland methods using mechanistic models are Reppert et al. (1979), the “Connecticut” method (Ammann et al. 1986), the Indicator Value Assessment (IVA) (Hruby et al. 1995), and methods developed

using the HGM Approach (Brinson 1995, and Brinson et al. 1996). Almost all wetland assessment methods that generate a number use the "mechanistic" approach to model development.

### 2.1.1. What are Mechanistic Models?

Rapid wetland assessment methods based on mechanistic approaches provide a clear and concise way of organizing our current, and often subjective, knowledge (based on literature and regional expertise) about wetland functions. They do not assess the rates or dynamics of ecological processes occurring in wetlands.

This is a limitation of current methods that is often misunderstood both by wetland managers and by the scientific community. The misunderstanding is fostered by the fact that many functions are defined as ecological processes that are usually expressed as rates. For example, Brinson et al. (1995) define the function "Organic Carbon Export" as "export of dissolved and particulate organic carbon from a wetland." When an assessment method provides a number for this function it is easy to assume that this represents the gm-carbon exported per year, especially when the index is defined as a "level of performance" (Smith et al. 1995). A wetland with an index of 0.5 would then be expected to export ½ of the carbon exported by a wetland scoring a 1.

Unfortunately, this would be a misinterpretation of the results. Scores are only a numeric representation of a qualitative assessment. A result of 0.5 from an assessment method using mechanistic models means that the wetland is judged to be performing a function at a "moderate" rate relative to those considered to be performing at the "highest" levels and those performing at the "lowest" levels.

> **All of the rapid assessment methods available**, and under development, are modeling a process of judgement used by experts to assess how well wetlands perform functions, or how sustainable the functions might be. They **are not mathematical representations of actual environmental processes taking place.**

Measuring the rates or dynamics of environmental processes requires intensive sampling because the processes are highly variable in both space and time. Such procedures, however, are not possible if the method is to be rapid. Rapid, for most wetland managers and environmental consultants, means that a result can be obtained with one site visit. The entire process of data collection and analysis, therefore, for a rapid assessment method should take no more than one day for a single site, unless the area being assessed is large and complex.

**Mechanistic Models Are Decision-making Models**

It is easier to understand the information provided by logic and mechanistic models if they are treated as environmental decision-making models (also known as "multiple criteria assessment" models). Decision-making models represent "the acquisition and merging of subjective, expert knowledge…Often several persons with varying backgrounds are to be taken into the analysis, e.g., engineers, ecologists, economists, managers, and politicians" (Varis et al. 1994). **Each variable in a model represents a decision criterion used to establish a level of performance, rather than an independent variable that estimates the rate of an environmental process.** These decision criteria are based on the judgements and experience of the Assessment Teams and on the research that has been done to date.

### 2.1.2 What Do Mechanistic Models Represent?

Mechanistic models assessing wetland functions are constructed as a set of relationships between environmental characteristics and the performance of a function. Many of the relationships are only hypothesized because specific information about the relationship may be lacking.

For example, a model for the function "Removing Sediments" might be phrased as follows: "The performance of a wetland in removing sediments from incoming surface waters is based on its ability to reduce water velocities and to filter out sediments." These environmental processes of reducing velocities and filtering sediments become variables in an equation. The equation for "Removing Sediments" would be:

*Performance = reduction in water velocity + amount of filtration of sediment*

It is not possible to develop a rapid assessment methods that measures how much a wetland reduces water velocities or filters water to estimate sediment removal. Such estimates would require measuring changes in current velocities over the entire wetland for at least one year, and the relative cross section provided by vegetation. Rapid assessment methods have to rely on easily observed characteristics that are correlated with the actual environmental processes.

### 2.1.3 Use of Indicators as Surrogates for Variables

When it is not feasible to use a variable because it cannot be rapidly assessed, it is sometimes possible to use an indicator as a surrogate for that variable. Indicators are easily observed characteristics that are correlated with quantitative or qualitative observations of an environmental variable.

Most indicators are fixed characteristics that describe the structure of the ecosystem or its physical, chemical, and geologic properties (Brinson 1995). Such indicators are time

independent conditions (on the scale of most environmental processes), and thus cannot reflect actual rates of performance. Rather, they reflect the potential or probability that functions are performed at a certain level. Model scores based on indicators, therefore, do not reflect the levels at which a function may actually be performed. Instead, they estimate the potential or probability that a function is being performed.

The potential of a wetland to reduce water velocities might be established by using the size and shape of its outlets and the depth of water stored in the wetland as indicators. An indicator of the potential for filtration of sediment might be based on the percent cover of dense erect vegetation near the ground surface. The equation for removing sediments could then be rewritten as:

> *Potential performance = type of outlets + depth of water storage + %cover of different types of vegetation*

In a logic model, the level of performance would be described using conditional phrases such as "the wetland rates high for removing sediments if it has a constricted outlet and an average depth of storage that is greater than 1 m and erect vegetation over more than 80% of its area."

With mechanistic models, the authors choose the variables and scale them based on their judgement. They assign scores to different "states" of a variable (e.g., > 80% cover of emergent vegetation might be given an index of [1]; 40 - 79% cover of emergent vegetation receives an index of [0.5], etc.). Different types of outlets, and different depths of water storage, would also be assigned scaled scores in this manner.

In developing models, the sum of the scores for the variables in an equation are adjusted (normalized) to [1] or [10] for each function. Normalizing is important because each function may have a different number of variables with correspondingly different total sums. The indices of different functions are more easily interpreted if the highest levels are all recorded as a [10].

### 2.1.4 Scoring Wetlands

Application of a method results in a set of indices, one for each function in each wetland unit being assessed. The indices are presented as a number, for example between 0 and 10, with a 10 representing the highest level of performance.

The index represents an index per hectare or acre of wetland. For example, a small, 1 hectare wetland, and a large 100 hectare wetland may both have an index of [10] for a specific function. If the method is being used to quantify impacts or total performance each index needs to be multiplied by the size of the impact or the size of the wetland. These overall "performance scores" should be presented using the units of "hectare-points," or "acre-points." For example, an impact that is 10 acres in size that occurred to a wetland with an index of 5 would be equivalent to an impact that is 5 acres in size to a wetland with an index of 10 (10 x 5 = 5 x 10 = 50 acre-points). An index itself is without any numeric "dimensions".

### 2.1.5 Validation vs. Calibration

None of the wetland assessment methods developed, or being developed, to date include any significant field validation because of the cost and time involved. Validation involves doing actual direct measurements of the performance of functions and comparing this with the numeric results obtained from the decision-making model.

**Validation vs. Calibration**

Data collected at reference sites for this methods was used for calibration, not validation of the models.

The collection of data in the field at reference sites during model development for western Washington methods and other HGM-based methods was focused on generating the numeric scaling for a variable, not on measuring the levels or rates at which wetlands perform functions. For this reason, the data collection used to scale the Washington methods is called "calibration" rather than "validation."

## 2.2 Understanding the Washington State Methods

The methods developed for Washington State use mechanistic models to determine performance of each function being assessed for a specific subclass. The interdisciplinary teams developed the variables, indicators and equations and scaled them using their judgement and data collected at reference wetlands during the calibration process.

### 2.2.1 Variables Used

The Assessment Teams considered many variables in developing each model. Some had to be rejected because they were not easily observed or had an indicator that could not be characterized during one site visit. Two criteria limited the choice of variables in the models: 1) the variable or its indicator had to be observable or could be determined at any time of the year; and 2) the variable or its indicator had to be observable during one site visit that took no more than one day for <u>most</u> wetlands. As a result, most variables or indicators reflect chemical, or biologic characteristics of a wetland that can be observed throughout the year. Appendix E (Part 1) contains a summary of each model, showing all the variables used in each one.

Most assessment methods, up to now, have been built on the premise that variables and their indicators are linked to the positive performance of a function. A wetland that has more of the appropriate variables performs a function better than one that has fewer. Variables are assigned a positive score and summed. Another option, however, is to include variables that are correlated with a reduction in the performance of a function. These would be environmental characteristics that indicate a function is not being performed as well as it could be given all the other variables present.

These models include both types of variables in some functions. If the performance of a function was considered impaired by certain characteristics, that characteristic became a variable that was included in the model equations as a fractional multiplier. The sum for the "positive" variables is multiplied by a fraction (numbers between 0 and 1) that represents the estimated reduction in performance.

For example, the presence of dikes in riverine flow-through wetlands is modeled as reducer for the function "Decreasing Downstream Erosion." The dikes increase the velocity of water during a flood event by constraining the flow and raising the hydraulic head across the width of the flood channel, thereby reducing the ability of the wetland to decrease erosion downstream.

### 2.2.2 Calibrating the Variables

To calibrate the models, the Assessment and Field Teams collected data on 60 different environmental characteristics at 86 reference sites. The data were collected in the lowland wetlands of western Washington during the summer and fall of 1997 (35 depressional outflow, 19 depressional closed, 12 riverine impounding, and 20 riverine flow-through) by field teams of volunteers from several resource agencies. Field teams were trained in the methods for collecting data by Ecology staff. In addition, the relative level of potential performance or habitat suitability for each function was judged at each site by the field teams. The assessment teams also visited a subset of the sites in each subclass and judged the performance of functions independently of the field teams. Judgements of performance were nominal and based on a scale of 1-7.

> The data from the reference sites used in calibrating the models are not included in this document. They are available on request on a CD-ROM in Excel spreadsheets.

Calibration of each function was a two step process. In the first step, all reference sites in a subclass were ranked based on their "judged" index for the function, and the data collected at the site tabulated in the order in which the wetlands were "judged." Data on each variable as it was recorded in the highest and lowest performers were tabulated and used to develop the maximum and minimum scaling for that variable. For example, the highest performers for general habitat suitability in the depressional outflow subclass had, on the average, 10 categories of large woody debris out of 24 possible. Ten was established as the value for $V_{lwd}$ (denotes the variable for large woody debris) that would be scaled a [1]. The lowest performers for the function had zero categories of large woody debris, and the bottom of the scaling for $V_{lwd}$ was set as [0]. Values of $V_{lwd}$ between 0 and 1 were scaled proportionally as # categories/10.

In the second step, an index for each reference wetland was calculated using a model based on the initial scaling of the variables. The index was normalized using the score from the highest scoring reference wetland as the denominator. The model scores for all reference wetlands were then compared to the "best professional judgement" scores for those wetlands. The average deviation between the model score and "best professional judgement" score for the entire set of reference sites was used as a guide to refine both the calibration and selection

of variables. The goal was to reduce the average deviation between the model score and the "best professional judgement" score to its lowest value, while maintaining the variables considered important by the Assessment Teams.

### 2.2.3 Normalizing the Scores

In these methods the Assessment Teams used the score from the reference site with the highest model score for that subclass to normalize to [10]. Structuring the models in this manner addresses the issue of wetlands performing high levels of functions in different ways, while still retaining the concept that certain reference sites represent the highest level of performance. The issue of natural variability among the highest scoring sites is addressed by rounding off the indices to the nearest 1.0. This means that wetlands within a subclass can score only one of 11 possible scores (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10). The Assessment Teams decided that the available data collected during the calibration phase permits this level of precision.

### 2.2.4 Opportunity Is Not Modeled

**The indices of potential performance or habitat suitability assess the capability of a wetland to perform a function based on its environmental characteristics. The models do not address the opportunity that a wetland has to actually perform a function.** Guidance is provided, however, on the factors to consider in developing a qualitative rating of opportunity.

The Assessment Teams originally developed equations for both potential and opportunity for all water quality, water quantity, and two habitat functions. They didn't develop models to assess opportunity for the majority of habitat functions because of the number and complexity of the variables, and the need for intimate knowledge of the watershed.

After reviewing data collected at reference wetlands, the Assessment Teams decided to abandon the equations assessing opportunity for all the functions. None of the data collected during the calibration could be adequately correlated with the judgements of opportunity made by the Assessment Teams. The conclusion of the Assessment Teams was that too many variables were involved in making a judgement of opportunity, and a simple model could not be developed. Instead, written guidance was developed for the user to qualitatively rate the opportunity.

### 2.2.5 "Habitat" Models Assess Suitability for Faunal Groups

The "habitat" models assess the suitability of a wetland for specific groups of organisms (e.g. wetland-associated birds), not for an individual species. Furthermore, the assessments do not estimate whether a species group is actually using a wetland, nor do they estimate the actual abundance of organisms in the wetland.

It is not feasible in a rapid assessment method to measure actual numbers and distributions of species. The requirement that assessment models use only variables that can be rapidly assessed at any time of the year imposes limitations on the type of data that can be collected. The presence of specific habitat characteristics in a wetland only indicates that the wetland may provide a suitable habitat. The methods are unable to assess whether a species or guild of species is actually using the wetland. Estimates of actual usage would require sampling procedures geared to each species, timed to reflect their seasonal behavior patterns.

**Structurally Simple Wetlands and Habitat Functions**

In some cases a wetland may score low for a habitat suitability function relative to the reference standard sites because its structural characteristics are simple. For example, a sedge meadow will score relatively low for its vertical plant structure and its number of plant associations. It may, however, be a critical habitat for rails and certain waterfowl. Moreover, these rails and waterfowl species may only be found in sedge meadows, or may not breed in more complex wetlands. If the wetland is a habitat type that appears to be critical to a specific species, another method, such as HEP (USFWS 1981) is needed in order to determine the habitat suitability of that wetland.

## 2.3 Summary of What the Numeric Results Represent

The following is a list of points to keep in mind when interpreting the meaning of the numeric indices resulting from application of the methods. Some are repeated in other parts of the document and are offered here as a summary.

- Models that provide numeric assessments have certain limitations. The mechanistic models used in wetland assessment methods provide a means of displaying logical, but frequently untested, cause and effect relationships between variables and performance that is useful in management.
- The index of performance reflects the level of performance relative for the area being assessed within that subclass and region ONLY. An index of performance of 8 for depressional outflow is NOT comparable to an index of 8 for riverine flow-through.
- The index of performance is relative to reference standard sites for that particular subclass and domain. Reference standard sites are those judged by an Assessment Team to perform at the highest level for that subclass.
- The methods provide performance indices for individual functions. They don't provide a single summary performance index for the area being assessed. The methods were not designed to lump functions into group scores, nor were they designed to rank functions hierarchically by importance.

- The index of suitability for habitat functions represents an assumption that the more habitat niches provided (heterogeneity), the higher the performance of the habitat functions. In the case of the models for wetland-associated birds and mammals, for which habitat for a select groups of animals is assessed, a high index reflects the presence of habitat heterogeneity for those species.
- The index of performance reflects level of performance per unit area of the area being assessed. Another calculation must be made to factor in the size of the assessment unit (or, in some cases, area being altered) to get a final performance index (acre or hectare points) for that function for that assessment unit. This information is important in a number of situations. An example is determining how much performance might be lost as a result of alterations. The larger the area to be impacted within the same assessment unit, the more performance would be lost if alterations are approved. For example, if 2.5 acres (1 ha) of an assessment unit with an index of 8 for wetland-associated bird habitat were to be filled, loss of bird habitat would be: 2.5 x 8 = 20 acre points. If the fill were reduced to 1 acre (0.4 ha) loss of bird habitat would be reduced to: 1 x 8 = 8 acre-points.

  > To obtain a score that reflects size, multiply the index for each function by the size of the assessment unit, or the size of the area being impacted, whichever is applicable.

  Another example is comparing the performance of two assessment units of different sizes. For example, if the index of performance of assessment unit A is 3 for suitability of wetland-associated bird habitat and it is 10 acres (4 ha) in size, the performance score would be 30 acre-points ( 3 x 10 = 30 acre-points). If assessment unit B is 3 acres in size and has an index of 10, the performance index would also be 30 acre-points (10 x 3 = 30 acre-points).
- The performance indices for habitat functions don't assess the habitat suitability for any individual species. For example, the index for wetland-associated mammals doesn't differentiate if the assessment unit is better habitat for beaver or otter. For anadromous fish habitat, the models don't assess habitat suitability for specific types of salmonids. To get a species-specific assessment, another method such as HEP must be used.

## 2.4 What the Function Assessments Don't Do

In this section, we describe what the methods don't do. Understanding the limitations of the methods is important in order to discourage misconceptions about the methods. Additional clarifications and cautions regarding the methods and their numeric results are provided in Chapter 4.

**The assessment methods do not alter wetland regulations <u>nor</u> do they indicate to what degree different subclasses or functions should be protected**. They do not change the regulations or policies that determine how wetlands are managed and are not expected to be mandatory for all permit applications. Many agencies and governments currently require an

assessment of functions as a part of their permitting process. Each jurisdiction will need to decide independently whether or not to formally adopt or require these methods.

**The methods do not assess the economic values of wetlands or the importance of individual functions**. The models only establish the levels at which wetlands perform some functions. They do not estimate monetary value. They do not determine if one function is more important than another is. These are decisions made at the government, watershed, or community level. Decisions about the value of a wetland are usually made, however, with the help of information regarding performance of functions. An assessment of how well wetlands perform some functions, such as reducing peak flows or removing nutrients, is used to make value judgements about how wetlands should be managed - whether they should be filled, how much of a buffer is needed, etc. However, the methods can be used to provide a numeric baseline for conducting cost/benefit analyses.

**The methods do not assess all the functions that are performed by wetlands**. To reach the goal of developing relatively rapid methods, not all functions performed by a wetland are assessed. For example**,** the methods don't assess habitat suitability for terrestrial species using wetlands or the process of nutrient uptake by plants. The Assessment Teams decided which functions were to be modeled using guidance from the SWTC and IWRB. The guidance was provided in the form of a draft master list of functions.

**The methods do not assess cultural, recreational, educational or aesthetic functions**. For example, the importance of a wetland to a local elementary school or its use by bird watchers can not be determined using these methods. They focus on the physical, chemical, and biological processes that occur in wetlands (i.e. the wetland ecosystem.)

The methods developed under this project are improved technical tools used within the existing management and regulatory frameworks. They provide information to allow for more informed decision-making.

**The methods do not measure the rates of ecosystem processes.** Rapid wetland assessment methods do not model the rates or dynamics of ecological processes occurring in wetlands. Rather, they provide a clear and concise way of organizing our current knowledge about some wetland functions and the variables used to determine the performance of those functions. The variables are based on fixed characteristics of a wetland (i.e. % cover of plant species) that are correlated with performance of functions. They are not actual measures of rates (such as amount of nutrients removed) or processes.

**The results of assessments done with these methods do not represent an actual measurement of the performance of a function.** The indices that result for each wetland function are not absolute; they are relative. They represent an assessment of performance relative to reference standard wetlands identified as having the highest level of performance possible within that wetland subclass.

**The methods don't assess all wetlands, only the subclasses for which they are developed**. When working with subclasses of wetlands for which methods have not yet been developed, a user will have to apply a different assessment procedure until methods are developed for

that subclass. To maintain the integrity of the models, the models should not be modified in any way without a process involving regional Assessment Teams and public review.

**The methods don't provide a basis to compare the relative performance or habitat suitability across different functions.** For example, an index of 0.2 for habitat suitability for fish is not comparable to an index of 0.2 for habitat suitability for mammals. Each model and their variables have been individually calibrated for that specific function. Also, the same variable may be used in multiple models, but are calibrated differently for each function. For one model, having a large percentage of the assessment area be seasonally dry may be one factor needed for high performance, whereas, with another function model, the same condition would contribute to low performance.

**The methods don't provide for direct quantitative comparison between subclasses**. The level of performance is relative to wetlands in that subclass and region ONLY. An index of 0.8 for a function performed by depressional outflow wetland is NOT comparable to an index of 0.8 for the same function performed by a riverine flow-through wetland.

**The methods don't directly relate to protection of endangered species, watershed planning, or cumulative effects.** The methods may be of use for tracking impacts to specific functions, which may help provide additional information relating to threatened and endangered species, watershed planning, and cumulative effects. However, the methods were not designed to provide specific information on these uses and other methods may be more useful for each application. For example, when a user needs to assess use of a wetland by a threatened and endangered species, it may be more effective to use a method such as the Habitat Evaluation Procedure (HEP) that was developed by the US Fish and Wildlife Service (USFWS) (1981).

**The methods do not provide a single score or index for a wetland.** Indices for functions cannot be combined to develop an overall score.

# 3. Applying the Methods

The following is a summary of the general guidance for applying the methods. A full description of the steps to follow when applying the methods, as well as detailed guidance on classifying and determining assessment units, are provided in Part 2 of this document. Part 2 also provides guidance for collecting background information, methods for collecting data in the field, and forms for recording data.

## 3.1 Steps in Applying the Methods

We recommend the following sequence be used when conducting assessments using these methods. Some steps can be completed concurrently or in a different order.

1. Read and understand the methods, their models, and the procedures for collecting data

2. Collect information regarding the wetland area to be assessed including aerial photography and topographic maps

3. Review the information about the site and make preliminary observations

4. Visit the wetland and identify its approximate boundary

5. Determine the classification of the wetland and develop a preliminary map of assessment units if several subclasses are present within one wetland. Choose appropriate method(s) and data form(s)

6. Determine if the wetland should be divided into assessment units based on other factors such as water regime, etc

7. Collect data and create "photo" maps and other graphic tools to display the location and/or extent of various characteristics to assist with completing the data forms

8. Fill out the field data forms at the site

9. Calculate the indices of potential performance and habitat suitability. Enter data into the spreadsheets for the appropriate subclass. The spreadsheet will calculate the indices for all functions. As an alternative, complete the calculations by hand using the calculation tables provided for each function in Chapters 6 through 9

10. If needed, calculate the score (acre or hectare points) to reflect the size of the assessment unit or the impact area and provide a qualitative rating of opportunity

11. Fill out the summary form and prepare reports or other documentation as needed. Attach data forms, aerial photography, "photo" maps, sketches, and documentation of the rationale and logic for decisions made to complete the assessment

It is important to document the rationale for decisions made as a part of completing the assessment methods. This includes conclusions made regarding specific data needed to apply the methods. Decision-makers who have to interpret and apply the results must be able to understand how decisions were made about classification, assessment units, and the data.

## 3.2 Determining Classification

One of the tasks to be completed at a site is to determine the classification of the wetland being assessed. This is critical in choosing the appropriate method(s) and data form(s) to use. A preliminary determination can be made in the office using aerial photography and topographic maps; a final determination, however, must be made in the field.

Those who apply the methods must become familiar with the characteristics that distinguish the different wetland classes and subclasses. These are described in the profiles provided in Appendix C (Part 1). In addition, you can use a dichotomous key of the characteristics that distinguish the wetland types. The key is included as a part of the field data forms in Part 2.

Other methods should be used to assess the classes or subclasses for which Washington State methods have not yet been developed.

Some wetlands aren't easily classified within one class or subclass. In these cases, the user should consider how the wetland functions to help determine which method to use. Furthermore, some wetlands may consist of more than one class or subclass. In these cases, the extent of the subclasses should be identified and mapped, and each area assessed by collecting the appropriate data and using the appropriate method for that type. The area(s) within a wetland being assessed are called assessment unit(s) (AUs).

## 3.3 Identifying Assessment Units

An assessment unit (AU) is the wetland area in which the level of performance of various functions is being assessed. A unit may be an entire wetland or part of a wetland. A wetland is divided into AUs if, as mentioned above, it contains different classes or subclasses. For example, one continuous wetland could contain lacustrine fringe, depressional, and slope classes within its boundary. Each of the areas containing separate classes should be assessed separately.

A wetland may be broken into multiple AUs under other circumstances as well. For example, hydrologic differences such as changes in velocity of water flow within the wetland may warrant creating different AUs. Detailed guidance is provided in Part 2 as a part of methods for collecting data in the field and is not provided here. The following section describes situations in which a wetland <u>should not</u> be divided into AUs.

### 3.3.1 Assessment Units and Land Uses

Differences in land use within a wetland should not to be used to define AUs, unless they coincide with changes in water regime as described in Part 2. For example, if half a wetland is a mature forest and the other half is a dominated by saplings because of recent clear-cutting, the entire area functions as, and should be assessed as, one unit (if the water regime is intact.) For functions where vegetation variables predominate, the performance indices will be based on an average of the altered and unaltered portions.

### 3.3.2 Assessment Units and Property or Project Boundaries

Property boundaries or a project footprint should also not be used to define an AU unless they coincide with changes in water regime. For example, a project may be proposed to fill two acres of a 10-acre wetland. The entire 10-acre wetland should be assessed as one unit to determine the index of performance of the wetland. The index is a score per acre or hectare. Performance scores should then be calculated by multiplying the index for each function by the two acres to be impacted to arrive at the performance being lost by filling two acres.

Guidance regarding AUs in Part 2 is based on the Washington State Wetland Rating System. It doesn't cover all situations a user could encounter. There is a certain amount of subjectivity involved in making judgements about AUs

In all circumstances, the extent of the AU(s) should be mapped and, if there are multiple units, the logic and rationale for dividing them be adequately documented

### 3.3.3 Assessment Units and Proposed Alterations

A wetland should not be divided into AUs by different proposed or actual alterations. For example, as long as the AU is one subclass and has no hydrologic breaks, the entire wetland is the AU even if it is proposed that one area is filled and another is ditched.

### 3.3.4 Dividing AUs Based on Existing Disturbance to Vegetation Communities

There may be circumstances where a wetland has no hydrologic breaks and is in one subclass, but there are areas that are dramatically different, especially in regard to disturbances in vegetation. An example is a wetland in which one part is a grazed pasture and the other is a complex mosaic of mature forest, sedge meadow, and scrub-shrub.

A wetland should *not* be divided into sub-units for assessment based on different vegetation communities. The methods are not sensitive enough to allow for division of AU based on existing disturbance to vegetation. Data collected during field-testing revealed that the methods do not produce reliable, or necessarily accurate results when AUs are broken into sub-units

# 4. Using the Results of the Methods

These methods will provide information about how well individual wetlands are likely to perform different functions. This information may be useful in a wide range of wetland management applications. It is important, however, for anyone using the methods to understand what the results mean and what other information may be needed prior to making wetland management decisions.

This section describes:

- Some ways in which the results can be used
- Other information to consider when making wetland management decisions
- A summary of what the results represent
- Tips for users

The index denotes the assessed potential performance or habitat suitability based on the structural characteristics present in and around the AU. It does not denote the actual performance, as that requires detailed monitoring. It is assumed that the AU will perform the function if the appropriate structural components are present, and if the opportunity is present.

## 4.1 Potential Uses of Method Results for Regulatory or Non-regulatory Applications

The methods were developed primarily for site-specific applications. The methods may also be used to assess a large group of wetlands for a variety of other purposes. Several of the most likely uses of the methods are described below.

**Establishing baseline levels of performance.** Knowing the level of performance of functions at a specific wetland is important in making management decisions about it. For example, information on the level of performance may be important when assessing the benefits of acquiring or preserving a wetland. It may also be useful to assess the current level of performance of a wetland to determine how much effort should be devoted to avoiding or minimizing impacts from a proposed project.

**Comparing the same wetland at different points of time.** Such comparisons will most commonly be used to evaluate a wetland before and after a proposed alteration to determine how a proposed project will change performance of functions. It may also be useful in determining the potential or actual benefits of various conservation activities such as restoration or enhancement. When evaluating the impacts of a proposed action, the user will need to first apply the methods to the existing wetland and then reapply the methods using the predicted characteristics of the wetland after the proposed action. The results of the two

applications can be compared to predict the changes to each function that would result from the proposed action. However, the accuracy of the results will be only as good as one's ability to predict future conditions and provide "predictive" data for each of the questions.

**Comparing different wetlands (same subclass) at the same point in time.** A potential regulatory use may be to assess several wetlands in a given area to help determine where to locate a project so as to have the least impact on wetland functions. A non-regulatory application might be to assess the wetlands in a given area that are likely to provide the greatest flood control or anadromous fish habitat. This will help target the "best" wetlands for acquisition.

**Establishing the adequacy or success of compensatory mitigation**. The methods can be used to direct compensatory mitigation efforts by determining which functions will be affected by a proposed impact. A proposed compensation action can also be assessed to determine if it will provide the appropriate functions at an adequate level. The methods can be used to compare alternative compensation actions to determine which is preferred. The methods can also be used in conjunction with other monitoring procedures to assess the "success" of a compensatory action. Performance standards could include requirements that a certain level of performance of a function or group of functions be met. As a compensatory wetland "matures", the methods can assess increases in function over time. The latter application may be particularly useful in mitigation banking.

**Using the methods for watershed-level applications.** The methods were designed to look at individual wetlands, not entire watersheds, and are therefore generally too time-intensive to use for broad-scale watershed planning. However, they may be useful if an intensive approach is warranted, particularly for small watersheds or sub-basins. In these situations, the methods can identify wetland functions that are deficient or are being lost in a watershed, develop restoration priorities, and make decisions about where to locate future development.

**Using the methods for assessing cumulative impacts**. An assessment of cumulative effects to a specific wetland, as a result of internal changes in the wetland or external changes in the watershed, can best be determined if the wetland is assessed periodically over time. Predicting level of performance before and after alterations due to watershed change is dependent on the degree of accuracy of those predictions. It is difficult to predict with certainty changes to the landscape and their effects on a wetland.

**Setting credits and debits for mitigation banks**. . In the future, the scores generated by the assessment methods may be useful in establishing an accounting system for mitigation banks. At present, however, the lack of methods for many wetland classes prevents the use of these methods for mitigation banking.

## 4.2 Making Management Decisions Using the Results

Assessment results will provide one important piece of information to use in managing or regulating a wetland. A decision-maker, however, will not only have to understand how to interpret the results, but also, how to incorporate other important information such as "values," in order to make sound wetland management decisions.

### 4.2.1 Interpreting the Results

The results will include two basic types of information: 1) a numerical index of the potential level of performance (water quality and quantity functions) or habitat suitability (habitat functions); and 2) a subjective rating of the opportunity for a function to be performed.

The numeric index represents the potential level of performance of a function on a scale of 0 to 10. The indices are a numerical representation of a qualitative assessment. An index score of 8 for a function does not mean that it provides "twice as much" of a function as an index score of 4 for the same function in a similar wetland. It means that a wetland that scores 8 has the potential to perform the function at a significantly higher level than a wetland that scores a 4 for that function. Furthermore, the indices for each function CANNOT BE COMBINED to obtain a single index for the whole wetland.

In addition to understanding the potential of a wetland to perform a function, it is often important to consider the opportunity for that wetland to provide certain functions. For example, a wetland may have all the components needed to provide a high level of removal of nutrients and would therefore receive a high performance index. However, if the water moving through the wetland does not carry excessive nutrients, the wetland has no opportunity to remove them.

In these methods, an assessment of opportunity is based on a qualitative description provided by the person using the methods. The methods originally included equations to assess opportunity. However, these equations could not be adequately calibrated. Too many factors were involved in determining a numeric assessment of opportunity. Thus, it was decided to drop the equations and provide written guidance for completing a qualitative rating of opportunity. A system is described for rating the opportunity of the water quantity, water quality functions, the General Habitat, and the Anadromous Fish functions as high, medium, or low. For the other habitat functions, the user is directed to qualitatively describe the opportunity for the function to be performed.

### 4.2.2 Incorporating Other Information Needed To Make Decisions

Assessment results should **never** be used independently to make management decisions about wetlands. There are several other types of information to consider prior to making a wetland management decision. These include, but are not limited to information on:

- whether the wetland provides important "social functions" such as recreational or educational opportunities or aesthetic values;
- whether the wetland provides habitat for endangered or threatened plant or animal species;
- whether the wetland is a rare or irreplaceable type such as a sphagnum bog or mature, forested system;
- whether there is potential for adaptive management;
- whether modifications to the contributing basin will effect the water regime of the wetland (the methods do not assess this); and
- whether the wetland is located in a natural hazard area such as a floodplain or steep slope.

There are methods available that take some of these other factors into consideration, and they should be used in conjunction with these methods. The Washington State Wetland Rating System (WDOE 1993) is one method that is used widely in Washington.

### 4.2.3 Incorporating Values in Wetland Management Decisions

Once all of the appropriate information has been gathered, a decision-maker must make value judgements about how to interpret and weigh the information. In most regulatory processes the applicable law or policy spells out which factors are most important in making a particular management decision. For example, the presence of an endangered species in a wetland is usually a critical piece of information that dictates a certain decision, irrespective of other factors. Some regulatory programs place greater weight on certain functions such as flood reduction or fish habitat. Others may specify whether certain wetland types, such as sphagnum bogs, may be altered or not. Most regulatory programs have certain standards that will dictate some decisions. However, in many cases, a regulatory program will leave some decisions up to individual discretion in order to make appropriate, site-specific decisions.

In these cases, the decision-maker will have to decide how to weigh the varying information in order to arrive at a decision. These methods do not specify how important any of the functions are; they simply provide information about the different functions that might be "valued" by the regulatory program or the decision-maker.

It is possible for an agency or community to develop a specific "values overlay" that can be used in conjunction with the assessment methods. This has been done with a similar assessment method in several geographic areas of Washington, including the Mill Creek watershed in King County and the lower Snohomish River area in Everett. In these cases, a specific multiplier was developed for each function, thus allowing some functions to be valued higher than others were. Committees of different interest groups and community members developed these multipliers. This approach could be used for a specific watershed or for a particular community.

## 4.3 Tips for Using Results

The following are some pointers for decision-makers when reviewing results of the assessment methods.

- Make sure that any reports providing results include all of the data and documents used, including data sheets and maps. This provides opportunity to confirm the results.

- Confirm that the appropriate subclass method was used. If the wrong subclass method is used (e.g. depressional outflow method used on a riverine flow-through wetland), the results are inaccurate.

- Be sure that all functions performed by that subclass were assessed. It is important to know the level of performance or habitat suitability for all functions to guard against management decisions that would lead unknowingly to maximizing one function at the expense of others.

- Pay close attention to the rationale for dividing a wetland into subclass or hydrologic AUs. How an area is divided can determine how it scores. This is one place where the methods can be manipulated to produce desired results.

- A comparison of performance of functions before and after alteration is only as accurate as the predictions of how the wetland characteristics will be changed by the alteration.

- It is not possible to compare the score for a function in a wetland of one class or subclass with the score for the same function in a wetland of a different subclass. A score of "7" for General Habitat Suitability in a depressional closed wetland is not necessarily equivalent to a score of "7" for the same function in a riverine flow-through wetland. Any comparisons between subclasses must be based on a subjective judgement of the levels of performance of individual functions.

- A "low" index (e.g. index of 1, 2, or 3) for a function does not necessarily mean the wetland is "unimportant." It may be the only wetland in the area providing that function, or the function may be critical in an area. For example, you may decide that an index of 2 for Reducing Peak Flows is "important" if you know that areas downstream of the wetland are prone to flooding.

# 5. *Introduction to the Functions Being Assessed*

## 5.1 Functions Explained

Functions have been defined as the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of wetland ecosystems (Brinson 1993), or in other words, they are the things that wetlands do (Smith et al. 1995). Some of these processes have importance to society because they have an economic value or aesthetic value. For example, water storage is a physical process in wetlands that is important to society because it reduces the impacts of flooding downstream.

Wetland processes, however, occur at all scales; from the microscopic (e.g. bacterial decomposition of organic matter), to continental (e.g. providing refuge and feeding for migrating waterfowl along the continental flyways). The functions defined in assessment methods usually are described as a group of related processes that are on a similar temporal and spatial scale.

If each environmental process were called out as a separate function, the number of functions would be almost infinite. For example, the decomposition of organic matter by bacteria is a combination of many processes; one for each individual species of bacteria found in the wetland. Each bacterial species decomposes organic matter at a different rate and under different environmental conditions, and each of these could be considered a separate wetland function (by the passionate "splitters").

On the other hand, the "removal of imported elements and compounds" is a function identified in the HGM Riverine Guidebook (Brinson, et al. 1995) that represents many different processes. It includes the removal of imported nutrients, contaminants, and other elements and compounds. The function, as defined, combines several hundred different environmental processes. The removal of each nutrient or compound represents a different environmental process, and there are at least a dozen nutrients and several hundred known contaminants that can be found in surface waters.

One of the initial tasks in developing methods, therefore, is to identify and group the range of environmental processes found in those wetlands for which assessments are being developed, into some manageable number of "functions." A draft list of functions was developed by the SWTC to guide Assessment Team decisions about which to assess for a particular subclass. This list was then modified by the Assessment Teams and confirmed by the SWTC.

The SWTC and Assessment Teams chose the functions, keeping the following considerations in mind. Functions should be:

- easily understood by decision-makers and the public,
- closely linked to the "beneficial uses" that are regulated, and
- as narrowly defined as possible.

The choice of functions is important because it determines the parts of the ecosystem that will be assessed. This step is crucial in deciding how to apply the best current science to complex resource management needs. Ideally, the choice of functions should also demonstrate how wetland processes are beneficial to the public.

For example, the functions selected are relatively narrowly defined in order to provide a level of specificity that is important to decision-makers. Specific information is important when making management and regulatory decisions about wetlands. Instead of a function such as "maintaining the distribution and diversity of vertebrates," as is suggested in the HGM Riverine Guidebook (Brinson et al. 1995), a habitat function was included for each of the main animal groups. Habitat needs for a large group such as vertebrates are so diverse that the methods based on such a definition of habitat would be too general. An index of 5 or 10 for "maintaining the distribution and diversity of vertebrates" would not be easy to interpret by a regulator or wetland manager having to make a decision about losing wetlands that provide habitat for anadromous fish. The same holds true for other functions that are broadly defined as "removal of elements and compounds."

The level of detail in the list of functions will be adequate for most general applications. Other methods, however, should be used when more detail is required (e.g. for assessing habitat needs of specific animals use the USFWS Habitat Evaluation Procedures – HEP's).

The Assessment Teams modeled each function as one or more ecosystem processes. The teams limited model development to those processes that best represent the performance of the function and that could be modeled in a rapid assessment. The processes that are used to assess each function are listed within each subclass model. (See "Models At A Glance" at the beginning of each function model). Processes weren't modeled individually, however, for the habitat functions. Instead, the team members identified variables that jointly assess breeding, feeding, and refuge. Habitat models were also developed using target species for birds and mammals. The team kept these target species in mind when identifying the appropriate variables to model. They decided to focus on four species of wetland-associated mammals for the mammal habitat model and several species of wetland-associated birds for the bird habitat model.

## 5.2 Functions Being Assessed

The functions for which assessment models were developed, and their descriptions, are provided below. Not all of these functions are performed by each of the riverine and

depressional subclasses. Other functions that were considered and the logic behind the choices made will be presented in the approach document.

*Functions Related to Water Quality Improvement*

- Potential for Removing Sediment
- Potential for Removing Nutrients
- Potential for Removing Heavy Metals and Toxic Organics

*Functions Related to Hydrology (Water Quantity)*

- Potential for Reducing Peak Flows
- Potential for Decreasing Downstream Erosion
- Potential for Recharging Groundwater

*Functions Related to Habitat Suitability*

- General Habitat Suitability
- Habitat Suitability for Invertebrates
- Habitat Suitability for Amphibians
- Habitat Suitability for Anadromous Fish
- Habitat Suitability for Resident Fish
- Habitat Suitability for Wetland-associated Birds
- Habitat Suitability for Wetland-associated Mammals
- Native Plant Richness
- Potential for Primary Production and Organic Export

**Performance is assessed for each individual function. No overall index for the wetland will be estimated.**

### 5.2.1 Descriptions of Functions

The following is a generic description of the functions that are included in the methods. The specific processes being assessed for each subclass are described at the beginning of each "methods" chapter.

**Potential for Removing Sediment** is defined as the wetland processes that retain sediment within a wetland, and keep it from going to downstream waters in the watershed.

> A wetland performs this function if there is a net annual decrease of sediment load to downstream surface waters in the watershed. Reduction in water velocity and filtration are the major processes by which sediment is removed from surface water (either streamflow or sheetflow) in wetlands. When water velocity is reduced,

particles present in the water will tend to settle out (Mitsch and Gosselink 1993). The size of the particles that settle out is directly related to the reduction in the velocity achieved in the wetland. Filtration is the physical blockage of sediment by erect vegetation.

**Potential for Removing Nutrients** is defined as the wetland processes that remove nutrients (particularly phosphorus and nitrogen) from incoming water, and keep them from going to downstream waters in the watershed.

A wetland performs this function if there is a net annual decrease in the amount of nitrogen and/or phosphorus going to downstream waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce nutrients are:

1) through the trapping of sediment with phosphorus,
2) removal of phosphorus by adsorption to soils that are high in clay content or organic matter, and
3) removal of nitrogen through nitrification and denitrification in alternating oxic and anoxic conditions (Mitsch and Gosselink 1993).

Plant uptake of nutrients is not modeled because nutrients taken up will be released again after a plant dies and exported through the surface outlet. Furthermore, some species of wetland plants actually fix nitrogen (Mitsch and Gosselink 1993). Plant uptake changes the timing of nutrient release from a wetland, but it does not significantly change the net balance of nutrients coming in, and going out of, a wetland (Phipps and Crumpton 1994, and Mitsch et al. 1995).

**Potential for Removing Toxic Metals and Toxic Organic Compounds** is defined as the wetland processes that retain metals and toxic organic compounds, and keep them from going to downstream waters in the watershed.

A wetland performs this function if there is a net annual decrease in the amount of metals and toxic organics flowing to downstream waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce metals and toxic organic loading to downstream receiving waters are through sedimentation of particulate metals, adsorption, chemical precipitation, and plant uptake. Metals that tend to have a high particulate fraction, such as lead (Pb), may be removed through sedimentation. Adsorption is promoted by soils high in clay content or organic matter. Chemical precipitation of many toxic compounds is promoted by wetland areas that are flooded and remain aerobic, as well as those with pH values below 5 (Mengel and Kirkby 1982). Finally, plant uptake is maximized when there is significant wetland coverage by emergent plants (Kulzer 1990).

**Potential for Reducing Peak Flows** is defined as the wetland processes or characteristics by which the peak flow in a watershed can be reduced during major storm events that cause flooding.

Surface water that may otherwise cause flooding is stored to a greater degree in a wetland than typically occurs in terrestrial environments. Wetlands reduce peak flows on streams and rivers by slowing and storing stream flow in overbank areas, and by holding back runoff from the watershed during high water that would otherwise flow directly downstream and cause more severe flooding (Reinelt and Horner 1990).

Reduction in peak flows is often called water storage in other assessment methods (e.g. Brinson et al. 1995). The Assessment Team, however, decided to model more than just water storage. One of the major hydrologic functions of wetlands in a watershed is to attenuate the severity of peak flows during flood events. The level of reduction in flows provided by a wetland is a result of both the storage present within the wetland and the amount of water entering the wetland. Wetlands that have the same amount of storage may not reduce peak flows by the same amount if one has 10 times the volume of water entering it than the other during a flood event.

**Potential for Decreasing Downstream Erosion** is defined as the wetland processes that detain high flows during storms and reduce the duration of erosive flows, thus decreasing downstream erosion in the stream.

A wetland performs this function if it stores excess runoff during and after storm events, before slowly releasing it to downstream surface waters. This is similar to the function provided by stormwater retention/detention (R/D) ponds that are designed to prevent downstream erosion in developed areas.

The major process by which wetlands reduce downstream erosion is through the reduction of the velocity of water flowing downstream. The wetland retains runoff water and reduces downstream flows during storms (water has a higher retention time in the wetland than in the stream). The amount of detention provided is dependent on the available storage and the release rate of runoff. The function of decreasing downstream erosion is closely related to that of reducing peak flows because a reduction in peak flows will also result in a reduction of velocity. All of the variables used in the “peak flow” model are used in this model.

**Potential for Recharging Groundwater** is defined as the wetland processes by which surface water coming into a wetland is transported into subsurface water that flows either into unconfined aquifers, or interflow, that support flows in streams during the dry season.

Wetlands recharge groundwater by holding back precipitation and surface flows. This water then infiltrates into the groundwater system.

There are two aspects of recharge. The first is the recharge of shallow subsurface flows (called interflow) that help maintain low flows in streams during the dry season. The second aspect of the function is recharge of subsurface aquifers. The wetland process that is important to both aspects of the function is infiltration.

The first draft of the assessment methods included separate functions for the recharge of interflow (called Maintaining Seasonal Low Flows) and the recharge of unconfined aquifers (called Recharging Unconfined Aquifers). During the field calibrations, however, it was not possible to characterize the conditions of the subsurface geology and soils well enough to determine if water infiltrating through the wetland would become part of the "interflow" or part of an unconfined aquifer. As a result, the functions were combined, and the model only assesses the relative rates of infiltration in an AU.

Surface outflow from the wetland is not judged to be an important factor in maintaining low flows in streams. Perennial surface outflow from a wetland is not usually a result of waters stored within the wetland. The wetland may be a location where groundwater is discharged, but the source of this groundwater is not within the wetland itself. Rather, it comes from waters stored in the ground throughout the watershed.

If there is no significant groundwater input, a wetland in western Washington will usually dry out by the time dry season low flows are important in streams. Surface water stored within the wetland will usually have evaporated or flowed out. The contribution of a wetland to seasonal low flows is the water that enters the groundwater system during the wet season.

**General Habitat Suitability** is defined as the characteristics or processes present in a wetland that indicate a general suitability as habitat for a broad range of animal species. It also includes processes or characteristics within a wetland that help maintain ecosystem resilience (characteristics that are important in maintaining the ecosystem when it is disturbed).

The assessment model attempts to assess how well an AU provides a number of different habitats. The model is not focused on individual species groups, but rather it emphasizes the elements in a AU that help support a range of different animal species. The "General Habitat Suitability" function may be used as a surrogate for "General Wildlife Habitat", though it is not restricted to the common definition of "wildlife" as mammals, birds, amphibians, and fish. The general habitat function also incorporates elements that are important to invertebrates and other decomposers as well as the macro-fauna.

Many of the variables used to assess the performance of an AU for general habitat are also used in the assessments of habitat suitability for individual species groups. The SWTC and Assessment Teams, however, thought it important to assess General Habitat Suitability in broad terms as well as the individual species groups.

**Habitat Suitability for Invertebrates** is defined as the wetland processes and characteristics that help maintain a high number of invertebrate species in the wetland. The term invertebrates is here more narrowly defined as "macro-invertebrates" or free-living organisms readily seen with the naked eye (> 200 - 500 um) including: Insecta (insects), Amphipoda (scuds,

sideswimmers), Eubranchiopoda (fairy, tadpole, and clam shrimps) Decapoda (crayfishes, shrimps), Gastropoda (snails, limpets), Pelecypoda (clams, mussels), Hydracarina (water mites), Arachnida (spiders) and Annelida, (worms and leeches).

The intent of the assessment is to highlight those wetlands that provide a habitat for the greatest number of invertebrate species within the regional subclass. Invertebrates are diverse and abundant zoological components of freshwater aquatic systems that include wetlands. As such almost any wetland will provide a habitat for some invertebrates. There is a distinct difference, however, between a wetland that has a high abundance of one or two species and one that has a high richness of different species. The important aspect of invertebrate populations that is being assessed is species richness. Wetlands with a high richness tend to be more important in maintaining the regional biodiversity of invertebrate populations and provide a genetic source and genetic refuge that helps maintain ecosystem integrity. Note, however, that some wetlands with a high abundance of a few species may be important to individual wildlife species that feed on these invertebrates.

**Habitat Suitability for Amphibians** is defined as the wetland processes and characteristics that contribute to the feeding, breeding, or refuge needs of amphibian species using wetlands of the regional subclass.

Amphibians are a vertebrate group that include wetland-breeding frogs and toads (e.g., Order Anura, tailless amphibians except as larvae) and salamanders and newts (e.g., Order Caudata (Uradela) tailed amphibians) in the Pacific Northwest. Their richness and abundance indicates they are extremely important in wetland trophic organization. Many native species only breed for a short time in wetlands and as metamorphosed juveniles and adults live upland. Some species may be found in or close to wetlands throughout the year. Eggs and larvae of all species, however, require water for development.

Wetlands play an important role in the life cycles of amphibians by providing the quiet waters and food sources needed for the early stages of amphibian development. The suitability of wetlands as amphibian habitat is assessed by characterizing the conditions in a wetland that support the development of eggs and larvae, and provide protection and food for adults moving in and out of the wetland.

In general, the suitability of a wetland as amphibian habitat increases as the number of the appropriate habitat characteristics increase. The assessment models are focused on species richness and conditions that would support many different species, not on the importance of a wetland to a specific species, including threatened or endangered species.

**Habitat Suitability for Anadromous Fish** is defined as the environmental characteristics that contribute to the feeding, breeding, or refuge needs of anadromous fish species that are using wetlands.

Many wetlands provide cover, depth, surface area, and other attributes necessary for the over-wintering anadromous fish such as coho salmon (*Oncorhynchus kisutch*). Other anadromous fish noted in studies of ponded systems associated with off channel habitat include cutthroat trout (*Oncorhynchus clarki*) and steelhead (*Oncorhynchus mykiss*) (Peterson 1982). Because the distribution and habitat requirements of salmonids and non-salmonids overlap, it is assumed that an AU meeting the habitat requirements of salmonids will also meet the requirements of non-salmonid anadromous fish (Johnson and Stypula 1993).

**Habitat Suitability for Resident Fish** is defined as the wetland processes and characteristics that contribute to the feeding, breeding, or refuge needs of resident native fish.

The function is modeled based on the structural elements, physical components, and other characteristics of the wetland that are considered to be important elements of habitat for resident native fish. In general, the suitability of a wetland as habitat for resident fish is assumed to improve as the number of beneficial habitat characteristics increase.

**Habitat Suitability for Wetland-associated Birds** is defined as the processes and environmental conditions in a wetland that provides habitats or life resources for species of wetland-associated birds. Wetland-associated bird species are those that depend on aspects of the wetland ecosystem for some part of their life needs: food, shelter, breeding, and resting. The guilds of wetland dependent birds used as the basis for building the assessment model included waterfowl, shorebirds, and herons.

In general, the suitability of a wetland as bird habitat increases as the number of appropriate habitat characteristics increase. Another assumption used in developing the model is that wetlands that provide habitat for the greater number of bird species or bird guilds are more suitable than those that have fewer.

**Habitat Suitability for Wetland-associated Mammals** is defined as wetland features and processes that support one or more life requirements of aquatic or semi-aquatic mammals. Mammalian species whose habitat requirements were considered include the beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), river otter (*Lutra canadensis*), and mink (*Mustela vison*).

The SWTC and Assessment Teams decided to focus the model specifically on the aquatic fur-bearing mammals because these are wetland -associated species that are important to society, and they represent different guilds of mammals that use wetlands. Many terrestrial mammals will use wetlands, if they are available, to meet some of their life maintenance requirements. These species, however, do not need wetlands. It would have been too difficult to develop a mammal model that incorporates habitat features for all mammals using wetlands. Such models would have had to incorporate too much information about the surroundings uplands and expanded the scope of the assessment methods beyond their original purpose.

The model for this function is based on general habitat requirements for each of the four wetland-associated mammals. The model reflects a wetland's suitability for mammal richness rather than individual species abundance. It is assumed that

wetlands providing habitat for the greatest number of wetland-associated mammal species function more effectively than ones meeting the habitat needs of fewer species.

**Native Plant Richness** is defined as the wetland processes and characteristics that help maintain a diverse assemblage of native plant species within the wetland.

An AU is judged to provide habitat for native plants if it contains a diverse group of native plants. This function is the only one for which an actual estimate of performance can be made because the number of plant species can be estimated during a single site visit. Many native plants are persistent and can be documented in a rapid assessment method. The assessment of species richness during the site visit is used as a surrogate for the total richness. If an AU contains a diverse and mature assemblage of native plants it is assumed to perform the function at a high level. Those lacking diverse native plant assemblages and structure are assumed to perform the function at a lower level.

The assumption is valid only if the AU has **not** been recently cleared or altered. If the AU has been recently altered, the index from the model will not provide an accurate assessment of the function.

**Potential for Primary Production and Organic Export** is defined as wetland processes that result in the production of plant material and its subsequent export to surface waters.

Wetlands are known for their high primary productivity (variously expressed as gm-Carbon/$m^2$/year or as total biomass) and the subsequent export of organic matter to adjacent aquatic ecosystems (Mitch and Gosselink 1993). In some cases wetlands may be highly productive, but most of the organic material produced is retained within the wetland where it originates. Alternatively, in some wetlands production may be lower, but most of it is exported. The exported organic matter provides an important source of food for downstream aquatic ecosystems (Mitch and Gosselink 1993). Performance of this function requires both that organic material is produced, and that a mechanism is available to move the organic matter to adjacent or contiguous aquatic ecosystems.

# 6. Method to Assess Depressional Outflow Wetlands

The method includes models for the following functions:

- Potential for Removing Sediment
- Potential for Removing Nutrients
- Potential for Removing Heavy Metals and Toxic Organics
- Potential for Reducing Peak Flows
- Potential for Decreasing Downstream Erosion
- Potential for Recharging Groundwater
- General Habitat Suitability
- Habitat Suitability for Invertebrates
- Habitat Suitability for Amphibians
- Habitat Suitability for Anadromous Fish
- Habitat Suitability for Resident Fish
- Habitat Suitability for Wetland-associated Birds
- Habitat Suitability for Wetland-associated Mammals
- Native Plant Richness
- Potential for Primary Production and Organic Export

# 6.1 Potential for Removing Sediment—Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.1.1 Definition and Description of Function

**Removing sediment is defined as the wetland processes that retain sediment in a wetland, keeping it from moving to downgradient surface waters in the watershed.**

A wetland performs this function if there is a net annual decrease of sediment load to downgradient surface waters in the watershed. Reduction in water velocity and filtration are the major processes that remove sediment from surface water (either streamflow or sheetflow) flowing into wetlands. When water velocity is reduced, particles present in the water will tend to settle out (Mitsch and Gosselink 1993). The size of the particles that settle out is directly related to the reduction in the velocity achieved in the wetland. Filtration is the physical blockage of sediment by erect vegetation.

## 6.1.2 Assessing this Function for Depressional Outflow Wetlands

The potential of depressional outflow wetlands to remove sediment is a function of their ability to reduce water velocities as determined by the retention time of the water they hold back and by vegetation structure near the ground surface (Adamus et al. 1991).

Retention time cannot be estimated directly in a rapid assessment method. The amount of storage and the shape of outlets (Adamus et al. 1991) are used as variables that capture two aspects of retention time – volume of water stored and potential for retention resulting from outlet constrictions. Attempts were made during the field calibration to calculate retention time using estimated runoff flows from rainfall data and USGS runoff data. However, these data did not provide enough resolution between wetlands, and the indicators described had to be used instead.

The area over which sediment retention occurs, however, may be smaller than the actual area of the AU. Since the model generates an index for the entire wetland, a correction factor ($V_{effectarea1}$) is included that reflects the portion of the AU that actually has the potential for performing the function.

## 6.1.3 Model at a Glance

### *Depressional Outflow — Removing Sediment*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Velocity reduction** | **Vstorage** | Average depth of both live and deadstorage |
| **Velocity reduction** | **Vout** | Qualitative descriptors of outlet constriction |
| **Velocity reduction** | **Veffectarea1** | % of AU that is seasonally inundated |
| **Filtration** | **Vvegclass** | % of AU in different Cowardin vegetation classes |
| **Filtration** | **Vunderstory** | % area of herbaceous understory in AU |
| | **Index:** | $\frac{\text{Vstorage + Vout + Veffectarea1 + Vvegclass + Vunderstory}}{\text{Score from reference standard site}}$ |

## 6.1.4 Description and Scaling of Variables

$V_{storage}$ – The amount of water stored in an AU can be assessed as a combination of both "live" storage and "dead" storage. Livestorage is a measure of the volume of storage available during major rainfall events. Another name used for this is "dynamic surface storage". Deadstorage is the amount of water stored below the bottom of the outlet. It is "dead" in the sense that, once filled, the AU does not have that volume available to store additional storm water. Livestorage is corrected by a factor to estimate the average depth of storage across the entire AU.

**Rationale:** Vstorage is a measure of the volume of storage available. It is related to residence time since it is a variable in the equation: residence time = storage/inflow volume. The assumption made is that AUs in this subclass with a higher average volume of storage will have a higher retention time than those with less storage for any given rate of inflow. Wetlands that store water tend to trap more sediment than those that do not (Fennessey et al. 1994). Attempts were made during the field calibration to estimate inflow volumes using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between wetlands, and the variable was not included in the model.

**Indicators:** The variable for storage has two indicators; one for livestorage and one for dead. The indicator for the amount of livestorage in a depressional outflow wetland is the difference in elevation between the bottom of the outlet and any flood marks or watermarks on vegetation or along the shore. The assumption is that any storage below the outlet elevation is deadstorage because it will have been filled by the time flooding occurs. To estimate the average depth of livestorage in the AU the maximum height as measured at the outlet is corrected by a factor representing the average cross section of the seasonally inundated areas in the AU.

The extent of permanent open water is used as the indicator for deadstorage. In the calculations it is assumed that the average depth of the permanent open water is 2 m and this is used to estimate volume of storage. The average depth of deadstorage is determined by multiplying the 2 m depth by the percent of the AU that is permanent open water. Depth of water is used to estimate storage volumes because the index score is calculated on a per acre basis. Total storage can be estimated by multiplying the average depth by the area of the AU.

**Scaling:** AUs with average depths of dead and livestorage (as the sum of the two) that are equal to or greater than 1 m are scored a [1] for the variable. Values for storage that are less than 1 m are scaled as average depth/1.0.

$V_{out}$ – The amount of constriction in the surface outflow from the AU.

**Rationale:** Water velocities will be reduced in an AU if its outlet is constricted, regardless of its internal structure (Adamus et al. 1991). The constriction holds back water and thereby reduces velocity and increases retention time.

**Indicators:** No indicators are needed. The relative constriction of the outlet is determined in the field.

**Scaling:** The scaling of this variable is based on the amount of constriction found in the AU.

**Unconstricted or slightly constricted** – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

**Moderately constricted** – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

**Severely constricted** – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

$V_{effectarea1}$ – area of the AU wherein sediment retention is expected to take place. Some parts of an AU may never be inundated by surface waters and thus will not remove sediments from surface waters.

**Rationale:** In this assessment method, an index for an AU is calculated on a "per acre" basis. An overall index for an AU is then calculated by multiplying its "per acre" score by its area. Thus, a correction factor representing the area of the AU that actually performs the function, relative to its overall size, is needed.

**Indicators:** In western Washington, there is some difficulty in establishing the area of an AU that is regularly inundated because the water regime can be so variable for many AUs. The indicator chosen by the Assessment Teams to represent this variable is the area of the AU that is inundated or flooded on a seasonal basis. Indicators such as water marks, deposition lines, or other discoloration on vegetation or rocks can be used to determine the area of inundation during summer.

**Scaling:** This variable is scaled based on the percentage of the AU that is seasonally inundated. AUs that are seasonally inundated over their entire surface (100%) score a [1]. Areas of inundation less than 100% are scaled proportionally as %area/100.

$V_{vegclass}$ – Percent of ground in an AU that is covered by each of four Cowardin (1979) vegetation classes (emergent, scrub/shrub, forest, and aquatic bed).

**Rationale:** Persistent plants enhance sedimentation by resisting the flow of water thereby reducing velocity (Jackson and Starrett 1959, Karr and Schlosser 1977, see also review in Adamus et al. 1991). It is assumed that three of the four Cowardin vegetation classes represent persistent vegetation.

**Indicators:** No indicators are needed. The areal extent of the four vegetation classes can be estimated directly.

**Scaling:** The scaling of the variable is based on the percent of the AU covered by four different vegetation classes with a scaling factor based on the type of vegetation. Emergent vegetation is assumed to provide the best sediment retention because it is usually the densest and provides the best trapping near the ground surface (relative factor = 1). Scrub/shrub vegetation is judged to provide almost as much sediment trapping and is factored at 0.8. Forests usually do not have a very high stem density near the surface and are factored at 0.3. Aquatic bed vegetation is not usually permanent and persistent, and therefore, is not expected to provide much sediment trapping. It is factored as [0].

The score for this variable is calculated as (fraction of AU with emergents x 1) + (fraction of AU with scrub/shrub x 0.8) + (fraction of AU with forest x 0.3).

$V_{understory}$ – The areal extent of herbaceous vegetation under forested and scrub/shrub areas of the AU.

**Rationale:** This variable was included to correct a potential error in the previous variable ($V_{vegclass}$). The Cowardin classification characterizes only the highest layer of vegetation and does not characterize the understory. AUs that are forested may still

provide good sediment retention if they have an herbaceous understory. Only relatively dense areas of understory with a minimum cover of 20% are included in this variable.

**Indicators:** No indicators are needed. The areal extent of the herbaceous understory can be estimated directly.

**Scaling:** The scaling of the variable is based on the percent of the AU covered by a herbaceous understory. AUs with a 100% cover of understory over the entire unit are scaled as [1]. AUs with a cover of less than 100% are scaled proportionally as %area/100.

## 6.1.5 Calculations of Potential Performance

### *Depressional Outflow – Removing Sediment*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vstorage** | *Highest:* | Average depth of live + deadstorage > = 1 m | If calculation >= 1.0 Enter "1" | |
| | *Lowest:* | No live or deadstorage | If calculation = 0 Enter "0" | |
| | *Calculation:* | Scaling is set as average depth/1 | Enter result of calculation | |
| | 1. Calculate livestorage as: D10 x (0.67 x D11.1 + 0.5 x D11.2 + 1 x D11.3)<br>2. Calculate deadstorage as: D8.3 x 0.01 x 2<br>3. Storage = live + deadstorage<br>4. Result = storage/1.0 | | | |
| **Vout** | *Highest:* | Severely constricted | If D13.3 = 1, enter "1" | |
| | *Moderate:* | Moderately constricted | If D13.2 = 1, enter "0.5" | |
| | *Lowest:* | Slightly, or un-constricted | If D13.1 = 1, enter "0" | |
| **Veffectareal** | *Highest:* | 100% of the AU, is seasonally inundated | If D8.1 = 100, enter "1" | |
| | *Lowest:* | 0% of the AU is seasonally ponded or inundated | If D8.1 = 0, enter "0" | |
| | *Calculation:* | Scaling = (% of AU inundated /100 rounded off to 1 decimal) | Enter result of calculation | |
| | Calculate D8.1/100 to get result | | | |
| **Vunderstory** | *Highest:* | 100% of AU has herbaceous understory and FO + SS =100% | If calculation = 1, enter "1" | |
| | *Lowest:* | No herbaceous understory in AU | If D16 = 0, enter "0" | |
| | *Calculation:* | Scaling based on understory as % of the total area of AU | Enter result of calculation | |
| | Calculate (0.01xD16) x (D14.1 +D14.2+D14.3 +D14.4)/100 to get result | | | |
| **Vvegclass** | *Highest:* | 100% of AU has emergent class | If D14.5 = 100, enter "1" | |
| | *Lowest:* | No emergent, scrub/shrub, or forest vegetation present in AU | If sum of (D14.1 to D14.5) = 0, enter "0" | |
| | *Calculation:* | Emergent vegetation scaled as 1, scrub/shrub as 0.8 and forested as 0.3 x the relative % area of each in AU | Enter result of calculation | |
| | Calculate [(D14.5x1) +((D14.3+D14.4) x 0.8) + ((D14.1+D14.2) x0.3))] x 0.01 to get result | | | |
| | | | **Total of Variable Scores:** | |
| | | | ***Index for Removing Sediment = Total x 2.56 rounded to nearest 1*** | |
| | | | ***FINAL RESULT:*** | |

## 6.1.6 Qualitative Rating of Opportunity

The opportunity of AUs in this subclass to remove sediment is a function of the level of disturbance in the landscape. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower sediment loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that an AU has to remove sediment is, therefore, linked to the amount of development, agriculture, or logging present in the upgradient part of its contributing basin.

Users must make a qualitative judgement on the opportunity of the AU to actually trap sediment by considering the land uses in the contributing watershed and the condition of its buffer. The opportunity for an AU in the depressional outflow subclass to remove sediments is "**Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged. Densely vegetated watersheds (e.g., undisturbed forest) stabilize soils, reduce runoff velocity, and thus export less sediment (Bormann et al. 1974, and Chang et al. 1983).

The opportunity is "**Low"** if the AU receives most of its water from sheetflow rather than from an incoming stream, and it has a good vegetated buffer. Vegetated buffers will trap sediments coming from the surrounding landscape before they reach the AU. A buffer that is only 5 m wide will trap up to 50% of the sediment while one that is 100 m wide will trap approximately 80% of the sediments (Desbonnet et al. 1994). The opportunity is also "**Low"** if the AU receives most of its water from groundwater since this source of water does not carry any sediments.

The opportunity for the AU to remove sediments is "**High"** if the contributing watershed is mostly agricultural, or it contains recent construction, or clear-cut logging. In contrast to undisturbed watersheds, urban, agricultural, or logged watersheds have more exposed soils and thus higher sediment loadings. AUs with upgradient disturbances to the watershed will have a greater opportunity to remove sediment and improve water quality than those in undisturbed watersheds. In general, AUs that are in urban or rapidly urbanizing watersheds will usually have some on-going construction. These AUs can all be assumed to have a "**High"** opportunity for sediment removal. Some watersheds may also have a high sediment load from natural geologic processes such as landslides or avalanches. If you know that the AU is in a watershed with "geologically" induced sediment loads, its opportunity should also be rated as "**High"**.

The opportunity to remove sediment is "**Moderate"** if the activities that generate sediment are a small part of the contributing watershed, or if they are relative far away from the AU. The user must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the summary page of the assessment.

# 6.2 Potential for Removing Nutrients — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.2.1 Definition and Description of Function

**Removing Nutrients is defined as the wetland processes that remove nutrients (particularly phosphorus and nitrogen) present in surface waters, and keep them from going to downgradient waters in the watershed.**

A wetland performs this function if there is a net annual decrease in the amount of nitrogen and phosphorus going to downgradient waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce nutrients are: 1) trapping of sediment with phosphorus; 2) removal of phosphorus by adsorption to soils high in clay content or organic matter; and 3) removal of nitrogen through nitrification and denitrification in alternating oxic and anoxic conditions (Mitsch and Gosselink 1993).

Plant uptake of nutrients is not modeled because nutrients taken up will be released again after a plant dies and exported through the surface outlet. Furthermore, some species of wetland plants actually fix nitrogen (Mitsch and Gosselink 1993). Plant uptake changes the timing of nutrient release from a wetland, but it does not significantly change the net balance of nutrients coming in, and going out of, a wetland (Phipps and Crumpton 1994, and Mitsch et al. 1995).

## 6.2.2 Assessing this Function for Depressional Outflow Wetlands

The potential that wetlands in the depressional outflow subclass have to remove phosphorus from water is modeled as their ability to trap sediments and to adsorb the nutrient to its soils. The ability to trap sediments is characterized by the index generated in the "Removing Sediments" model. The sorptive properties of the soils are characterized based on the organic or clay content of the soils since these are the two types of soils with the highest rates of adsorption of phosphorus (Mitsch and Gosselink 1993).

The potential of wetlands to remove nitrogen is modeled using the area of the wetland that undergoes a seasonal oxic/anoxic cycling. Since seasonal redox potentials cannot be measured in a wetland during a rapid assessment, the indicator used is the percent of the AU that is seasonally inundated minus the percent of the AU that is permanently inundated/ponded. It is assumed that the permanently ponded area is mostly anoxic and does not receive enough oxygen to stimulate the nitrification process. In addition, the relative amount of constriction of the outlet is used as a surrogate for detention time, or the length of time the seasonal waters are held back in the AU.

## 6.2.3 Model at a Glance

### *Depressional Outflow — Removing Nutrients*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Phosphorus Removal** | **Ssed** | Index for Removing Sediments |
| **Phosphorus Removal** | **Vsorp** | % of AU with clay soil; % of AU with organic soil |
| **Nitrogen transformation** | **Veffectarea2** | Area of seasonal inundation - area of permanent open water |
| **Nitrogen transformation** | **Vout** | Qualitative description of outlet characteristics |
| | **Index:** | $\frac{\text{Ssed + Vsorp + Veffectarea2 + Vout}}{\text{Score from reference standard site}}$ |

## 6.2.4 Description and Scaling of Variables

$S_{sed}$ – Index from the function "Removing Sediments."

**Rationale:** The index is used to model the removal of phosphorus from incoming waters because much of this nutrient comes into an AU already bound to particulate sediments (for a review see Adamus et al. 1991).

**Indicators:** No indicators are needed. The variable is an index from another function.

**Scaling:** The index is already scaled between 0 and 1 and this is normalized to 0 - 1.

$V_{sorp}$ – The sorptive properties of the surface soils present in an AU.

**Rationale:** Uptake of dissolved phosphorus through adsorption to soil particles is highest when soils are high in clay or organic content (Mitsch and Gosselink 1993).

**Indicators:** The indicator for sorptive properties of soils is the extent of the AU with high content of clay or organic matter.

**Scaling:** AUs with large areas of organic soils or clay soils (> 30% clay) are scaled higher than those with less. The actual scaling is calculated based on the area of mineral soil that is not clay or organic for ease of computation. AUs with less than 50% mineral soils (not clay or organic) are scored a [1]. Those with 50 – 95% mineral soils are scored a 0.5, and those with >95% mineral soils (not clay or organic) are scored a [0].

$V_{effectarea2}$ – Areal extent of the AU (as a % of total) that undergoes changes between oxic and anoxic conditions.

**Rationale:** Nitrogen transformation occurs in areas of the AU that undergo changes between oxic and anoxic regimes. The oxic regime is needed to change ammonium ions ($NH_4^+$) to nitrate, and the anoxic regime is needed for denitrification by bacteria (changing nitrate to nitrogen gas) (Mitsch and Gosselink 1993).

**Indicators:** The indicator for the zone where oxygen saturation changes is the seasonally inundated area minus the area of permanent inundation. The assumption for using this indicator is that areas that are seasonally inundated are saturated for a long enough period to develop anoxic conditions and thus denitrification. The seasonal drying then re-introduces oxic conditions that promote nitrification. The area that is permanently inundated, however, is not expected to have enough oxygen at the surface to promote nitrification.

**Scaling:** AUs that are completely inundated seasonally, and have no permanent open water, are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is only seasonally inundated (%area / 100).

***$V_{out}$*** – The amount of constriction in the surface outflow from the AU.

**Rationale:** Water will tend to be held longer in an AU if its outlet is constricted, regardless of its internal structure (Adamus et al. 1991). The constriction is judged to increase the residence time and permit a longer period for the denitrification to occur in the AU. *NOTE:* $V_{out}$ is also a variable in the "removing sediments" model. It is used again here because in Ssed is used only to model the removal of phosphorus. Since it is also important in the removal of nitrogen it is used again to model the latter process.

**Indicators:** No indicators are needed. The relative constriction of the outlet is determined in the field.

**Scaling:** The scaling is based on the amount of constriction found in the AU.

**Unconstricted or slightly constricted** – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

**Moderately constricted** – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

**Severely constricted** – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

## 6.2.5 Calculations of Potential Performance

### *Depressional Outflow – Removing Nutrients*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Sssed** | *Score is scaled* | Index for Removing Sediment | (Index of function)/10 | |
| **Vsorp** | *Highest:* | Non-clay mineral soils are <50% of area | If D47.3 < = 1, enter "1" | |
| | *Moderate:* | Non-clay mineral soils are 50-95% of area | If D47.3 = 2, enter "0.5" | |
| | *Lowest:* | Non-clay mineral soils are >95% of area | If D47.3 = 3, enter "0" | |
| **Veffectarea2** | *Highest:* | 100% of the AU is seasonally inundated (no POW) | If calculation = 1, enter "1" | |
| | *Lowest:* | 0% of the AU is seasonally ponded | If calculation = 0 enter "0" | |
| | *Calculation:* | Scaling = (% of AU inundated/100) | Enter result of calculation | |
| | Calculate (D8.1-(D8.3+D14.6))/100 to get result | | | |
| **Vout** | *Highest:* | Severely constricted | If D13.3 = 1, enter "1" | |
| | *Moderate:* | Moderately constricted | If D13.2 = 1, enter "0.5" | |
| | *Lowest:* | Slightly or Unconstricted | If D13.1 = 1, enter "0" | |
| | | | **Total of Variable Scores:** | |
| ***Index for Removing Nutrients = Total x 2.56 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

### 6.2.6 Qualitative Rating of Opportunity

The opportunity of AUs to remove nutrients should be judged based on the characteristics of its upgradient watershed. Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower nutrient loads than those that have been impacted by development, agriculture, or logging practices (Hartmann et al. 1996, and Reinelt and Horner 1995). The opportunity that an AU has to remove nutrients is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin. In addition, there are areas in western Washington that have naturally high phosphorus levels in groundwater (Van Denburgh and Santos 1965). AUs in these areas will have an increased opportunity to remove phosphorus if groundwater is a major source of water to the AU.

Users must make a qualitative judgement of the opportunity the AU actually has to remove nutrients by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass to remove nutrients is "**Low"** if most of its contributing watershed is undeveloped, or not farmed.

The opportunity for the AU to remove nutrients is "**High"** if the contributing watershed is mostly agricultural.

The opportunity to remove nutrients is "**Moderate"** if the activities that generate nutrients are a small part of the contributing watershed, or if they are relatively far away from the AU. It should also be considered moderate if the AU is located in a region of high concentrations of phosphorus in groundwater. AUs fed by groundwater high in phosphorus content have a greater opportunity to remove phosphorus through soil adsorption. [See results from study of groundwater phosphorus and removal in the Patterson Creek 12 AU discussed in Reinelt and Horner (1995)]. Areas in western Washington with high levels of phosphorus in groundwater can be identified from data presented in Van Denburgh and Santos (1965).

The user must use their judgement in rating the opportunity, and document their decision on the data sheet (see Part 2).

# 6.3 Potential for Removing Metals and Toxic Organic Compounds — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.3.1 Definition and Description of Function

**Removing Metals and Toxic Organic Compounds is defined as the wetland processes that retain toxic metals and toxic organic compounds coming into the wetland, and keep them from going to downgradient waters in the watershed.**

An AU performs this function if there is a net annual decrease in the amount of toxic metals and toxic organics flowing to downgradient waters (either surface or groundwater) in the watershed. The major processes by which wetlands reduce metals and toxic organic loadings to downgradient waters are through:

- sedimentation of particulate metals,
- adsorption,
- chemical precipitation, and
- plant uptake.

Metals that tend to have a high particulate fraction, such as lead (Pb), may be removed through sedimentation. Adsorption is promoted by soils high in clay content or organic matter. Chemical precipitation is promoted by wetland areas that are inundated and remain aerobic, as well as those with pH values below 5 (Mengel and Kirkby 1982). Finally, plant uptake is maximized when there is significant wetland coverage by emergent plants (Kulzer 1990).

## 6.3.2 Assessing this Function for Depressional Outflow Wetlands

The potential that wetlands in the depressional outflow subclass have to remove metals and toxic organic compounds is assessed by their ability to reduce water velocities and trap sediment that might contain toxic compounds, and specific characteristics that indicate potential for adsorption, precipitation and uptake by plants. The index for sediment removal is used to simplify the model. Adsorption, precipitation and uptake by plants are each modeled by a separate variable.

## 6.3.3 Model at a Glance

### *Depressional Outflow — Removing Metals and Toxic Organics*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Sedimentation** | **Ssed** | Index for "Removing Sediments" |
| **Adsorption** | **Vsorp** | % of AU with clay soil; % of AU with organic soil |
| **Precipitation** | **Vph** | pH of interstitial water |
| **Plant uptake** | **Vtotemergent** | % area of emergent vegetation in AU |
| **Plant uptake** | **Veffectarea1** | % of AU that is seasonally inundated |
| | **Index:** | $\frac{\text{Ssed + Vsorp + Vph + Vtotemergent + Veffectarea1}}{\text{Score from reference standard site}}$ |

## 6.3.4 Description and Scaling of Variables

$S_{sed}$ – Index from the function "Removing Sediments."

**Rationale:** The index is used to model the removal of toxic compounds from incoming waters because many of them are transported into an AU already bound to particulate sediments (for a review see Adamus et al. 1991).

**Indicators:** No indicators are needed. The variable is an index for a function.

**Scaling:** The index is already scaled between 0 and 1 and this is normalized to a range of 0 - 1.

$V_{sorp}$ – The sorptive properties of the surface soils present in an AU.

**Rationale:** Adsorption of both toxic metals and toxic organic compounds is highest when the soils have a high cation exchange capacity (Mengel and Kirkby 1982 ). These are the soils high in either clay or organic content.

**Indicators:** The indicator for sorptive properties of soils is the extent of the AU with high content of clay or organic matter.

**Scaling:** AUs with large areas of organic soils or clay soils (> 30% clay) are scaled higher than those with less. The actual scaling is calculated based on the area of mineral soil that is not clay or organic for ease of computation. AUs with less than 50% mineral soils (not clay or organic) are scored a [1]. Those with 50 –95% mineral soils are scored a 0.5, and those with >95% mineral soils (not clay or organic) are scored a [0].

$V_{pH}$ – The pH of interstitial water.

**Rationale:** Many toxic metals are precipitated out of water when the pH is low. Although there are a few, such as lead, that precipitate out at high pH, the Assessment Team judged that a low pH was better for removing toxic metals overall. Furthermore, the high pH needed to precipitate a few metals (>9) are rarely, if ever, encountered in the wetlands of western Washington.

**Indicators:** pH can be measured directly using pH tabs.

**Scaling:** Low pH (<= 4.5) in the interstitial waters of an AU results in the highest score [1] and optimal removal. A pH between 4.5 and 5.5 scores a [0.5] and a pH > 5.5 score a [0].

$V_{totemergent}$ – The areal extent (as % of AU) of emergent plant species in both the emergent zone and as an herbaceous understory to areas of forest and scrub/shrub.

**Rationale:** Emergent species have, in general, been found to sequester metals and remove oils and other organics better than other plant species (Hammer 1989, and Horner 1992). AUs dominated by emergents were judged to sequester toxic metals and remove organic compounds better than those dominated by forest or scrub/shrub. Furthermore, the emergent vegetation and herbaceous understory support a higher microbial population that can decompose organic toxicants. This is due to a larger surface area exposed to incoming water.

**Indicators:** No indicators are needed. The areal extent (as % of AU) of emergent species and herbaceous understory is estimated directly.

**Scaling:** The scaling of the variable is based on the percent of the AU covered by emergent species (using the Cowardin definition) and by an herbaceous understory. AUs with a 100% cover of emergents + understory are scaled as [1]. AUs with a cover of less than 100% are scaled proportionally as %area/100.

$V_{effectarea1}$ – The area of the AU over which the removal of metals and toxic organic compounds is expected to take place. Some parts of an AU may never be inundated by surface waters and thus will not remove toxics from surface waters.

**Rationale:** In this assessment method, an index for an AU is calculated on a "per acre" basis. An index for an AU is then calculated by multiplying its "per acre" score by its area. Thus, a correction factor representing the area of the AU that actually performs the function, relative to its overall size, is needed.

**Indicators:** In western Washington, there is some difficulty in establishing the area of an AU that is regularly flooded because the water regime can be so variable for many AUs. The indicator chosen by the Assessment Teams to represent this variable

is the area of the AU that is inundated or flooded on a seasonal basis. The area of surface water inundation during the summer must be determined by indicators such as water marks, deposition lines, or other discoloration on vegetation or rocks.

**Scaling:** This variable is scaled based on the percentage of the AU that is seasonally inundated. AUs that are seasonally inundated over their entire surface (100%) score a [1]. Areas or inundation less than 100% are scaled proportionally as %area/100.

## 6.3.5 Calculations of Potential Performance

### *Depressional Outflow – Removing Metals and Toxic Organics*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Ssed** | *Score is scaled* | Index for Removing Sediment Function | (Index of Function)/10 | |
| **Vsorp** | *Highest:* | Non-clay mineral soils are <50% of area | If D47.3 < =1, enter "1" | |
| | *Moderate:* | Non-clay mineral soils are 50-95% of area | If D47.3 = 2, enter "0.5" | |
| | *Lowest:* | Non-clay mineral soils are >95% of area | If D47.3 = 3, enter "0" | |
| **Vph** | *Highest:* | pH less than of equal to 4.5 | If D26. 1 < = 4.5, enter "1" | |
| | *Moderate:* | pH between 4.5 and 5.5 | If D26.1 > 4.5 and < = 5.5, enter 0.5 | |
| | *Lowest::* | pH greater than 5.5 | If D26. 1 > 5.5, enter "0" | |
| **Vtotemergent** | *Highest:* | 100% of AU has herbaceous understory and/or emergents | If calculation = 1, enter "1" | |
| | *Lowest:* | AU has 0% of emergents | If D14.5 + D16 = 0, enter "0" | |
| | *Calculation:* | Scaling = (% of AU with emergents + understory/100) | Enter result of calculation | |
| | Calculate D14.5 + (D16/100x sum (D14.1 to D14.4)) /100 to get result | | | |
| **Veffectarea1** | *Highest:* | 100% of the AU is seasonally ponded or inundated | If D8.1 =100, enter "1" | |
| | *Lowest:* | 0% of the AU is seasonally ponded | If D8.1 = 0, enter "0" | |
| | *Calculation:* | Scaling = (% of AU inundated/100) | Enter result of calculation | |
| | Calculate D8.1/100 to get result | | | |
| | | | **Total of Variable Scores:** | |
| ***Index for Removing Metals and Toxic Organics = Total x 2.38 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

### 6.3.6 Qualitative Rating of Opportunity

The opportunity of AUs in these subclasses to remove metals and toxic organic compounds should be judged using the characteristics of the upgradient watershed. Those land uses or activities that contribute metals and toxic organics to surface waters include urban and residential areas and agricultural activities involving pesticide/herbicide applications.

Relatively undisturbed watersheds in the lowlands in western Washington will carry much lower loads of toxic chemicals than those that have been impacted by residential, urban development or agriculture (Reinelt and Horner 1995). The opportunity that an AU has to remove toxic compounds is, therefore, linked to the amount of development and agriculture present in the upgradient part of its contributing basin

Users must make a qualitative judgement of the opportunity the AU actually has to remove toxic compounds by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass to remove toxic compounds is "**Low"** if most of its contributing watershed is undeveloped, and not farmed.

The opportunity for the AU to remove nutrients is "**High"** if the contributing watershed is mostly agricultural, urban, commercial, or residential.

The opportunity is "**Moderate"** if the activities that generate toxic compounds are a small part of the contributing watershed, or if they are relative far away from the AU.

The user must use their judgement in deciding whether the opportunity is moderate or high, and document their decision on the summary sheet (Part 2).

# 6.4 Potential for Reducing Peak Flows — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.4.1 Definition and Description of Function

**Reducing Peak Flows is defined as the wetland processes or characteristics by which the peak flow in the downgradient part of the watershed is reduced during major rainfall events that cause flooding.**

Surface water that may otherwise cause flooding is stored to a greater degree in a wetland than typically occurs in terrestrial environments. Wetlands reduce peak flows on streams and rivers by slowing and storing streamflow in overbank areas, and by holding back runoff during high water periods when it would otherwise flow directly downgradient and increase flooding.

Reduction in peak flows is often called water storage in other assessment methods (e.g. Brinson et al. 1995). The Assessment Team, however, decided to model more than just water storage. One of the major hydrologic functions of wetlands in watersheds of western Washington is to attenuate the severity of peak flows during flood events. The level of reduction in flow provided by an AU is the result of both the storage present within it and the amount of surface water entering the AU. AUs that have the same amount of storage may not reduce peak flows by the same amount if one has 10 times the volume of water entering it than the other during a flood event.

> *NOTE:* Depressional outflow wetlands that have been created or modified by dikes with outflow structures cannot be assessed using this model because the residence time can be changed quickly and unpredictably by human manipulation.

## 6.4.2 Assessing this function for Depressional Outflow Wetlands

The potential of depressional outflow AUs to reduce peak flows is modeled based on the short-term storage capabilities of the AU and an estimate of the relative amount of flow it captures from the upgradient contributing basin. Short-term storage is often called “live-storage” by hydrologists, or “dynamic surface storage” in the national HGM approach (Brinson et al. 1995). In western Washington it is modeled as the amount of water an AU stores above its outlet level.

Any storage below the outlet level of the AU was considered "deadstorage" by the Assessment Team because it is usually filled in western Washington by the time a flood event occurs, and not available to capture storm flows. Since most flooding events occur somewhat later in the late fall, winter and early spring, reductions in peak flow will occur only when an AU has some live-storage as well.

The same argument was judged to apply to the storage within the interstices of the soil. Wetland soils in western Washington are usually saturated by the time most flood events occur, and were not judged to be important in reducing peak flows.

An important factor in peak flow attenuation of depressional wetlands is how much of the surface flow from rainfall event they may actually capture. Wetlands further upgradient in a watershed or basin are judged to be more important in reducing peak flows because they generally hold back a larger percentage of the surface flows. Attempts were made during the field calibration to estimate flows to an AU using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between AUs. Another variable for flows considered was the stream order. Again the information available on stream order was not easily accessible nor was it very accurate. The ratio of the area in an AU that is inundated to the area of its contributing basin is used to estimate the relative amount of surface water a depressional outflow AU will capture.

## 6.4.3 Model at a Glance

### *Depressional Outflow — Reducing Peak Flows*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Short term storage** | **Vlivestorage** | Elevation difference between bottom of outlet and flood marks |
| **Short term storage** | **Vout** | Qualitative descriptors of outlet constriction |
| **Amount of surface flow captured** | **Vinund/shed** | Ratio of area of inundation to contributing basin |
| | **Index:** | $\frac{\text{Vlivestorage + Vout + Vinund/shed}}{\text{Score from reference standard site}}$ |

## 6.4.4 Description and Scaling of Variables

***$V_{livestorage}$*** – The amount of livestorage present in the AU during an inundation or flooding event.

> **Rationale:** $V_{livestorage}$ is a measure of the volume of storage available during major rainfall events that cause flooding. This variable recognizes that some AUs, particularly those with groundwater connections, have water present below the outlet elevation during peak flows that does not contribute to reductions in peak flows (so called "deadstorage"). Others, fill up during small rainfall events, and thus, have no storage below the level of the outflow.

**Indicators:** The indicator for the amount of livestorage in a depressional outflow AU is the difference in elevation between the bottom of the outlet and any flood marks or water marks on vegetation or along the shore. The assumption is that any storage below the outlet elevation is deadstorage because it will have been filled by the time flooding occurs.

To estimate the average depth of livestorage, the maximum depth, as estimated at the outflow, is corrected by a factor to reflect the shape of the inundated area (see Calculation Table 6.4.5).

Livestorage can be estimated as an average depth rather than volume because the index for the AU is established on a per acre basis. The relative index for a specific function is multiplied by the acreage of the AU to establish an overall index for the entire unit.

**Scaling:** AUs that have an average depth of 1 m, or more, of livestorage are scored a [1] for the variable. The rest are scored on a proportional scale (depth of livestorage in m / 1).

***$V_{out}$*** – The amount of constriction in the surface outflow from the AU.

**Rationale:** The variable is a measure of the relative capacity of the outlet to impound and store water temporarily during a flood event. AUs that have constricted outlets due to undersized road culverts, or narrow incised channels hold back water longer than a flooding event and will therefore delay and "spread out" the peak flows. Water velocities and flows out of an AU will be reduced in an AU if its outlet is constricted regardless of its internal structure (Adamus et al. 1991).

**Indicators:** No indicators are needed. The relative constriction of the outlet is determined in the field.

**Scaling:** The scaling of this variable is based on the amount of constriction found in the AU.

**Unconstricted or slightly constricted** – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

**Moderately constricted** – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

**Severely constricted** – These are small culverts or heavily incised channels anchored to steep slopes. In general, you will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

***$V_{inund/shed}$*** – The ratio of the area that is seasonally ponded or inundated within the AU to the area of its contributing basin.

**Rationale:** The potential of an AU to reduce peak flows from its contributing basin is partially a function of how much storm flow it can capture. This is based on the amount of storage available at the time of a storm relative to the volume coming into the AU during a storm. In this model, the area of the contributing basin is used to estimate the relative amount of water (volume as cubic meters/second) entering it, while the area of inundation is used to estimate the relative volume that can be stored. Live-storage was not used because it is a different unit of measurement and the ratio would not have been mathematically correct.

Large contributing basins are expected to generate larger volumes of water for any given storm event than smaller basins. Wetlands that are completely inundated seasonally, are judged to provide more storage (on a per acre basis) than those that are only partially inundated.

**Indicators:** No indicators are needed. The ratio can be estimated from data on the area of inundation and the area of the contributing basin.

**Scaling:** AUs whose area of seasonal inundation is more than 10% (1/10) of the contributing basin are scored a [1]. Units whose ratio is smaller are scaled as the absolute value (the positive value of either a negative number or positive number, e.g. the absolute value of –1 is 1) of the logarithm (base 10) of the ratio. It was necessary to transform the ratio to a logarithm to encompass the range of variability in the data from the reference AUs.

## 6.4.5 Calculations of Potential *Depressional Outflow – Reducing Peak Flows*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| ***Diked AU*** | *Function cannot be assessed for AUs with water regimes controlled by dikes and control structures* | | *If D0 = 1, record N/A for Function* | |
| **Vlivestorage** | *Highest:* | Average depth of livestorage > = 1 m | If livestorage > = 1, enter "1" | |
| | *Lowest:* | No livestorage | If livestorage = 0, enter "0" | |
| | *Calculation:* | Scaling is set as average depth | Enter result of calculation | |
| | Calculate livestorage as: D10 x (0.67 x D11.1 + 0.5 x D11.2 + 1 x D11.3). Scaled score = livestorage/1 | | | |
| **Vout** | *Highest:* | Severely constricted | If D13.3 = 1, enter "1" | |
| | *Moderate:* | Moderately constricted | If D13.2 = 1, enter "0.5" | |
| | *Lowest::* | Slightly or unconstricted | If D13.1 = 1, enter "0" | |
| **Vinund/shed** | *Highest:* | Ratio of area seasonally inundated to area of contributing basin is > = 0.1 | If (D8.1x0.01 xD1)/D2 > = 0.1, enter "1" | |
| | *Lowest:* | 0% of the AU is seasonally inundated | If D8.1 = 0, enter "0" | |
| | *Calculation:* | Scaling is based on the absolute value of the log of the ratio | Enter result of calculation | |
| | Calculate 1/ABS [log {(D8.1 x 0.01 x D1)/D2}] | | | |
| | | | **Total of Variable Scores:** | |
| ***Index for Reducing Peak Flows = Total x 3.33 rounded to nearest 1 If D0 = 1, Record an "N/A" for the function*** | | | | |
| | | | ***FINAL RESULT:*** | |

### 6.4.6 Qualitative Rating of Opportunity

The opportunity for an AU to reduce peak flows will increase as the water regime in the upgradient watershed is destabilized. Research in western Washington has shown that peak flows increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.

Users must make a qualitative judgement on the opportunity of the AU to actually reduce peak flows by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass is **"Low"** if most of its contributing watershed is undeveloped, not farmed, or not recently logged.

The opportunity is also **"Low"** if the AU receives most of its water from groundwater, rather than from an incoming stream, ditches, or storm drains).

The opportunity for the AU is **"High"** if the contributing watershed is mostly urban or high density residential. The opportunity is **"Moderate"** if the development is a small part of the contributing watershed, if the upgradient watershed is mostly agricultural, or if these areas are relative far away from the AU. Clear cut logging can also increase peak flows if a significant part of the watershed has recently been cut. These areas, however, will re-vegetate and within 5-7 years the peak flows may again be close to those found before logging. Too many variables are involved in trying to assess the increase in peak flows from logging (e.g. road density, time of cutting, % of watershed cut, etc.) and the rating for opportunity is too difficult to describe in a rapid method. Users must use their judgement to decide whether the opportunity is low, moderate or high, and document their decision on the summary sheet (see Part 2).

# 6.5 Potential for Decreasing Downstream Erosion — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.5.1 Definition and Description of Function

**Decreasing Downstream Erosion is defined as the wetland processes that decrease erosion of stream channels further downstream in the watershed by reducing the duration of erosive flows.**

An AU performs this function if it stores excess runoff during and after storm events, before slowly releasing it to downgradient waters. This is similar to the function provided by stormwater retention/detention (R/D) ponds that are designed to prevent downstream erosion in developed areas. The AU decreases downstream erosion by reducing the duration of erosive flows (erosive flows are the high velocity, high volume flows that cause much of the erosion in a watershed).

The major processes by which wetlands reduce the duration of erosive flows is by storing some of the peak flows and thus reducing the time during which erosive flows occur, and by reducing the velocity of water flowing through the AU during a storm event. Erosive flows in a watershed occur above a certain velocity based on geomorphology. By reducing the velocity in general, an AU can reduce the overall time during which the erosive velocities occur.

The function of decreasing downstream erosion is closely related to that of reducing peak flows because a reduction in peak flows will also result in a reduction of velocity. All of the variables used in the "peak flow" model are used for this function as well. One way to consider the function being assessed is to ask "What would happen to erosive flows in the watershed if the AU were filled?".

## 6.5.2 Assessing this Function for Depressional Outflow Wetlands

The potential of depressional outflow to decrease downstream erosion is modeled as the process of velocity reduction. Velocity reduction is modeled by the "live-storage" in the unit, by the characteristics of its outlet, by the amount of woody vegetation present, and by the relative amount of a storm-flow it can capture.

## 6.5.3 Model at a Glance

### *Depressional Outflow — Decreasing Downstream Erosion*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Velocity reduction** | **Vlivestorage** | Elevation difference between bottom of outlet and flood marks |
| **Velocity reduction** | **Vout** | Qualitative descriptors of outlet constriction |
| **Velocity reduction** | **Vwoodyveg** | % of AU in forest and shrubs |
| **Velocity reduction** | **Vinund/shed** | Ratio of area of inundation to contributing basin |
| | **Index:** | $\frac{\text{½ x Vlivestorage + Vout + Vwoodyveg + 2 x Vinund/shed}}{\text{Score from reference standard site}}$ |

## 6.5.4 Description and Scaling of Variables

***$V_{livestorage}$*** – The amount of livestorage available in the AU during an inundation or flooding event. **This variable is judged to be less important than the others in the equation (see scaling below)**.

**Rationale:** $V_{livestorage}$ is a measure of the volume of storage present during major flooding events. The Assessment Team assumed that AUs having relatively more storage decrease water velocities more than those with less storage. This variable also recognizes that some AUs, particularly those with ground-water connections, may have water present below the outlet elevation during peak flows. Storage below the outlet, however, does not contribute to velocity reductions. Once an AU fills up to the level of the outlet, the velocity of the water coming in will be equal to the velocity leaving unless there are other factors such as outlet constrictions.

**Indicators:** The indicator for the amount of livestorage in a depressional outflow AU is the difference in elevation between the bottom of the outlet and any marks of inundation on vegetation or along the shore.

To estimate the average depth of livestorage, the maximum depth, as estimated at the outflow, is corrected by a factor to reflect the shape of the inundated area of the AU (see Calculation Table 6.5.5).

Livestorage can be estimated as an average depth rather than volume because the index for the AU is established on a per acre basis. The index for a specific function will be multiplied by the acreage of the AU to establish an index for the entire unit.

**Scaling:** AUs that have an average depth of 1 m, or more, of livestorage are scored as 0.5 x [1] for the variable. The rest are scored on a proportional scale (e.g. 0.5 m of livestorage would score a 0.25 for the variable). The Assessment Team judged that the variable was less important for the function that the others in estimating velocity reductions and thus was weighted less (the factor of 0.5 in the equation).

$V_{out}$ – The amount of constriction in the surface outflow from the AU.

**Rationale:** The variable is a measure of the relative capacity of the outlet to impound water and store it temporarily during a flood event. This reduces the velocity of water downstream of the AU. Units that have constricted outlets due to undersized road culverts or narrow outlets hold water longer than a flooding event and will therefore reduce the duration of erosive flows. Water velocities and flows out of an AU will be reduced if its outlet is constricted regardless of its internal structure (Adamus et al. 1991).

**Indicators:** No indicators are needed. The relative constriction of the outlet is determined in the field.

**Scaling:** The scaling of this variable is based on the amount of constriction found in the AU.

**Unconstricted or slightly constricted** – The outlet allows water flow out of the AU during the wet season across a wide distance. The outlet does not provide much hindrance to waters coming downstream. In general, the distance between the low point of the outlet and inundation height (D28) will be small (< 30 cm - 1 ft). Beaver dams are considered unconstricted unless they are anchored to steep bank on either side because they are usually wide and do not retard flows once the water reaches the crest. Unconstricted or slightly constricted outlets are scored a [0].

**Moderately constricted** – The outlet is small or narrow enough to hold back some water during the wet season. The outlet is categorized as moderately constricted if it cannot be categorized as either unconstricted or severely constricted. Moderately constricted outlets are scored a [0.5].

**Severely constricted** – These are small culverts or heavily incised channels anchored to steep slopes. In general, one will find marks of flooding or inundation a meter or more above the bottom of the outlet. Another indicator of a severely constricted outlet is evidence of erosion on the downstream side of the outlet. Severely constricted outlets are scored a [1].

$V_{woodyveg}$ – The areal extent (as a % of the AU) of woody vegetation present that will reduce water velocities during a flood.

**Rationale**: Surface water flowing through areas of woody vegetation will have its velocity reduced because the stiff vegetation provides a structural barrier to flow (Adamus et al. 1991). The extent of the woody vegetation over the entire AU is used because the vegetation can also reduce velocities of water coming in as sheetflow in areas that are not inundated by flooding.

**Indicators**: The indicator for stiff erect vegetation is the percent area within the AU of two Cowardin vegetation classes – forest and scrub/shrub. The Assessment Team judged that these two classes represent vegetation that will remain erect during a flood event and will provide the structural barrier needed to reduce velocities.

**Scaling**: AUs that have a 100% cover of forest or scrub/shrub are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is covered by forest and/or scrub/shrub (% area / 100).

$V_{inund/shed}$ – The ratio of the area that is seasonally ponded or inundated with the AU to the area of its contributing basin. **This variable was judged to be more important than the others in the equation and was given a weighting factor of 2.**

**Rationale:** The potential of an AU to reduce velocity is partially a function of the retention time of water in the wetland during a storm event. Retention time is the relative volume coming into a unit during a storm event divided the amount of storage present. The area of the contributing basin is used as a surrogate for the relative amount of water (volume as cubic meters/second) entering the AU, while the area of inundation is used to estimate the relative volume stored. Attempts were made during the field calibration to estimate flows to an AU using estimated runoff flows from rainfall data and USGS runoff data. Unfortunately, these data did not provide enough resolution between AUs. Another variable for flows considered was the stream order. Again the information available on stream order was not easily accessible nor was it very accurate.

Large contributing basins are assumed to generate larger volumes of water for any given storm event than smaller basins. AUs that are completely inundated seasonally, are judged to provide more storage (on a per acre basis) than those that are only partially inundated.

**Indicators:** No indicators are needed. The ratio can be estimated from map measurements.

**Scaling:** AUs whose area of seasonal inundation is more than 10% (1/10) of the contributing basin are scored a [2]. Units whose ratio is smaller are scaled as 2 times the absolute value of the logarithm (base 10) of the ratio. It was necessary to transform the ratio to a logarithm to encompass the range of variability in the data from the reference units. The 2x multiplier is a scaling factor reflecting the importance of the variable. The Assessment Team judged that this variable is more important than the others in the performance of the function.

## 6.5.5 Calculation of Potential Performance

## *Depressional Outflow – Decreasing Downstream Erosion*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| ***Diked AU*** | *Function cannot be assessed for AUs with water regimes controlled by dikes and control structures* | | *If D0 = 1, record N/A for the function* | |
| **Vlivestorage** | *Highest:* | Average depth of livestorage > = 1 m | If livestorage > = 1, enter "0.5" | |
| | *Lowest:* | No livestorage | If livestorage = 0, enter "0" | |
| | *Calculation:* | Scaling is set as (average depth of livestorage /1) x 0.5 | Enter result of calculation | |
| | Calculate average livestorage as [D10 x (0.67xD11.1 + 0.5xD11.2 + 1xD11.3)]. If livestorage < 1 m, scaled score = (livestorage/1.0 x 0.5) | | | |
| **Vout** | *Highest:* | Severely constricted | If D13.3 = 1, enter "1" | |
| | *Moderate:* | Moderately constricted | If D13.2 = 1, enter "0.5" | |
| | *Lowest:* | Slightly or unconstricted | If D13.1 = 1, enter "0" | |
| **Vwoodyveg** | *Highest:* | 100% cover of shrub or forest | If calculation = 1, enter "1" | |
| | *Lowest:* | No cover of forest or shrubs | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling is set as % cover of (SS+FO)/100 | Enter result of calculation | |
| | Calculate (D14.1+D14.2+ D14.3+D14.4) / 100 | | | |
| **Vinund/shed** | *Highest:* | Ratio of area inundated to area of contributing basin is > = 0.1 | If (D8.1 x 0.01 xD1)/D2 > = 0.1, enter "2" | |
| | *Lowest:* | 0% of AU, is seasonally inundated | If D8.1 = 0, enter "0" | |
| | *Calculation:* | Scaling is based on the absolute value of the log of the ratio | Enter result of calculation | |
| | Calculate 2 x 1/ ABS[log{(D8.1 x 0.01 x D1)/D2}] | | | |
| | | | **Total of Variable Scores:** | |
| ***Index for Decreasing Downstream Erosion = Total x 2.44 rounded to nearest 1 If D0 = 1, record "N/A" for the function.*** | | | | |
| | | | ***FINAL RESULT:*** | |

## 6.5.6 Qualitative Rating of Opportunity

The opportunity for an AU to decrease erosion will increase as the water regime in the upgradient watershed is destabilized. Research in western Washington has shown that peak flows and velocities increase as the percentage of impermeable surface increase (Reinelt and Horner 1995). The opportunity should therefore be judged by the amount of upgradient watershed that is developed.

Users must make a qualitative judgement on the opportunity of the AU to actually decrease erosion by considering the land uses in the contributing watershed. The opportunity for an AU in the depressional outflow subclass is **"Low":** if most of its contributing watershed is undeveloped, not farmed, or not recently logged.

The opportunity is also **"Low"** if the AU receives most of its water from groundwater, rather than from an incoming stream, ditches, storm drains , or other surface water sources.

The opportunity for the AU is **"High"** is the contributing watershed is mostly urban or high density residential. The opportunity to is **"Moderate"** if the development is a small part of the contributing watershed, if the upgradient watershed is mostly agricultural, or if these areas are relative far away from the AU. Users must use their judgement in deciding whether the opportunity is low, moderate or high, and document their decision on the summary sheet (Part 2).

# 6.6 Potential for Recharging Groundwater — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.6.1 Definition and Description of Function

**Recharging Groundwater is defined as the wetland processes by which surface water coming into a wetland is transported into subsurface water that moves either into unconfined aquifers or into interflow. It is the "interflow" that supports flows in streams during the dry season.**

Wetlands recharge groundwater by holding back precipitation and surface water. This water then may infiltrate into the groundwater system.

There are two aspects of recharge. The first is the recharge of shallow subsurface flows (called interflow) that help maintain low flows in streams during the dry season. The second aspect of the function is recharge of subsurface aquifers. The wetland process that is important to both aspects of the function is infiltration.

The first draft of the assessment methods included separate functions for the recharge of interflow (called Maintaining Seasonal Low Flows) and the recharge of unconfined aquifers (called Recharging Unconfined Aquifers). During the field calibrations, however, we were unable to characterize the conditions of the subsurface geology and soils well enough to determine if water infiltrating through the wetland would become part of the "interflow" or part of an unconfined aquifer. As a result, the functions were combined, and the model only assesses the relative rates of infiltration in an AU.

Surface outflow from the wetland is not judged to be an important factor in maintaining low flows in streams. Perennial surface outflow from an AU is not usually a result of waters stored within the wetland. The wetland may be a location where groundwater is discharged, but the source of this groundwater is not within the wetland itself. Rather, it comes from waters stored in the ground throughout the watershed.

The contribution of a wetland to seasonal low flows is the water that enters the groundwater system during the wet season. A wetland in western Washington will usually dry out by the time support to dry season low flows is important in streams. Surface waters stored within the wetland will usually have evaporated, infiltrated, or flowed out.

## 6.6.2 Assessing this Function for Depressional Outflow Wetlands

The potential for AUs to recharge groundwater is modeled as the relative rate of infiltration. Two variables are used; the first is a qualitative rating of the infiltration rate of the soils within the unit; and the second is the percent of the AU with seasonal inundation.

## 6.6.3 Model at a Glance

### *Depressional Outflow — Recharging Groundwater*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Infiltration** | **Vinfilt** | Rating infiltration rate of soils |
| **Infiltration** | **Veffectarea2** | Area of seasonal inundation minus permanent open water |
| | **Index:** | $\frac{\text{Vinfilt + Veffectarea2}}{\text{Score from reference standard site}}$ |

## 6.6.4 Description and Scaling of Variables

$V_{infilt}$ – A qualitative rating of the infiltration capacity of the soils in the AU.

**Rationale:** Infiltration can occur only where the soils are permeable. Many AUs in the lowlands of western Washington are formed on impermeable shallow tills or have developed extensive peat deposits. These conditions hinder the recharge of groundwater. Recharge is an important process only if the soils have a high sand, gravel or cobble content, and a low content of clays, silts, or organic matter. The layer with the lowest infiltration rate in the top 60 cm is used to develop the rating.

**Indicators**: The indicator of infiltration is the relative amount of sand, silt, gravel, clay or organic matter present in the soils. Infiltration of soils is rated down to a depth of 60 cm (2 ft).

**Scaling**: Soils with more than 50% of gravel and cobbles and less than 30% of clay or organic matter are scaled a [1] since these have the highest infiltration rate. Soils with more than 50% sand and less than 30% of clay or organic matter are scaled a [0.5]. Soils with more than 30% clays or organic matter are scaled a [0.1] because these have little or no infiltration.

$V_{effectarea2}$ – The area of the AU where infiltration occurs. The variable is measured as the percent of the AU that is seasonally inundated minus the area that has permanent open water.

**Rationale:** Infiltration can occur only where the surface waters provide a hydraulic head to push water into the soils. Areas of permanent open water, however, are judged by the Assessment Team not to be permeable. Areas of permanent water usually develop a layer of fine sediments, often organic, that severely reduce infiltration. The effective area where infiltration occurs, therefore, is considered only

to be the area that is seasonally inundated (area that is permanently inundated is excluded from this variable).

**Indicators:** The indicator for the effective area is the seasonally inundated area minus the area of permanent inundation.

**Scaling:** AUs that are completely inundated seasonally and have no permanent open water are scored a [1] for this variable. Scaling for the others is proportional, based on the % area that is only seasonally inundated (%area / 100).

## 6.6.5 Calculations of Potential Performance

### *Depressional Outflow – Recharging Groundwater*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vinfilt** | *Highest:* | Gravel, cobble >50% of soil and silt, clays, and organics <30% | If D48.1 = 1, enter "1" | |
| | *Moderate:* | Sand >50% of soil and silt, clays, and organics <30% | If D48.2 = 1, enter "0.5" | |
| | *Lowest:* | Silt, clay, and organics > 30% of soil | If D48.3 = 1, enter "0.1" | |
| **Veffectarea2** | *Highest:* | 100% of the AU, is seasonally ponded or inundated with no permanent open water | If calculation = 1 enter "1" | |
| | *Lowest:* | 0% of the AU is seasonally ponded | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling = (% of AU inundated/100) | Enter result of calculation | |
| | Calculate (D8.1-(D8.3+D14.6))/100 | | | |
| | | | **Total of Variable Scores:** | |
| ***Index for Recharging Groundwater = Total x 6.67 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

### 6.6.6 Qualitative Rating of Opportunity

Groundwater is an integral component of the water cycle throughout western Washington. The Assessment Teams have judged that all AUs in the lowlands of western Washington have a **"High"** opportunity to recharge either interflow or an unconfined aquifer if the surface soils within the AU are permeable enough. The assumption is that all AUs have some link to groundwater.

# 6.7 General Habitat Suitability — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.7.1 Definition and Description of Function

**General Habitat Suitability is defined as the characteristics or processes present in a wetland that indicate a general habitat suitability for a broad range of wetland dependent species**. It also includes processes or characteristics within a wetland that help maintain ecosystem resilience (characteristics that are important in maintaining the ecosystem when it is disturbed). The assessment model attempts to assess how well an AU provides habitat for fauna. The model is not focused on individual species groups, but rather it emphasizes the elements in an AU that help support a range of different animal species. Native Plant Richness is addressed in a separate function. The "General Habitat Suitability" function may be used as a surrogate for "General Wildlife Habitat," though it is not restricted to the common definition of "wildlife" as mammals, and birds. The general habitat function incorporates elements that are important to invertebrates and decomposers as well as to amphibians.

Many of the variables used to assess the performance of an AU for general habitat are also used in the assessments of habitat suitability for individual species groups. The SWTC and Assessment Teams, however, thought it important to assess General Habitat Suitability in broad terms as well as the individual species groups.

## 6.7.2 Assessing this Function for Depressional Outflow Wetlands

An AU in the depressional closed subclass provides suitable habitat if it has a complex physical structure, high plant richness, and the presence of seasonal or year-round standing water. Suitability also increases if there is high interspersion of habitat types within the AU.

The model is additive so that physical structures in the wetland (i.e. channels, upland/wetland edge, etc.) and biologic characteristics such as plant assemblages add to the general habitat suitability of an AU. The operative assumption is that the suitability of an AU for all species groups increases as the number of characteristics in the AU increase.

**The presence of urban or high-density residential areas around an AU is included as a variable to reflect the potential for a reduction in the performance of this function.** Development in the area around a wetland can result in increased surface water velocities,

surface water volumes, pollution loadings, and changes in the water regime that have an impact on the suitability of a wetland as habitat (Reinelt and Horner 1995).

## 6.7.3 Model at a Glance

### *Depressional Outflow — General Habitat Suitability*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Structural heterogeneity (applies to all variables)** | **Vbuffcond** | Descriptive table of conditions in buffer |
| | **V%closure** | % area of canopy closure over AU |
| | **Vstrata** | Maximum number of strata in any one assemblage |
| | **Vsnags** | Categories of snags present |
| | **Vvegintersp** | Interspersion between vegetation classes -diagrams |
| | **Vlwd** | Categories of LWD present |
| | **Vhydrop** | Number of water regimes present |
| | **Vwaterdepth** | Number of water depth categories present |
| | **Vwintersp** | Characteristics of water interspersion - diagrams |
| | **Vprichness** | Number of plant species present |
| | **Vmature** | Presence/absence of mature trees |
| | **Vedgestruc** | Structural complexity of AU edge |
| ***Reducers*** | | |
| **Surrounding land uses** | **Vupcover** | Land uses within 1 km of wetland |
| | **Index:** | $\frac{(\text{Vbuffcond} + \text{V\%closure} + \text{Vstrata} + \text{Vsnags} + \text{Vvegintersp} + \text{Vlwd} + \text{Vhydrop} + \text{Vwaterdepth} + \text{Vwintersp} + \text{Vprichness} + \text{Vmature} + \text{Vedgestruc}) \times \text{Vupcover}}{\text{Score for reference standard site}}$ |

## 6.7.4 Description and Scaling of Variables

$V_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

> **Rationale:** The condition of the buffer affects the ability of the AU to provide appropriate habitat for some species groups (Zeigler 1992). Terrestrial species using the wetland that are dependent upon upland habitats for a portion of their life-cycles are benefited by the presence of relative undisturbed upland community types immediately surrounding the wetland. Some guilds may not require upland habitats for a portion of their life-cycle but the presence of humans and domestic animals in

close proximity to the wetland impacts those species which are sensitive to human/domestic animal presence and which cannot escape to other refuge habitats.

**Indicators:** This variable is assessed using the buffer categorization described in Part 2.

**Scaling:** AUs with buffers that are relatively undisturbed for at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8.

$V_{\%closure}$ – The % canopy closure of woody vegetation higher than 1 m over the entire AU.

**Rationale:** The Assessment Teams judged canopy closure an important general habitat feature because it: 1) influences the micro-climate within the AU; 2) is a source of organic material to the duff layer, 3) stabilizes soils within the AU; and 4) provides structural complexity for perches, nest sites and invertebrates. All of these factors contribute to increasing faunal richness.

**Indicators:** No indicators are needed to assess this variable. Canopy cover can be estimated directly.

**Scaling:** Generally, a canopy provides the best habitat conditions when the closure is moderate. The data from the reference sites suggests that a canopy closure between 30 and 60% is best (scaled as a [1]). Either more or less canopy cover is not as good. Canopy closures between 10-29% and 61-100% were scored a [0.5], and canopy closures lower than these were scored a [0].

$V_{strata}$ – The maximum number of strata in any single plant assemblage. A plant assemblage (Part 2 for an operational definition of a plant assemblage) can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, mosses, and bryophytes). To count as a stratum, however, the plants of that stratum must have 20% cover in the assemblage in which they are found.

**Rationale:** A greater number of strata provide more niches for different species than fewer strata. Strata are important to wildlife because different species utilize different strata for feeding, cover, and reproduction. Some species use a single strata exclusively throughout their life history (many invertebrates, for example, and some small mammal species) (Andrewartha and Birch 1984). Other species, on the other hand, require several strata to meet their life requirements. Consequently, an increase in number of strata will increase the suitability of an AU by increasing the potential species richness.

**Indicators:** No indicators are needed to assess this variable. The number of strata can be estimated directly.

**Scaling:** AUs with 6 strata are scored a [1] for this variable. AUs with only one are scored a [0]. AUs with 2, 3, 4 and 5 strata are scaled proportionally as 0.2, 0.4, 0.6, and 0.8 respectively.

$V_{snags}$ – The number of different snag categories, and their size, based on states of decomposition, found in the AU.

**Rationale:** Snags are the source of cavities in standing woody vegetation that provides habitat for numerous bird and mammal species. Many species of birds and mammals utilize cavities for nesting, roosting, denning, and/or refuge. Snags are invaded by invertebrates and other organisms of decay, which in turn provide food for many species of wildlife (Davis et al. 1983). In addition, when snags fall, they contribute to the overall health of an ecosystem by decaying, which contributes nutrients to the soil (Maser et al. 1988). Furthermore, the presence of large snags was judged to be more important as a habitat feature than small snags because they have the potential for larger cavities as well as small ones; thus providing an additional niche in the wetland.

**Indicators:** The number and size of cavities within snags of an AU cannot be measured directly because they can be difficult to see during a "rapid" site visit. Snag characteristics and decay classes can, however, be an estimate of the presence of cavities. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities. It is assumed that snags will be used and cavities formed or excavated if dead branches or trunks are present. In addition, more importance is given if at least one of the snag categories is larger than 30 cm dbh.

**Scaling:** A depressional outflow AU with 6 or more of the 8 categories of snag characteristics are present is scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6). If the AU has any snag that is larger than 30 cm dbh, the score for $V_{snag}$ is increased by 0.3.

$V_{vegintersp}$ – The extent of interspersion between Cowardin vegetation classes.

**Rationale:** The extent of interspersion between vegetation classes is a structural element of the wetland plant community that reflects habitat complexity. This is a measure of interspersion between classes, not a measure of the number of classes present. Consequently, an AU with only two Cowardin vegetation classes may have a higher degree of interspersion than an AU with 3 Cowardin vegetation classes.

In general, more "edge" between different vegetation community types increases the suitability for some wildlife taxa. For example, a higher interspersion of plant types

(as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, and Lodge 1985).

**Indicators:** The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).

**Scaling:** AUs with more interspersion between vegetation classes score higher than those with fewer. The model has four categories of interspersion (none, low, moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion is scored a 1, a moderate a 0.67, a low = 0.33, and none = 0.

$V_{lwd}$ – The number of categories (size and decay level) of downed large woody debris in the AU. This consists of woody debris found floating or partially submerged in permanent open waters as well as that found in the vegetated parts of the AU.

**Rationale:** Woody debris provides a major habitat niche for decomposers and invertebrates. Is also provides refuge for amphibians and other vertebrates, and contributes to the production of organic soils.

Downed woody material is an important structural element of wildlife habitat for many species. In the water, it is important cover for both resident and anadromous fish, as well as numerous amphibians. In upland areas of the AU it provides shelter for small mammals, birds, and amphibians (Thomas et al. 1978). The downed woody material is also an important structural element for invertebrate species, which in turn provide food for much of the AU trophic web (Maser et al. 1988).

**Indicators:** Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different classes and decay levels is used as an indicator for the variable. The matrix is based on the assessment procedure developed for the Timber Fish and Wildlife watershed assessment methods (Schuett-Hames et al. 1994).

**Scaling:** AUs with 10 or more categories of large woody debris in permanent open water and in vegetated areas score a [1]. The rest are scored proportionally to 10 (# categories /10).

$V_{hydrop}$ – The number of different hydroperiods, or water regimes, present in the AU.

**Rationale:** Many aquatic species have their life cycles keyed to different water regimes of permanent, seasonal, or saturated conditions. A number of different water

regimes in an AU will, therefore, support more species than an AU with fewer water regimes. For example, some species are tolerant permanent pools, while others can live in pools that are temporary (Wiggins et al. 1980).

**Indicators:** The variable is assessed using specific hydroperiod classes as descriptors. These are permanently flooded, seasonally flooded, occasionally flooded, and saturated but not flooded as described below.

**Permanently Flooded or Inundated** – Surface water covers the land surface throughout the year, in most years. This includes the Cowardin classes of **Intermittently Exposed** (surface water is present throughout the growing season except in years of extreme drought), and **Semipermanently Flooded** (surface water persists throughout the growing season in most years).

**Seasonally Flooded or Inundated** – Surface water is present for extended periods (1 month), especially early in the growing season, but is absent by the end of the season in most years. During the summer dry season it may be difficult to determine the area that is seasonally flooded. Use the indicators described in D8.1 to help you determine the area that is seasonally flooded or inundated.

**Occasionally Flooded or Inundated** – Surface water is present for brief periods during the growing season, but the water table usually lies below the soil surface for most of the season. Plants that grow in both uplands and wetlands are characteristic of the temporarily flooded regime.

**Saturated** – The substrate is saturated to the surface for extended periods during the growing season, **but surface water is seldom present**. The latter criterion separates saturated areas from inundated areas. In this case there will be no signs of inundation on plant stems or surface depressions.

**Scaling:** AUs with all four hydroperiod classes are scored a [1]. Those with fewer are score proportionally (3 classes = 0.67, 2 = 0.33, 1 = 0).

$V_{waterdepth}$ – The number of water depth categories present in the AU in the permanent or seasonal inundated areas.

**Rationale:** Different water depths provide habitat for different plant communities (emergent vs. aquatic bed as examples) that in turn provide different habitats for waterfowl (Weller 1990), amphibians (Richter 1997), birds, and other vertebrate taxa as well as invertebrates (Wilcox and Meeker 1992). A wetland with a range of water depths will therefore, provide a broader range of habitats than one with only one water depth.

**Indicators:** The variable is scored using a condensed form of the depth classes developed for the Wetland Evaluation Technique (Adamus et al. 1987). These are 0-20 cm, 21-100 cm, and >100 cm depth classes.

**Scaling:** AUs with all 3 depth classes are scored a [1]; those with 2 are scored [0.67]; 1 class = [0.33], and 0 classes = [0] .

$V_{wintersp}$ – The extent of interspersion between vegetated areas of the AU and permanent open water.

**Rationale:** The extent of water interspersed with vegetation is another structural element of the AU that can add habitat complexity. The complexity of the mosaic pattern of the interface between open water and erect vegetation is an indicator of more habitat niches being available.

High interspersion between vegetation and water is important because of the increased variety of vegetation types and cover conditions that can result from such interspersion (Adamus et al. 1991). Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries for wildlife (Golet and Larson 1974). The transition between water and vegetation also provide habitat elements for both open-water and more terrestrial species (Weller and Spatcher 1965, and Willard 1977).

**Indicators:** The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

**Scaling:** AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0]

$V_{prichness}$ – The total number of plant species present.

**Rationale:** The number of plant species in an AU is an indicator of the potential number of habitats present for insects, other invertebrates, and microfauna. Many insects and detritivores are associated with a specific plant species in a parasitic, commensal or symbiotic relationship. The total number of wildlife species in an AU is expected to increase as the number of plant species increases. Plant species include both native and non-natives because both provide food, cover, and other habitat requirements for invertebrates.

**Indicators:** The indicator of overall plant richness is the number of species that is found during the field visit.

**Scaling:** Depressional outflow AUs with 40 or more plant species are scored a [1]. Those with less are scored proportionally to 40 (# species/40). The Assessment Team recognizes that there may be some discrepancy between the number of species that can be identified in the summer and the number that can be identified in the winter.

$V_{mature}$ – The AU has, or does not have mature trees present.

**Rationale:** The presence of mature trees within an AU is used as an indicator of habitat richness that is not captured in other variables. Mature trees are an indication that the area within the AU has had time to develop a complex physical structure on its surface (e.g. large and small woody debris with different levels of decomposition, a range of vegetation in different growth stages from seedlings to senescent). These structural elements provide an increased number of niches for many organisms.

**Indicators:** This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of each species. If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees. See Part 2 for a more detailed description of how to assess this variable. The size of trees at maturity used in the data are based on measurements made in wetlands of the Puget Sound Lowlands (Cooke pers. comm.) and on the judgement of the Assessment Team.

**Scaling:** This is an "on/off" variable. AUs with mature trees are scored a [1], those without are scored a [0].

$V_{edgestruc}$ – The vertical structure and linear characteristics of the AU edge.

**Rationale:** The convolutions (e.g., length of edge in relation to area of AU) and differences in heights of vegetation classes along the edge of the AU are important habitat characteristics for many wildlife species. Additional habitat exists within vegetated lobes and scalloped edges of wetlands. Further, embayments and peninsulas provide "micro-habitats" for certain species that require hiding cover, or visual isolation (USDI 1978, Verner et al. 1986, and WDOE 1993).

For example, a simple AU may be a circular pond with a fringing emergent marsh composed of cattails, which adjoins immediately to a grazed pasture. The edge in this case is characterized as having low structural richness (lack of shrubs and trees), and no convolutions (as the edge is nearly circular, with no embayments or peninsulas). In contrast, a more complex AU may adjoin an area composed of trees and shrubs, adding to the structural richness, and may be irregular along its edge, with many twists and turns, resulting in enclosed bays of emergent vegetation and jutting peninsulas of forest or shrub.

**Indicators:** The edge structure of the AU is assessed by using a descriptive key that groups the edges and vertical structure along the edge into high, medium, low, and no structural diversity.

**Scaling:** AUs with a highly diverse edge are scored a [1]; moderate = 0.67, low = 0.33, and none = 0.

***$V_{upcover}$*** – the types of land uses within 1 km of the estimated edge of the AU. **This variable is used to indicate potential reductions in the level of performance for the function.**

**Rationale:** It is assumed that development (land conversion) around an AU will alter the water regime of the AU by shortening the time between the event and the peak within the AU. This will increase rates of flows through the AU, increase peak flows, increase volumes of water, and decrease low-flow duration from storm-water runoff from converted land-forms in the AU contributing basin. Increases in flow rates can increase export of nutrients from the AU, it often increases the input of sediments and nutrients, and it results in less stable water level conditions. Wetland invertebrates and plants are also known to decrease in richness and abundance with greater water level fluctuations and concomitant pollution loads (Ludwa 1994, Schueler 1994, Azous and Richter 1995, and Hicks 1995)

**Indicators:** The indicator for this variable is the % of the land within a 1 km radius of the AU that is in urban, residential, or clear cut.

**Scaling:** The index of general habitat suitability is reduced by 10% (factor of 0.9) if the land uses within 1 km total more than 60% high density residential, low density residential, urban/commercial or clear cut.

## 6.7.5 Calculation of Habitat Suitability

### *Depressional Outflow – General Habitat Suitability*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vbuffcond** | *Highest:* | Buffer categorization of Category 5 | If D42 =5, enter "1" | |
| | *High:* | Buffer categorization of Category 4 | If D42 =4, enter "0.8" | |
| | *Moderate:* | Buffer categorization of Category 3 | If D42 =3, enter "0.6" | |
| | *Medium Low:* | Buffer categorization of Category 2 | If D42 =2, enter "0.4" | |
| | *Low:* | Buffer categorization of Category 1 | If D42 =1, enter "0.2" | |
| | *Lowest:* | Buffer categorization of Category 0 | If D42 =0, enter "0" | |
| **V%closure** | *Highest:* | Canopy closure is between 30-60% | If D17 > = 30 and D17 < = 60, enter "1" | |
| | *Moderate:* | Canopy closure is between 10-29% or 61-100% | If D17 = 10 to 29 or D17 = 61-100, enter "0.5" | |
| | *Lowest:* | Canopy closure is <10% | If D17 < 10, enter "0" | |
| **Vstrata** | *Highest:* | 6 strata present | If D21 = 6, enter "1" | |
| | *High:* | 5 strata present | If D21 = 5, enter "0.8" | |
| | *Moderate:* | 4 strata present | If D21 = 4, enter "0.6" | |
| | *Medium Low:* | 3 strata present | If D21 = 3, enter "0.4" | |
| | *Low:* | 2 strata present | If D21 = 2, enter "0.2" | |
| | *Lowest:* | 1 strata present | If D21 = 1, enter "0" | |
| **Vsnags** | *Highest:* | At least 6 categories of snags are present in the AU and some have > 30 cm dbh | If D31 >= 6 and D31.1 =1, enter "1.3" | |
| | *Lowest:* | No snags present | If D31 = 0, enter "0" | |
| | *Calculation:* | Scaled as the number of categories divided by 6 + 0.3 if dbh > 30 cm | Enter result of calculation | |
| | If D31 < 6 calculate D31/6 + D31.1x 0.3; if D31 > 6 calculate 1 + D31.1x0.3 | | | |
| **Vvegintersp** | *Highest:* | High interspersion | If D39 = 3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D39 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D39 = 1, enter "0.33" | |
| | *Lowest:* | No interspersion present (1 class only) | If D39 = 0, enter "0" | |
| **Vlwd** | *Highest:* | AU has at least 10 categ. of sizes and decomposition states of LWD | If calculation >= 1, enter "1" | |
| | *Lowest:* | No categories of LWD | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling based on # of categ./10 | Enter result of calculation | |
| | Calculate (D44 + D45)/10 to get result | | | |

**Table continued on next page**

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vhydrop** | *Highest:* | AU has 4 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 4, enter "1" | |
| | *High:* | AU has 3 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 3, enter "0.67" | |
| | *Moderate:* | AU has 2 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 2, enter "0.33" | |
| | *Low:* | AU has 1 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 1, enter "0" | |
| **Vwaterdepth** | *Highest:* | AU has 3 classes of depths | If D12.1 + D12.2 + D12.3 = 3, enter "1" | |
| | *Moderate:* | AU has 2 classes of depths | If D12.1 + D12.2 + D12.3 = 2, enter "0.67" | |
| | *Low:* | AU has 1 class of depths | If D12.1 + D12.2 + D12.3 = 1, enter "0.33" | |
| | *Lowest:* | AU has no surface inundation | If D12.1 + D12.2 + D12.3 = 0, enter "0" | |
| **Vwintersp** | *Highest:* | High interspersion | If D38 =3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D38 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D38 = 1, enter "0.33" | |
| | *Lowest:* | No interspersion | If D38 = 0, enter "0" | |
| **Vprichness** | *Highest:* | Number of plant species > = 40 | If calculation >= 1.0, enter "1" | |
| | *Lowest:* | AU has 2 or less plant species | If D19.1 + D19.2 < = 2, enter "0" | |
| | *Calculation:* | Scaled as # of species/40 | Enter result of calculation | |
| | Calculate (D19.1 + D19.2)/40 to get result | | | |
| **Vmature** | *Highest:* | AU has mature trees present | If D22 = 1, enter "1" | |
| | *Lowest:* | AU has no mature trees present | If D22 = 0, enter "0" | |
| **Vedgestruc** | *Highest:* | High structure at edge of AU | If D41 = 3, enter "1" | |
| | *Moderate:* | Moderate structure | If D41 =2, enter "0.67" | |
| | *Low:* | Low structure | If D41 =1, enter "0.33" | |
| | *Lowest:* | No structure | If D41 =0, enter "0" | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vupcover** | If clear cutting, high or low density residential, and urban land uses within 1 km are > = 60%. | | If D3.3 + D3.4 + D3.5 + D3.6 > = 60, enter "0.9" | |
| | If critical land uses < 60% | | Enter "1" | |
| | | | **Score for Reducer** | |
| ***Index for General Habitat Suitability = Total for variables x reducer x 0.85 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

## 6.7.6 Qualitative Rating of Opportunity

The land-use patterns within the upland buffer and surrounding landscape influences the opportunity that an AU has to provide general habitat. Connectivity of AUs to other protected areas affects specific use of the habitat within the AU, in particular those species whose life history needs include a large range of landscape types (e.g. the larger predators, raptors, etc.). For some populations, the connectivity between wetland habitats may be crucial to the survivability of the population.

The opportunity that an AU has to provide habitat for a broad range of species should be judged by characterizing the landscape in which an AU is found. An AU may have many internal structural elements that indicate it provides good habitat. Its landscape position, however, may reduce the actual performance because it is not accessible to the populations that would use it.

Users must make a qualitative judgement on the opportunity the AU has in providing habitat for a broad range of species by considering the land uses in the contributing watershed, the condition of the AU's buffer, and its connection to other habitat areas. Two data on the data sheets can be used to help guide your judgement (D43 on corridors and D42 on buffers).

In general, the opportunity for an AU in the depressional outflow subclass to provide habitat is **"High"** if it has extensive natural buffers and forested or riparian corridors to other habitats. Other habitats may include undisturbed grasslands, open water, shrubs, or forested areas. The opportunity is **"Moderate"** if the AU has some connections to other habitat areas or less extensive undisturbed buffers. It is **"Low"** if the AU is surrounded by development and has no naturally vegetated corridors to other habitat areas.

The user must use their judgement in deciding whether the opportunity is low, moderate or high, and document their decision on the data sheet.

# 6.8 Habitat Suitability for Invertebrates — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.8.1 Definition and Description of Function

**Habitat Suitability for Invertebrates is defined as the wetland characteristics that help maintain a high number of invertebrate species in the wetland.** The term invertebrates is here more narrowly defined as "macro-invertebrates" or free-living organisms readily seen with the naked eye (>200-500 um). This includes: Insecta (insects), Amphipoda (scuds, sideswimmers), Eubranchiopoda (fairy, tadpole, and clam shrimps) Decapoda (crayfishes, shrimps), Gastropoda (snails, limpets), Pelecypoda (clams, mussels), Hydracarina (water mites), Arachnida (spiders) and Annelida (worms and leeches).

The intent of the assessment is to identify those wetlands providing habitat for the greatest number of species within the regional subclass. Invertebrates are diverse, abundant, and essential components of freshwater aquatic ecosystem. Most AUs will provide habitat for some invertebrates. There is a distinct difference, however, between an AU with a high richness of one or two species and one that has a high abundance of many different species. The important aspect of invertebrate populations being assessed is species richness. Wetlands with high richness tend to be more important in maintaining the regional biodiversity of invertebrate populations and by providing genetic diversity that helps maintain ecosystem integrity.

Invertebrates have evolved unique adaptations enabling them to occupy most wetland habitats and trophic levels. Consequently, wetland invertebrates are pivotal components of food webs, significantly increasing the number of links with the rich diversity and abundance of their taxa. As filter feeders, shredders, and scrapers, insects convert microorganisms and vegetation into biomass, providing significant production that then becomes available to secondary and tertiary consumers. Research focusing on aquatic invertebrates in wetlands indicates the importance of macro-invertebrates in energy and nutrient transfer within aquatic ecosystems (Rosenberg and Danks 1987). They furnish food for other invertebrates and comprise significant portions of the nutritional requirements of amphibians, water birds and small mammals. They are an especially important food for young fish. The trophic diversity and numerical abundance of insects, and especially Diptera (true flies), make these taxa the most important in wetland environments.

In addition, macro-invertebrates have been used as bioindicators of stream and lake (Rosenberg and Resh 1996) and increasingly of wetland health (Hicks 1996); their taxa and numbers indicating conditions of hydrodynamics, water regime, soils, vegetation, eutrophication, and anthropogenic pollution.

## 6.8.2 Assessing this Function for Depressional Outflow Wetlands

The habitat suitability of depressional outflow wetlands for a highly diverse assemblage of invertebrates is assessed by characterizing the complexity of the biologic and physical structures of the AU. The model is built on the assumption that almost any structure in the AU (i.e. channels, ponds, upland/AU edge, etc.) or plant assemblage hosts a specialized invertebrate community. The operative assumption is that the richness of invertebrate species increases as the number of structural characteristics in an AU increase.

Certain conditions present in an AU, however, are considered to be detrimental to invertebrates and these are modeled as reducers of the performance. The presence of tannins is considered to reduce the performance of an AU as invertebrate habitat because many species are sensitive to the organic acids present in tannins.

## 6.8.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Invertebrates*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Number of habitat niches for invertebrates (applies to all variables)** | **Vpermflow** | Channels or streams in AU with permanently flowing water |
| | **Vsubstrate** | Types of surface substrates present |
| | **Vwintersp** | Characteristics of water interspersion - diagrams |
| | **Vlwd** | Categories of LWD present |
| | **Vstrata** | Number of strata present in any plant assemblage |
| | **Vvegintersp** | Interspersion between vegetation classes -diagrams |
| | **Vassemb** | Number of plant assemblages |
| | **Vhydrop** | Number of water regimes |
| | **Vaquastruc** | Categories of different aquatic bed structures |
| ***Reducers*** | | |
| | **Vtannins** | Qualitative estimate of presence/absence of tannins |
| | **Index:** | $\frac{(\text{Vpermflow} + \text{Vsubstrate} + \text{Vwintersp} + \text{Vlwd} + \text{Vstrata} + \text{Vvegintersp} + \text{Vassemb} + \text{Vhydrop} + \text{Vaquastruc}) \times (\text{Vtannins})}{\text{Score from reference standard site}}$ |

## 6.8.4 Description and Scaling of Variables

$V_{permflow}$ – Channels or streams are present in an AU and contain permanent flowing water.

**Rationale:** Permanent flowing water is a habitat feature that supports a unique assemblage of invertebrate species ( Needham and Needham 1962, and Wiggins et al. 1980). Invertebrates that are found in flowing permanent channels are an important resource for many other aquatic species (Needham and Needham 1962). The presence of permanent flowing water is a characteristic whose presence adds to the overall invertebrate richness in an AU.

Streams or channels with intermittent seasonal flow also have the potential for providing a special invertebrate habitat. They are not scaled in the model, however, because it was not possible to determine, in the field, if an intermittent stream or channel is maintained by seasonal flows or by high rainfall events. If an intermittent stream is a result of storm flows, the water does not remain long enough to provide a unique invertebrate habitat.

**Indicators:** No indicators are needed for this variable because the presence of permanent flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

**Scaling:** This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$V_{substrate}$ – The composition of surface layers present in the AU (litter, mineral, organic etc).

**Rationale:** Not much is known about invertebrate distributions in different substrates within a wetland. Data from rivers, streams, and lakes, however, show that the local invertebrate species have preferences for specific substrate (Dougherty and Morgan 1991, Gorman and Karr 1978). In streams it is well known that Chironomid community composition is strongly affected by sediment characteristics (McGarrigle 1980, and Minshall 1984). The Assessment Teams assumed that a similar relationship between invertebrate populations and substrates is also found in wetlands. Thus, AUs with different substrates present will provide habitat for a broader group of invertebrate species than those with only one type. Moreover, those with organic matter will exhibit greater richness and abundance than those found in sand substrates.

**Indicators:** No indicators are needed to assess this variable. The number of different substrate types can be determined by direct field observations.

**Scaling**: AUs with five or more types of substrates of the eight identified (deciduous leaf litter, other plant litter, decomposed organic, exposed cobbles, exposed gravel, exposed sand, exposed silt, exposed clay) are scored a [1]. Those with fewer are scaled proportionally (# types/5). AUs with no soil surface exposed (e.g. sphagnum bog) are scored a [0].

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of AU and permanent open water.

**Rationale:** The amount of interspersion between permanent open water and vegetation is another structural element of the AU that can add habitat complexity. Studies have shown that high invertebrate richness occurs in water interspersed with stands of emergent vegetation (Voigts 1976).

**Indicators:** The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

**Scaling:** Depressional outflow AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33]; and those with no interspersion (i.e. no permanent open water) = [0].

$V_{lwd}$ – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

**Rationale:** Downed woody material is an important structural element for invertebrate species. Decaying wood provides an important habitat for invertebrates (Maser et al. 1988). The Assessment Teams assumed that downed debris of different size and different levels of decay classes would provide habitat for a wide variety of invertebrates, especially those that decompose, feed, and seek shelter in, wood.

**Indicators:** Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. Consequently, a descriptive matrix of different sizes and decay classes of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

**Scaling:** AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

***$V_{strata}$*** **–** The number of vegetation strata in any single plant assemblage. A plant assemblage can have up to 6 strata (layers: trees, high shrubs, low shrubs, woody vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the assemblage in which it is found.

**Rationale: Rationale:** Different invertebrate taxa are found on different plant species (Cyr and Downing 1988). The vegetation strata are used as an indicator of distinct groups of plant species that might have specific ecological characteristics to which invertebrate taxa might be adapted.

**Indicators:** No indicators are needed for this variable. The number of strata present in any single plant assemblage can be determined by direct field observations.

**Scaling:** AUs with 6 strata are scored a [1] for this variable. AUs with one are scored a [0]. AUs with 2-5 strata are scaled proportionally as 0.2, 0.4, 0.6, and 0.8, respectively.

***$V_{vegintersp}$*** – The extent of interspersion between Cowardin vegetation classes.

**Rationale:** The extent of interspersion between vegetation class is a structural element of the plant community in an AU that reflects on habitat complexity. A higher diversity of plant communities (as characterized by Cowardin vegetation classes) is likely to support a higher diversity of macro-invertebrates (Chapman 1966, Dvorak and Best 1982, and Lodge 1985).

**Indicators:** The extent of interspersion between vegetation classes is assessed using diagrams found in the Washington State Rating System (WDOE 1993).

**Scaling:** AUs with more interspersion between vegetation classes score higher than those with fewer. The method has four categories of interspersion (none, low, moderate, high) and these are used as for developing the scaled score. A high level of interspersion is scored a 1, a moderate = 0.67, a low = 0.33, and none = 0.

***$V_{assemb}$*** – The number of distinct plant assemblages found within the AU.

**Rationale:** A mix of plant assemblages exhibits greater diversity and biomass in invertebrates than does a single assemblage (Andrews and Hasler 1943). For example, the standing crop of invertebrates varies considerably among species of submerged aquatic macrophytes (Murkin and Batt 1987), and different epiphytic invertebrate taxa are found on different plant species (Cyr and Downing 1988.)

**Indicators:** No indicators are needed to assess this variable. The number of assemblages can be determined through field observations.

**Scaling:** Depressional outflow AUs with 10 or more plant assemblages are scored a [1]. AUs with fewer are scaled proportionally.

$V_{hydrop}$ – The number of different water regimes present in the AU.

**Rationale:** Many lentic invertebrates have their life cycles keyed to different water regimes. A diversity of water regimes in an AU will, therefore, support more species than an AU with a less diverse water regime. For example, some species are characteristics of permanent pools while other live in pools that are strictly temporary (Wiggins et al. 1980).

**Indicators:** The variable is assessed using four hydroperiod classes as descriptors. These are permanently flooded, seasonally flooded, saturated, occasionally flooded (see detailed descriptions in Section 6.7.4).

**Scaling:** AUs with four hydroperiod classes are scored a [1]. Those with fewer are score proportionally (3 classes = 0.67, 2 = 0.33, 1 = 0).

$V_{aquastruc}$ – The number of different types of plant structures present in aquatic bed vegetation.

**Rationale:** Different types of aquatic bed vegetation provide different structure and consequently different niches for invertebrates (Wilcox and Meeker 1992). Thus, species richness increases as the structural diversity of aquatic bed vegetation increases.

**Indicators:** This variable is quantified using a diagram showing different types of structures found in aquatic bed vegetation.

**Scaling:** AUs with all three types of structure present score a [1]. Those with 2 score a [0.67]; those with 1 score [0.33]; and those with none score a [0].

$V_{tannins}$ – The concentration of tannins present in water. **This variable is used to indicate potential reductions in the level of performance for the function.**

**Rationale:** Tannins occur in undisturbed systems and may be limiting to invertebrates. For example, in Atlantic Canada isopods are presumed absent from ponds because they are humic (i.e. have tannins in them) (Walker et al. 1985).

**Indicators:** The presence of clear, brown, water (i.e. brown without any sediment or particulate matter) is used as the indicator that tannins are present in sufficient concentrations to deter use by, or impair growth of, invertebrates. A detailed description of how to characterize concentration levels of tannins is in Part 2.

**Scaling:** This is an “on/off” variable that results in a reduction in the overall score. AUs with tannins present have their score reduced by a factor of 0.7.

## 6.8.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Invertebrates*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vpermflow** | *Highest:* | AU has permanently flowing stream | If D4.1 = 1, enter "1" | |
| | *Lowest:* | AU has no permanent stream | If D4.1 = 0, enter "0" | |
| **Vsubstrate** | *Highest:* | 5 categories of surface layers | If calculation is > = 1, enter "1" | |
| | *Lowest* | AU has no solid surface exposed | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling is based on the number of categories of surface layers present/5 | Enter result of calculation | |
| | Calculate sum (D46.1 – D46.8)]/5 to get result | | | |
| **Vwintersp** | *Highest:* | High interspersion between land and water | If D38 = 3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D38 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D38 = 1, enter "0.33" | |
| | *Lowest:* | no interspersion | If D38 = 0, enter "0" | |
| **Vlwd** | *Highest* | AU has at least 10 categories of different sizes and decomposition states of large woody debris | If calculation > = 1, enter "1" | |
| | *Lowest:* | No categories of LWD | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling based on the number of categories divided by 10 | Enter result of calculation | |
| | Calculate (D44 + D45)/10 to get result | | | |
| **Vstrata** | *Highest:* | 6 strata present | If D21 = 6, enter "1" | |
| | *High:* | 5 strata present | If D21 = 5, enter "0.8" | |
| | *Moderate:* | 4 strata present | If D21 = 4, enter "0.6" | |
| | *Medium Low:* | 3 strata present | If D21 = 3, enter "0.4" | |
| | *Low:* | 2 strata present | If D21 = 2, enter "0.2" | |
| | *Lowest:* | 1 strata present | If D21 = 1, enter "0" | |
| **Vvegintersp** | *Highest:* | High interspersion between vegetation classes | If D39 = 3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D39 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D39 = 1, enter "0.33" | |
| | *Lowest:* | No interspersion (1 class only) | If D39 = 0, enter "0" | |

**Table continued on next page**

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vassemb** | *Highest:* | AU has at least 10 plant assemblages | If calculation > = 1, enter "1" | |
| | *Lowest:* | AU has 1 plant assemblage | If D20 = 1, enter "0" | |
| | *Calculation:* | Scaling based on the number of assemblages divided by 10 | Enter result of calculation | |
| | Calculate (D20-1)/9 to get result | | | |
| **Vhydrop** | *Highest:* | AU has 4 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 4, enter "1" | |
| | *Moderate:* | AU has 3 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 3, enter "0.67" | |
| | *Low:* | AU has 2 water regimes present | If D9.1 + D9.2 + D9.3 + D9.4 = 2, enter "0.33" | |
| | *Lowest:* | AU has 1 water regime present | If D9.1 + D9.2 + D9.3 + D9.4 = 1, enter "0" | |
| **Vaquastruc** | *Highest* | AU has 3 structures of aquatic bed vegetation | If D25 = 3, enter "1" | |
| | *High:* | AU has 2 structures of aquatic bed vegetation | If D25 = 2, enter "0.67" | |
| | *Moderate:* | AU has 1 structures of aquatic bed vegetation | If D25 = 1, enter "0.33" | |
| | *Lowest:* | AU has 0 structures of aquatic bed vegetation | If D25 = 0, enter "0" | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vtannins** | AU has tannins present | | If D36 =1, enter "0.7" | |
| | AU has no tannins present | | If D36 = 0, enter "1" | |
| | | | **Score for Reducer** | |
| ***Index for Habitat Suitability for Invertebrates = Total for variables x reducer x 1.22 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.9 Habitat Suitability for Amphibians — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.9.1 Definition and Description of Function

**Habitat Suitability for Amphibians is defined as the wetland characteristics that contribute to the feeding, breeding, or refuge needs of amphibian species.** Amphibians in the lowlands of western Washington are a vertebrate group that include wetland-breeding frogs and toads (e.g., Order Anura, tailless amphibians except as larvae) and salamanders and newts (e.g., Order Caudata (Uradela) tailed amphibians). Their richness and abundance indicates they are extremely important in wetland trophic organization. Many native species only breed for a short time in wetlands and live in uplands as metamorphosed juveniles and adults (Richter 1997). Some species may be found in or close to wetlands throughout the year. Eggs and larvae of wetland breeding species, however, require free water for development.

Wetlands play an important role in the life cycles of amphibians by providing the quiet waters, shelter, and food sources needed for the early stages of development. The suitability of and AU as amphibian habitat is assessed by characterizing the conditions in a wetland that enable spawning, support the development of eggs and larvae, and provide protection and food for larvae in addition to adults moving in and out of the wetland.

In general, the suitability of an AU as amphibian habitat increases as the number of the appropriate habitat characteristics increase for all life stages. **The assessment model is focused on species richness and conditions that would support many different species, not on the importance of a wetland to a specific threatened or endangered species.**

**If the wetland is a habitat type that appears to be critical to a specific species, another method is needed to better determine the habitat suitability of that wetland**.

## 6.9.2 Assessing this Function for Depressional Outflow Wetlands

The suitability of an AU in the depressional outflow subclass as habitat for amphibians is modeled on the different types of physical and biologic characteristics present that have been shown to be important for the survival of amphibians.

Not all important wetland characteristics, however, could be assessed. For example, water level fluctuations are known to be important (Richter and Azous 1995, Azous and Richter 1995, and Richter 1997), but could not be characterized adequately in one site visit. Another variable known to be critical to amphibians in wetlands is the presence of corridors to other wetlands or to upland habitat. The presence of relatively undisturbed migration routes between the AU and upland feeding and hibernation sites are an important habitat element for many amphibian species (Heusser 1968, Berven and Grudzien 1990, and Beebee 1996). Moreover, dispersal routes from source populations are critical when populations are eliminated by stochastic processes including drought (Pounds and Crump 1994), disease (Bradford 1991), pollution (Richter pers. obs.), or when populations produce insufficient offspring to permanently occupy a site (Gill 1978a, b; and Sinsch 1992). Finally, amphibians within an AU benefit as members of a metapopulation extending across several wetlands by maintaining healthy populations that otherwise go extinct from inbreeding depression (Sofgren 1991, 1994, and Pechmann and Wilbur 1994).

Unfortunately, the information required to adequately assess the presence and suitability of corridors for amphibians proved to be too complex for a rapid assessment method. The data that can be collected from maps and aerial photos does not provide the resolution needed to adequately represent the needs of amphibians. Corridors need to be assessed on site, and the access to them may not be possible. The nature of suitable corridors for amphibians is not intuitive nor can it be clearly generalized. A culvert may provide an adequate corridor in one AU but not another.

Two variables included ($V_{phow}$ and $V_{upcover}$) reflect the potential for a reduction in the performance of this function. Acidic water will impair egg and larval development (Sadinski and Dunson 1992, and Rowe et al. 1992). Furthermore, natural habitats in the surrounding uplands are considered to be of paramount importance for maintaining viable amphibian populations (Semlitsch 1981, Kleeberger and Werner 1983, Bury and Corn 1988, and Dupuis et al. 1995). The absence of relatively undisturbed vegetation is modeled as a reduction in suitability of the wetland itself because it is a necessary condition if the wetland is to provide a suitable habitat for amphibians.

The Assessment Teams considered using the presence of fish and bullfrogs as a reducer of habitat suitability because both of these predators are known to prey on native amphibians. However, the presence of these species cannot always be determined during a single site visit. Users of the method are encouraged, however, to record the presence of either fish or bullfrogs in their report. If either predator is present, the index that is calculated by the assessment model may not reflect the actual habitat suitability of the AU.

## 6.9.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Amphibians*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Breeding, feeding, and refuge for amphibians (applies to all variables)** | **Vbuffcond** | Descriptive table of conditions in buffer |
| | **Vsubstrate** | Types of surface substrates present |
| | **Vwintersp** | Diagrams |
| | **Vlwd** | Categories of LWD present |
| | **Vwater** | % of AU with permanent water, or permanent water under FO or SS |
| | **Vsubstruc** | Categorization by dichotomous key |
| ***Reducers*** | | |
| | **Vphow** | pH tabs, direct measurement |
| | **Vupcover** | Land uses within 1 km of wetland |
| | **Index:** | $\frac{(\text{Vbuffcond} + \text{Vsubstrate} + \text{Vwintersp} + \text{Vlwd} + \text{Vwater} + \text{Vsubstruc}) \times (\text{Vphow or Vupcover})}{\text{Score from reference standard site}}$ |

## 6.9.4 Description and Scaling of Variables

$V_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

**Rationale:** Conditions in the buffers of an AU are especially important in providing cover to amphibian females and to newly metamorphed animals. Female *R. aurora*, *A. gracile* (Richter pers. obs.) and *A. macrodactylum* (Beneski et. al. 1986, and Leonard and Richter 1994) generally wait in buffers near wetlands until environmental and biological conditions are favorable to spawning. They then enter wetlands during one or a few nights to spawn, thereafter quickly retreating to cover of buffers. Metamorphs of most species also benefit from wetland buffers. They are important to the tiger salamander (*A. tigrinum*) seeking shelter in rodent burrows during the first days following emigration from natal ponds (Loredo et al. 1996). Metamorphs of *P. regilla*, *B. boreas R. aurora* and *T. granulosa* may spend several weeks in buffers prior to dispersing upland if soil and vegetation is dry beyond the buffer (Richter pers. obs.) Vulnerable metamorphs and juveniles have moisture, cover, and abundant invertebrate prey within forested wetland buffers.

**Indicators**: This variable is determined using a buffer categorization developed from the Washington State Rating System (WDOE 1993) (see data sheets in Part 2).

**Scaling:** Buffer categories are scaled as follows: category 5 = 1, category 4 = 0.8, category 3 = 0.6, category 2 = 0.4, category 1 = 0.2, category 0 = 0.

$V_{substrate}$ – The composition and types of surface layers present in the AU (litter, mineral, organic etc).

**Rationale:** Organic matter and leaf litter are important to larval amphibians as substrates for the zooplankton, phytoplankton, algae, and invertebrates that provide their food. Moreover, structural diversity in the form of leaf litter and woody debris provides shelter from weather and cover from predation. Different types of substrates provide niches for different invertebrate communities and thereby increase the richness of potential food sources.

**Indicators:** No indicators are needed to assess this variable. The substrate types can be determined by direct field observations.

**Scaling:** Scaling is based on the total number of different types of substrate present in the AU. Organic substrates, however, are given more importance (by a factor of two) because of their additional role as shelter. AUs with 3 categories of organic litter and 2 categories of inorganic surface types are scored a 1. Those with fewer are scaled proportionally (see Calculation Table 6.9.5).

$V_{wintersp}$ – The extent of interspersion present between vegetated portions of the AU and permanent open water.

**Rationale:** Most species of amphibians generally avoid both open water and densely vegetated sites, instead selecting habitats with an interspersion of both features (Strijbosch 1979, Ildos and Ancona 1994, Richter and Roughgarden in preparation, and Richter pers. obs.). Quantitative comparisons of vegetation cover surrounding *A. gracile* eggs suggest dense (95-100%) and light (0-5 %) cover is avoided (Richter and Roughgarden in prep.). Research findings suggest that for most species an interspersion between open water and vegetation is selected for oviposition. A 25-75 or 75-25 ratio of open water to vegetation may, therefore, be considered optimum for spawning.

**Indicators:** The extent of interspersion in a wetland is characterized by using a series of diagrams that rate interspersion into high, medium and low. Diagrams are based on those used in Wetland Evaluation Technique (Adamus et al. 1987) and in the Western Washington Rating Systems (WDOE 1993).

**Scaling:** Depressional outflow AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0] .

$V_{lwd}$ – The number of categories, based on size and level of decay, of fallen large woody debris (LWD) in the permanent open water and on the vegetated surface of the AU. The categories are based on the Timber, Fish, and Wildlife rating criteria (Schuett-Hames et al. 1994).

**Rationale:** There is no clear documentation of the quantity and type of large woody debris that is of benefit to amphibians in wetlands. However, tadpoles of western toads (*Bufo boreas*) frequently rest attached to large floating logs (Richter pers. obs.). Large woody debris in water most likely is important also as cover for larvae and adults, and as attachment sites for the algae and invertebrates that provide food.

**Indicators:** Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay classes of woody debris was developed as quantification for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

**Scaling:** AUs with 10 (out of 24 possible) or more categories of LWD in open water and on the surface are scored a [1]. Those with less are scaled proportionally (# categories/10).

$V_{water}$ – The percent of the AU with permanent open water, aquatic bed vegetation, and areas of permanent standing water under a canopy of trees or shrubs.

**Rationale:** The extent of water without emergent vegetation is used as a surrogate for water level fluctuation. The assumption is that AUs with some open or standing water have lower water level fluctuations during the breeding season. Attempts were made to characterize water level fluctuations during the field calibration, but it was impossible to estimate the fluctuations that actually occur during the breeding season. The presence of open water is used as an indicator that water is present during the breeding season and that fluctuations will be lower than if no permanent water is present.

Most species of amphibians in temperate climates minimize exposure of eggs to fluctuating depths and temperatures by both spawning in mid-depth water and by submerging eggs below the surface (Richter 1997). Amphibian egg development also depends on permanent or partial submergence, and, therefore, optimum habitat conditions are those where water levels are stabilized from spawning through hatching. In most Puget Sound species this is from mid-December through mid-May. Although mean water level fluctuations exceeding 20 cm have been correlated to decreased amphibian richness in wetlands (Azous and Richter 1995) experiments suggest that extended drops of more than 7 cm from oviposition through hatching

may harm *A. gracile*. Moreover, eggs of *A. macrodactylum* and *P. regilla* spawned in shallow water are harmed by stranding and desiccation on shore if water level fluctuations are severe.

**Indicators:** The percent of the AU that is in permanent open water or in aquatic bed vegetation can be estimated during the site visit. The presence of permanent standing water under a canopy of trees or shrubs is characterized only as present/absent.

| **Scaling:** | | **Score** |
|---|---|---|
| *Highest* | AU has at least 50% open water (Permanent Open water + aquatic bed) | 1 |
| *High* | AU has 10- 49% open water | 0.8 |
| *Moderate* | AU has no open water, but has permanent water under SS or FO or EM | 0.5 |
| *Low* | AU has 1-9% open water | 0.2 |
| *Lowest* | AU has no open water, or permanent water under SS or FO or EM | 0 |

$\boldsymbol{V_{substruc}}$ – A characterization of plant structures present under the water surface.

**Rationale:** Northwest caudates attach their eggs directly to vegetation within the water column (Slater 1936, Anderson 1967, Richter 1997 and reference therein). Anurans anchor eggs to vegetation either below or near the surface (e.g. *R. aurora*, *B. boreas*) or occasionally spawn free-floating eggs (*R. pretiosa*; Licht 1969).

Experimental evidence suggests that vegetation structure, particularly plant shape and stem diameter are the oviposition criteria most important to caudates. Wetland surveys and controlled field studies of several northwest salamanders confirm that distinct stem widths are preferred by ovipositing caudates (Richter 1997). From these surveys and studies it can be inferred that species of submerged vegetation are unimportant for oviposition. Rather, the important factor is the size and structure of submerged vegetation.

Underwater structure is also important as a source of diversity in the food source. It provides a substrate for invertebrates and algae.

**Indicators:** This variable is determined by using a descriptive key outlining different categories of underwater structures for egg laying (see data sheets in Part 2 for key). The key rates the structures on a scale of 0-4.

**Scaling:** AUs with a rating of 4 in the key are scored a 1; those with a rating of 3 are scored a 0.75; rating of 2 = 0.5; rating of 1 = 0.25; and rating of 0 = 0.

***$V_{phow}$* – T**he pH of open surface water in the AU. **This variable is used to indicate potential reductions in the level of performance for the function.**

**Rationale**: Acidic waters impair egg and larval development of Pacific Northwest amphibians. Hence they are generally absent from wetlands with a pH in its surface waters of 4.5 or less (Richter unpub. data).

**Indicators:** No indicators are needed. The pH of surface water can be measured directly using pH strips.

**Scaling:** AUs with a pH of 4.5 or less are assigned an index of [0] for the function. Those with a pH >4.5 but < 5.5 have their index reduced by a factor of 0.5. AUs with a pH of 5.5 or greater do not have their index reduced.

***$V_{upcover}$*** – The types of land uses within 1 km of the estimated AU edge. **This variable is used to indicate potential reductions in the level of performance for the function.**

**Rationale:** Wetlands that provide full range of biological processes of consequence to amphibians are located in relatively undeveloped areas (Schueler 1994, and Richter and Azous 1995). Development increases water discharges, current velocities, and water level fluctuations in the AU. These environmental conditions diminish suitable amphibian breeding, feeding, and rearing habitat. Moreover, wetland invertebrates and plants are also known to decrease in richness and abundance with greater water level fluctuations and concomitant pollution loads (Schueler 1994, Ludwa 1994, Azous and Richter 1995, and Hicks 1995) further reducing the quality of amphibian habitat in the AU.

**Indicators**: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the wetland can be established from aerial photographs or site visits.

**Scaling:** AUs with at least 60% of their surrounding land in urban or high density residential use have their index for the function reduced by a factor of 0.5. Those with at least 50% in clear-cut are also reduced by 0.5. AUs with at least 30% of their surrounding areas in any active land use (residential, urban, clear-cut, or agriculture) have their index reduced by a factor of 0.8.

## 6.9.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Amphibians*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vbuffcond** | *Highest:* | Buffer category of 5 | If D42 = 5, enter "1" | |
| | *High:* | Buffer category of 4 | If D42 = 4, enter "0.8" | |
| | *Moderate:* | Buffer category of 3 | If D42 = 3, enter "0.6" | |
| | *Medium Low:* | Buffer category of 2 | If D42 = 2, enter "0.4" | |
| | *Low:* | Buffer category of 1 | If D42 = 1, enter "0.2" | |
| | *Lowest:* | Buffer category of 0 | If D42 = 0, enter "0" | |
| **Vsubstrate** | *Highest:* | 3 categories of organic litter + 2 inorganic surface layers | If D46.1 + D46.2 + D46.3 =3 **and** sum (D46.4 to D46.8) > = 2, enter "1" | |
| | *Lowest:* | AU has no ground surface exposed | If sum (D46.1-D46.8) = 0, enter "0" | |
| | *Calculation:* | Scaling is based on the number of categories of surface layers present; with organic surface layers weighted by a factor of two. | Enter result of calculation | |
| | If Sum(D46.4 – D46.8) >= 2 calculate [(D46.1+D46.2+D46.3)x2 + 1]/8<br>If Sum( D46.4-D46.8) <= 1 calculate [(D46.1+D46.2+D46.3)x2 + sum (D46.4 - D46.8)]/8 | | | |
| **Vwintersp** | *Highest:* | High interspersion between land and water | If D38 = 3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D38 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D38 = 1, enter "0.33" | |
| | *Lowest:* | no interspersion | If D38 = 0, enter "0" | |
| **Vlwd** | *Highest:* | AU has at least 10 size categories and decomposition states of LWD | If calculation > = 1, enter "1" | |
| | *Lowest:* | No categories of LWD | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaling based on the number of categories divided by 10 | Enter result of calculation | |
| | Calculate (D44 + D45)/10 to get result | | | |
| **Vwater** | *Highest:* | AU has at least 50% exposed water (POW +AB) | If D8.3 + D14.6 > = 50, enter "1" | |
| | *High:* | AU has 10- 49% exposed water | If D8.3 + D14.6 > = 10 and < 50, enter "0.8" | |
| | *Moderate:* | AU has no exposed water, but has permanent water in SS, FO or EM | If D8.3 + D14.6 = 0 **and** D9.1 = 1, enter "0.5" | |
| | *Low:* | AU has 1-9% exposed water | If D8.3 + D14.6 > = 1 and < 10, enter "0.2" | |
| | *Lowest:* | AU has **no** water, or permanent water under SS or FO or EM | If D8.3 + D14.6 = 0 **and** D9.1 = 0, enter "0" | |

**Table continued on next page**

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vsubstruc** | *Highest:* | Score of 4 on underwater structures for egg laying | If D35 = 4, enter "1" | |
| | *High:* | Score of 3 on underwater structures for egg laying | If D35 = 3, enter "0.75" | |
| | *Moderate:* | Score of 2 on underwater structures for egg laying | If D35 = 2, enter "0.5" | |
| | *Low:* | Score of 1 on underwater structures for egg laying | If D35 = 1, enter "0.25" | |
| | *Lowest:* | Score of 0 on underwater structures for egg laying | If D35 = 0, enter "0" | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vphow** | pH of standing water < 4.5 | | If D26.2 < = 4.5, enter "0" | |
| | pH of standing water >4.5 and < 5.5 | | If D26.2 > 4.5 and < 5.5, enter "0.5" | |
| | pH of standing water > =5.5 | | If D26.2 > = 5.5, enter "0.8" | |
| **Vupcover** | AU has > + 60% urban or high density residential land use; OR > = 50% clear cut within 1 km | | If D3.4 + D3.5 > = 60 **OR** D3.3 > = 50, enter "0.5" | |
| | AU has as least 30% of area within 1 km in active land uses | | If sum (D3.2-D3.6) > = 30, enter "0.8" | |
| | AU has less than 30% of area within 1 km in active land uses | | If sum (D3.2-D3.6) < 30, enter "1" | |
| | | | **Score for Reducer (Choose Lowest Value)** | |
| ***Index for Amphibians = Total for variables x reducer x 1.85 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.10 Habitat Suitability for Anadromous Fish — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.10.1 Definition and Description of Function

**Habitat Suitability for Anadromous Fish is defined as the environmental characteristics that contribute to the feeding, breeding, or refuge needs of anadromous fish.** Many wetlands provide cover, depth, surface area, and other attributes necessary for the over-wintering life history phase of coho salmon (*Oncorhynchus kisutch*). Other anadromous fish noted in off channel wetlands include cutthroat trout (*Oncorhynchus clarki*) steelhead (*Oncorhynchus mykiss*) (Peterson 1982). Because the distribution and habitat requirements of salmonids and non-salmonids overlap, it is assumed that an AU meeting the habitat requirements of salmonids will also meet the requirements of non-salmonid anadromous fish (Johnson and Stypula 1993).

**The models assess general habitat suitability, not the importance of a wetland to a specific threatened or endangered species, or to a specific regionally important species assemblage.** The function is modeled based on the structural elements, physical components, and the characteristics of the AU that are considered to be important elements of habitat for anadromous fish. In general, the suitability of an AU as habitat for anadromous fish is assumed to improve as the number of beneficial habitat characteristics increase.

**If the AU is a habitat type that appears to be critical to a specific species, another method is needed to better determine the habitat suitability of that AU** (e.g. USFWS Habitat Evaluation Procedures (HEP) USFWS 1980).

## 6.10.2 Assessing this Function for Depressional Outflow Wetlands

The suitability of a depressional outflow AU to provide habitat for anadromous fish is modeled by combining variables that represent feeding, refuge, and over-wintering conditions for fish. The elements of an AU considered to provide these conditions are: interspersion between land and water, adequate water depths, permanent open water, the presence of different types of cover, and adequate food in the form of invertebrates.

In this model $V_{bogs}$ is used to represent acidic conditions and low productivity that decrease the suitability of an AU to provide anadromous fish habitat. The general characteristics

considered suitable for anadromous fish were first developed from the work of Bjornn and Resier (1979) and supplemented by other references as described below for individual variables.

The model for depressional outflow wetlands does not have a variable to reflect an absolute requirement for permanent water, that would at first, seem to be a necessary pre-requisite for fish habitat. The presence of permanent open water is considered important but not necessary. The Assessment Teams judged that AUs would provide habitat features important to anadromous fish even in the absence of any permanent water because seasonal flooding in the winter and early spring provides both forage and refuge during a critical time in the life cycle some of anadromous fish.

Habitat Suitability for Anadromous Fish is one of the two habitat functions for which it may be possible to also judge opportunity as part of a rapid assessment method. The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. WDFW maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

## 6.10.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Anadromous Fish*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Feeding and refuge for anadromous fish (applies to all variables)** | **Vwintersp** | Diagrams of interspersion between land and water |
| | **Vwaterdepth** | Number of water depth categories present |
| | **Vcover** | Categories of refuge present in water |
| | **Vpow** | % of AU in permanent open water |
| | **Sinverts** | Score for function "Habitat Suitability for Invertebrates" |
| ***Reducers*** | | |
| **Acidic bogs** | **Vbogs** | % area of sphagnum bogs in AU |
| **Culverts** | **Vculverts** | Surface outflow is through a man-made culvert |
| | **Index:** | (Vwintersp + Vwaterdepth + 2xVcover + Vpow + Sinverts) x (Vbogs or Vculverts) / Score from reference standard site |

## 6.10.4 Description and Scaling of Variables

***$V_{wintersp}$*** **–** The amount of interspersion present between vegetated portions of an AU and open water.

**Rationale**: Interspersion between land and water permits aquatic organisms to enter and leave the AU via permanent or ephemeral surface channels, or overbank flow (Brinson et. al. 1995). These organisms provide food for anadromous fish. In addition, such interspersion provides refuge from predation for overwintering salmonids by increasing the area of protected shallow waters with vegetated banks. Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).

**Indicators:** The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

**Scaling:** Depressional outflow AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

***$V_{waterdepth}$*** – A categorization of different depths of water present in an AU.

**Rationale**: Anadromous fish need a certain water depth for optimum habitat conditions. Narver (1978) observed juvenile coho moving into areas with water depth over 45 cm and lower velocities (15 cm/s) when temperatures decline below $7^{o}$C. Beaver ponds and off-channel areas with similar depths have also been found to provide habitat (Reeves et al. 1989). Survival and growth of over-wintering fish may be maximized in systems that contain both shallow pools and deeper ones (Peterson 1982).

**Indicators:** The variable is characterized using a condensed form of the depth categories first developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and > 100 cm.

**Scaling**: AUs with three depth categories present are scored a [1]. Those with the two shallower ones are scored a [0.5]; those with 0-20 cm of water are scored a [0.1]. AUs with no permanent or seasonal inundation are scored a [0]. If the water depth is greater than 100 cm but the AU does not have enough shallow water to meet the size requirements (0.1 ha or 10%, whichever is the smaller) it is scored a [0.7].

***$V_{cover}$*** – Structures in the AU that provide cover in and over water. This variable is assessed based on two structural elements: 1) vegetation that overhangs permanent water; and 2) large

woody debris in permanent water. **This variable is considered to be a critical habitat component and is weighted by a factor of 2 relative to the other variables.**

**Rationale:** Overhanging vegetation provides both temperature control and protection from predation. McMahon (1983) reported the need for streamside vegetation for shading. Small coho juveniles tend to be harassed, chased and nipped by larger juveniles unless they stay near the bottom, obscured by rocks or logs (Groot and Margolis, 1994). Cover for salmonids can be provided by overhanging vegetation, submerged vegetation, submerged objects such s logs and rocks, floating debris, deep water, turbulence and turbidity (Giger 1973). Large woody debris plays an important role in Pacific Northwest streams, creating and enhancing fish habitat in streams of all sizes (Bisson et al. 1987).

When juvenile salmonids move into depressional wetlands they will need the same type of cover as found in streams. The Assessment Teams judged that the types of cover found in streams also are necessary in wetlands if the habitat is to be judged as suitable.

**Indicators:** The presence of overhanging vegetation is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

**Scaling:** AUs with overhanging vegetation and at least 4 categories of large woody debris in permanent open water are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having equal weight (see Calculation Table 6.10.5). AUs with no types of cover are scored a [0].

$\boldsymbol{V_{pow}}$ – The percent of the AU that is covered by permanent open water.

**Rationale**: AUs that have permanent surface water present provide habitat the entire year rather than just during the wet season. As mentioned in the introduction, the model for depressional outflow wetlands does not have a variable to reflect an absolute requirement for permanent water that would at first seem to be a necessary pre-requisite for fish habitat. AUs with permanent open water, however, provide better habitat than those flooded only seasonally.

**Indicators:** The variable is assessed by estimating the relative % of the AU that has permanent open water (described in Part 2).

**Scaling:** AUs that have 30% or more permanent open water are scored a [1]. Those with less are scored proportionally (%pow/30).

$S_{inverts}$ – The index from the function "Habitat Suitability for Invertebrates."

**Rationale**: Invertebrates in wetlands are a major food source for overwintering and young anadromous fish. The index for the function is an indication of the potential food sources available to the salmonids. Higher richness is indicative of a broader range of food sources and well as a more balanced availability of such food. The salmonids would not have to rely on only one or two species that could potentially be subject to large fluctuations.

**Indicators:** No indicators are needed for this variable since it is an index for another function.

**Scaling:** The index is already scaled and is re-normalized to 0-1.

$V_{bogs}$ – The percent area of AU that is covered by a sphagnum bog (defined as areas where sphagnum mosses represent more than 30% cover of the ground). **This is a variable of reduced performance.**

**Rationale:** The presence of a bog is an indication that the area has a low rate of primary production, regardless of its other characteristics (Mitch and Gosselink 1993). It also may contain acidic waters and high concentration of tannins. The Assessment Teams judged that the presence of bogs were a good indicator that the AU is not as suitable a habitat for anadromous fish.

**Indicators:** No indicators are needed for this variable since the % area of a bog can be determined directly.

**Scaling:** The variable is used to reduce the performance index for the function. AUs that are more than 25% bog have their index for this function reduced by 0.5.

$V_{culverts}$ – The only surface outflow in the AU is through a man-made culvert or other control structure.

**Rationale:** The presence of a culvert or water control structure is an indication that access to and from the AU for overwintering young and adult spawners is reduced. Culverts tend to be undersized or subject to easy blockages. Also, the young salmonids will tend to shun the darkness found in a culvert and not swim through it. Water control structures, such as flap gates, siphons, tide gates, will also limit access to and from the AU by limiting the times during which water leaves the AU.

**Indicators:** No indicators are needed for this variable since the presence of a culvert or other water control structure can be established in the field.

**Scaling:** The variable is used to reduce the performance index for the function. AUs with culverts or water control structures have their index for this function reduced by 0.5.

## 6.10.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Anadromous Fish*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vwintersp** | *Highest:* | Interspersion is high | If D38 = 3, enter "1" | |
| | *Moderate:* | Interspersion is moderate | If D38 = 2, enter "0.67" | |
| | *Low:* | Interspersion is low | If D38 = 1, enter "0.33" | |
| | *Lowest:* | No interspersion | If D38 = 0, enter "0" | |
| **Vwaterdepth** | *Highest:* | All water depth categories present | If D12.1 = 1 **and** D12.2 = 1 **and** D12.3 = 1, enter "1" | |
| | *Medium High:* | Only water depths > 100 cm present | If D12.3 = 1 **and** D12.1 +D12.2 = 0, enter "0.7" | |
| | *Moderate:* | Depths between 0-20 cm and 20-100 cm present | If D12.1 =1 **and** D12.2 = 1, enter "0.5" | |
| | *Low:* | Depths between 0-20 cm present | If D12.1 = 1, enter "0.1" | |
| | *Lowest:* | No surface water present | If all D10 = 0, enter "0" | |
| **Vcover** | *Highest:* | AU scored 1 for overhanging veg. **and** has 4 or more categories of woody debris in permanent water | If D32 = 1 **and** D45 > = 4, enter "2" | |
| | *Lowest:* | No categories of cover present | If D32 + D45 = 0, enter "0" | |
| | *Calculation:* | Scaled as overhanging vegetation + # of categories of woody debris/4 | Enter result of calculation | |
| | If D45 < 4 calculate D32 + (D45/4) to get result<br>If D45 > 4 calculate D32 + 1 to get result | | | |
| **Vpow** | *Highest:* | AU has > = 30% perm. open water | If D8.3 > = 30, enter "1" | |
| | *Lowest:* | No permanent open water in AU | If D8.3 = 0, enter "0" | |
| | *Calculation:* | Scaled as % open water/30 | Enter result of calculation | |
| | If D8.3 < 30 calculate D8.3/30 to get result | | | |
| **Sinverts** | *Score is scaled* | Index for Habitat Suitability for Invertebrates | (Index of function)/10 | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vbogs** | Sphagnum bog component of AU is > = 25% | | If D23.1 + D23.2 + D23.3 > = 1, enter "0.5" | |
| | Sphagnum bog component of AU is < 25% | | If D23.1 + D23.2 + D23.3 = 0, enter "1" | |
| **Vculvert** | Only surface water outflow is through culvert or man-made water control structure | | If D4.3 = 1, enter "0.5" | |
| | Surface water outflow is NOT through culvert or man-made water control structure | | If D4.3 = 0, enter "1" | |
| | | | **Score for Reducer (Choose Lowest Value)** | |
| ***Index for Habitat Suitability for Anadromous Fish = Total for variables x reducer x 1.85 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

## 6.10.6 Qualitative Rating of Opportunity

The Assessment Teams decided that an AU does have the opportunity to provide habitat for anadromous fish if its surface water outlet has a direct connection that is passable by fish to a stream with anadromous fish in it. Information on locations used by anadromous fish is more readily available than for other wildlife. The Washington State Department of Fish and Wildlife maintains an extensive database of streams used by anadromous fish, and this can be used as a guide in rating the opportunity. Local sources may also be contacted for information on the presence of anadromous fish.

If the AU has an unobstructed passage to a stream or river with anadromous fish it should be rated as having a **"High"** opportunity to provide habitat. If there is no passage, or the passage is obstructed, the opportunity is **"Low"**.

# 6.11 Habitat Suitability for Resident Fish — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.11.1 Definition and Description of Function

**Habitat Suitability for Resident Fish is defined as the wetland characteristics that contribute to the feeding, breeding, or refuge needs of resident native fish.**

The function is modeled based on the structural elements, physical components, and other characteristics of an AU that are considered to be important elements of habitat for resident native fish. In general, the suitability of an AU as habitat for resident fish is assumed to improve as the number of beneficial habitat characteristics increase. **The assessment models are focused on general habitat suitability, not on the importance of an AU to a specific threatened or endangered species or to a specific regionally important species assemblage.**

The model for depressional outflow wetlands does not have a variable to reflect the requirement for permanent water, that would at first, seem to be a necessary pre-requisite for fish habitat. The presence of permanent open water is considered important but not necessary. The Assessment Teams judged that wetlands without permanent water can provide habitat for resident fish because seasonal flooding in the winter and early spring provides both forage and refuge when the wetland is connected by surface water to other bodies of water.

## 6.11.2 Assessing this Function for Depressional Outflow Wetlands

The suitability of AUs in the depressional outflow subclass as habitat for resident fish is modeled on specific physical and biologic characteristics of an AU. These characteristics include the interspersion between vegetation and water, the amount of cover for fish, the characteristics of the substrate, the depth water, and the presence of a permanently flowing stream. In addition, the models include the index for the “invertebrate function” that represents a food source for fish.

## 6.11.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Resident Fish*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Feeding, breeding and refuge for resident native fish (applies to all variables)** | **Vwintersp** | Diagrams of interspersion between land and water |
| | **Vwaterdepth** | Number of water depth categories present |
| | **Vcover** | Categories of refuge present in water |
| | **Vpow** | % of AU in permanent open water |
| | **Vpermflow** | Presence/absence of permanent flow in channel |
| | **Vsubstrate** | Types of surface substrates present |
| | **Sinverts** | Score for function "Habitat Suitability for Invertebrates" |
| **Index:** | | $\frac{(\text{Vwintersp} + \text{Vwaterdepth} + \text{Vcover} + \text{Vpow} + \text{Vpermflow} + \text{Vsubstrate} + \text{Sinverts})}{\text{Score from reference standard site}}$ |

## 6.11.4 Description and Scaling of Variables

$V_{wintersp}$ – The amount of interspersion present between vegetated portions of the AU and open water.

**Rationale**: Interspersion between land and water permits aquatic organisms to enter and leave the wetland via permanent or ephemeral surface channels, overbank flow, or unconfined hyporheic gravel aquifers (Brinson et. al. 1995). These provide food for resident fish as well as anadromous fish. In addition, such interspersion provides refuge from predation by increasing the area of protected shallow waters with vegetated banks. Contact zones between open water and vegetation provide protection from wind, waves, and predators, and may provide natural territorial boundaries (Golet and Larson 1974).

**Indicators:** The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none.

**Scaling:** Depressional outflow AUs with high interspersion are score a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

$V_{waterdepth}$ – The varying depths of water present in an AU.

**Rationale**: Resident fish need a range of water depths for different parts of their life cycles. Shallow waters provide refuge for young fish, while the deeper waters provide refuge for the larger adults. Varying water depths also provide different potential food sources since they are host to different populations of plants and invertebrates.

**Indicators:** The variable is characterized using a condensed form of the depth classes first developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and > 100 cm.

**Scaling**: AUs with all three depth classes present are scored a [1]. Those with the two shallower ones are scored a [0.5]; those with 0-20 cm of water are scored a [0.1]. AUs with no permanent or seasonal inundation are scored a [0]. In some cases an AU may have steep sides. If the water depth is greater than 100 cm but the AU does not have enough shallow water to meet the size requirements (0.1 ha or 10%, whichever is the smaller) it is scored a [0.7].

$V_{cover}$ – Structures in the AU that provide cover in and over water. This variable is assessed based on two structural elements: 1) vegetation that overhangs permanent water and 2) large woody debris in permanent water.

**Rationale:** Refuge from predators is an important habitat feature for maintaining successful fish populations, and wetlands that provide such refuge have a higher potential of performing than those that do not. Overhanging vegetation provides both temperature control and protection from predation. Large woody debris plays an important role in the Pacific Northwest, creating and enhancing fish habitat (Bisson et al. 1987).

**Indicators:** The presence of overhanging vegetation is characterized during the field visit based on presence/absence of certain characteristics as described in Part 2. Direct measures of the quantity and quality of decaying woody debris is not feasible for a rapid assessment method. A descriptive matrix of different sizes and decay levels of woody debris was developed as an indicator for the variable. The matrix is based on the assessment procedure developed for the TFW watershed assessment methods.

**Scaling:** AUs with overhanging vegetation, and at least 4 categories of large woody debris in permanent water are scored a [1]. AUs with fewer characteristics are scored proportionally, with each type of cover having a different weight (see Calculation Table 6.11.5). Large woody debris is weighted by a factor of 3 relative to overhanging vegetation. AUs with no types of cover are scored a [0].

$V_{pow}$ – The percent of the AU that is covered by permanent open water.

**Rationale**: Ponded surface water is needed for fish. Wetlands that have permanent surface water present provide habitat the entire year rather than just during the wet season, thereby increasing the suitability of the AU as habitat.

**Indicators:** The variable is assessed by estimating the relative % of the AU that has permanent open water (described in Part 2).

**Scaling:** AUs that have 30% or more permanent open water are scored a [1]. Those with less are scored proportionally (%pow/30).

$V_{permflow}$ – There are channels or streams present in the wetland that have permanently flowing water.

**Rationale:** This variable is included for the function because flowing water is an important characteristic for cottids and dace in western Washington (Mongillo pers. comm.). These species tend to be found usually in flowing water.

**Indicators:** No indicators are needed for this variable in the summer because the presence of permanent flow in a channel can be established directly during the dry season. Indicators for the presence of permanent channel flow in the winter during the wet season, however, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

**Scaling:** This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$V_{substrate}$ – The composition of surface layers present in the AU (litter, mineral, organic etc).

**Rationale:** Different types of surface layers present in a wetland provide different habitats for resident fish species in western Washington (Mongillo pers. comm.).

**Indicators:** No indicators are necessary to assess this variable. The types of substrate present can be determined during the site visit.

**Scaling:** Since each type of substrate provides a different habitat feature for resident fish, the scaling is based on the number of types of organic substrate present and cobbles and gravel. Wetlands with 4, or more, of the 5 types of substrate present score a [1]. Those with fewer are scaled proportionally (# types/4). AUs with no exposed substrate score a [0].

$S_{inverts}$ – The index for the function "Habitat Suitability for Invertebrates."

**Rationale**: Invertebrates are a major food source for both resident and anadromous fish. The index for the function is an indication of the potential food sources available to resident fish. Higher richness is indicative of a broader range of food sources and well as a more balanced availability of such food. Resident fish would not have to rely on only one or two species that could potentially be subject to large fluctuations.

**Indicators:** No indicators are needed for this variable since it is an index for another function.

**Scaling:** The index is already scaled from 0-1. The index is re-normalized to 0 – 1.

## 6.11.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Resident Fish*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vwintersp** | *Highest:* | Interspersion is high | If D38 = 3, enter "1" | |
| | *Moderate:* | Interspersion is moderate | If D38 =2, enter "0.67" | |
| | *Low:* | Interspersion is low | If D38 =1, enter "0.33" | |
| | *Lowest:* | No interspersion | If D38 =0, enter "0" | |
| **Vwaterdepth** | *Highest:* | All water depth categories present | If D12.1 + D12.2 + D12.3 = 3, enter "1" | |
| | *High:* | Water depths between 0-100 cm present | If D12.1 = 1 **and** D12.2 = 1, enter "0.8" | |
| | *Medium High:* | Water depths > 100 cm present | If D12.3 = 1 **an**d D12.1 + D12.2 = 0, enter "0.7" | |
| | *Low:* | Depths between 0-20 cm present | If D12.1 = 1, enter "0.1" | |
| | *Lowest:* | No surface water present | If all D10 = 0, enter "0" | |
| **Vcover** | *Highest* | AU has overhanging veg. **and** 4+ categ. of LWD in perm. water | If D32 = 1 **and** D45 > = 4, enter "1" | |
| | *Lowest:* | No categories of cover present | If D32 + D45 = 0, enter "0" | |
| | *Calculation:* | Scaled as the # of categ. with weights of: 1 for overhang, and 3 for LWD normalized to 4 | Enter result of calculation | |
| | If D45> = 4 calculate (D32 + 3)/4; if D45 < 4 calculate [ D32 + 3 x (D45/4)]/4 | | | |
| **Vpow** | *Highest:* | AU has > = 30% perm. open water | If D8.3 > = 30, enter "1" | |
| | *Lowest:* | AU has no permanent open water | If D8.3 = 0, enter "0" | |
| | *Calculation:* | Scaled as % open water/30 | Enter result of calculation | |
| | If D8.3 < 30 calculate D8.3/30 to get result | | | |
| **Vpermflow** | *Highest* | Perm. flowing channel or stream | If D4.1 = 1, enter "1" | |
| | *Lowest* | AU has no permanent channel | If D4.1 = 0, enter "0" | |
| **Vsubstrate** | *Highest:* | AU has at least 4 types of substrate | If calculation > = 1, enter "1" | |
| | *Lowest:* | AU has no exposed substrate | If calculation > = 0, enter "0" | |
| | *Calculation:* | Scaled as # of substrate types / 4 | Enter result of calculation | |
| | Calculate[sum (D46.1 - D46.5)]/4 to get result | | | |
| **Sinverts** | *Score is scaled* | Index for Habitat Suitability for Invertebrates | Index of function/10 | |
| | | | **Total of Variable Scores:** | |
| ***Index for Habitat Suitability for Resident Fish = Total for variables x 1.61 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.12 Habitat Suitability for Wetland-Associated Birds — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.12.1 Definition and Description of Function

**Habitat Suitability for Wetland-associated Birds is defined as the environmental characteristics in a wetland that provide habitats or life resources for species of wetland-associated birds.** Wetland-associated bird species are those that depend on aspects of the wetland ecosystem for some part of their life needs: food, shelter, breeding, resting. The guilds of wetland-associated birds used as the basis for building the assessment model includes waterfowl, shorebirds, and herons.

In general, the suitability of an AU as bird habitat increases as the number of appropriate habitat characteristics increase. Another assumption used in developing the model is that AUs that provide habitat for the greater number of wetland-associated bird species are scored higher than those that have fewer. **The assessment models are focused on species richness, not on the importance of a wetland to a specific threatened or endangered species or to a specific regionally important guild.**

**If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU** (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

## 6.12.2 Assessing this Function for Depressional Outflow Wetlands

The suitability of wetlands in the depressional outflow subclass as habitat for wetland-associated birds is modeled based on the plant structure, physical components, and the condition of the buffers around the AU. In addition, the models include the indices for other habitat functions that represent prey of birds, namely the habitat suitability score for amphibians, invertebrates, and fish.

AUs that have a closed canopy are judged to have a reduced level of performance because access for waterfowl is limited. The Assessment Teams also judged that the presence of invasive or non-native birds might reduce the suitability of an AU. A variable for this factor was not included in the model because reproducible data on invasive or non-native birds could not be collected during one site visit.

Size is not used as a variable in the equation although it is often cited as an important characteristic of wetlands that provide bird habitat (Richter and Azous in preparation). The

question of size is a vexing one, and no satisfactory size thresholds have been identified in the literature that would define the importance of a small versus a large wetland as habitat specific to only wetland-associated birds. Size, however, is incorporated indirectly in the scaling of some of the other variables used. Thus, it is implicit that an AU with a diverse structure is large—small AUs simply cannot contain the same number of different structural elements as large ones.

## 6.12.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Wetland-associated Birds*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Breeding, feeding, and refuge for wetland-associated birds (applies to all variables)** | **Vbuffcond** | Descriptive table of conditions in buffer |
| | **Vsnags** | Categories of snags present |
| | **Vvegintersp** | Characteristics of interspersion between vegetation classes – diagrams |
| | **Vedgestruc** | Characteristics of AU edge |
| | **Vspechab** | Presence of special habitat features |
| | **Vpow** | % permanent open water |
| | **Sinverts** | Index for function (H.S. for Invertebrates) |
| | **Samphib** | Index for function (H.S. for Amphibians) |
| | **Sfish** | Index for higher of two: Anadromous or Resident Fish |
| ***Reducers*** | | |
| **Canopy closed** | **V%closure** | % canopy closure over AU |
| | **Index:** | $\frac{(\text{Vbuffcond} + \text{Vsnags} + \text{Vvegintersp} + \text{Vspechab} + \text{Vpow} + \text{Vedgestruc} + \text{Sinverts} + \text{Samphib} + \text{Sfish}) \times (\text{V\%closure})}{\text{Score from reference standard site}}$ |

## 6.12.4 Description and Scaling of Variables

$V_{buffcond}$ – Condition of buffer within 100 m of the edge of the AU, as rated by extent of undisturbed areas.

> **Rationale:** The condition of the AU buffer affects the ability of the AU to provide appropriate habitat for some guilds of birds (Zeigler 1992). Trees and shrubs provide screening for birds using the AU, as well as providing additional habitat in the buffer itself (Johnson and Jones 1977, Milligan 1985, and Zeigler 1992). The Assessment Teams judged, however, that good buffers are more important in small AUs because birds can use the interior of larger units and not be disturbed.

**Indicators:** This variable is assessed using the buffer categorization described in the data sheets (Part 2).

**Scaling:** If the AU is greater than 6 ha, the variable is scored a [1]. Smaller AUs with buffers that are vegetated with relatively undisturbed vegetation of at least 100 m around 95% of the AU (buffer category #5) are scored a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2,0.4, 0.6, and 0.8 respectively. **The size threshold is included so large wetlands are not penalized for having poor buffers**.

$V_{snags}$ – The number of different categories of snags, based on decomposition states, found in the AU.

**Rationale:** Snags are a source of cavities and perches for wetland-associated birds. Several species of birds utilize already existing cavities for nesting and/or refuge locations. The presence of cavities in standing trees can indicate the relative age or maturity of the trees within the AU, and therefore the structural complexity present. Dead wood attracts invertebrates and other organisms of decay, which in turn provide a food source for many species of birds (Davis et al. 1983).

**Indicators:** The number and size of cavities in an AU cannot be measured directly because they may be difficult to count and measure. Eight different categories of snags representing different levels of decay are used as the indicator for the different potential sizes of cavities. It is assumed that cavities will form or be excavated if dead branches or trunks are present.

**Scaling:** If a depressional outflow AU has 6 or more of the 8 categories of snags present it scored a [1]. Fewer categories are scaled as proportional to 6 (i.e. # of categories/6).

$V_{vegintersp}$ – The relative interspersion between Cowardin vegetation classes (Cowardin et al. 1979).

**Rationale:** Vegetation interspersion is the relative position of plant types to one another. As an example, an AU may have an emergent marsh of cattails; a nearby shrub-swamp of willows; and an adjacent area of alder swamp. This AU contains three Cowardin habitat classes: emergent, shrub, and forest. For some bird species, this is irrelevant, as many species are single habitat type users. Other species, though, may require several habitat types to being close proximity to aid their movements from one type to another (Gibbs 1991, Hunter 1996).

**Indicators:** The amount of interspersion between vegetation classes is assessed using diagrams developed from those found in the Washington State Rating System (WDOE 1993).

**Scaling:** AUs with more interspersion between vegetation classes score higher than those with fewer. The method has four categories of interspersion (none, low,

moderate, high) and these are used as the basis for developing a scaled score. A high level of interspersion is scored a 1, a moderate a 0.67, a low = 0.33, and none = 0.

$V_{edgestruc}$ – The vertical structure and linear characteristics of the AU edge.

**Rationale:** The configuration (e.g., length of shoreline in relation to area) and differences in vegetation strata along the edge of the AU are important habitat characteristics for many species of wetland-associated birds. Additional habitat exists within vegetated lobes and scalloped edges of AUs with a differences in edge strata and the shape of the AU edge.

For example, a simple AU may be a nearly circular pond with a fringing emergent marsh composed of cattails, which adjoin immediately to an upland of grazed pasture. The edge of the AU in this case is characterized as having low structural complexity (lack of shrubs and trees), and low linear complexity (as the edge is nearly circular, with no embayments or peninsulas). In contrast, a more complex AU may adjoin with an upland composed of trees and shrubs, adding to the structural complexity, and may be irregular along the edge, with many twists and turns, resulting in enclosed bays and jutting peninsulas. Further, embayments and peninsulas provide "micro-habitats" for certain species that require hiding cover, or "feel" more secure within a more enclosed system (USDI 1978, Verner et al. 1986, and WDOE 1993).

**Indicators:** The structure of the AU/upland edge is assessed by using a descriptive key that groups the edges and vertical structure along the edge into "high" structural complexity, medium, low, and none.

**Scaling:** AUs with a high structural complexity at the edge are scored a [1]; moderate = 0.67, low = 0.33, and none = 0.

$V_{spechab}$ – Special habitat features that are needed or used by wetland-associated birds. Five different habitat characteristics are combined in one variable. These are:

- the AU is within 8 km (5 mi) of a brackish or salt water estuary;
- the AU is within 1.6 km (1 mi) of a lake larger than 8 ha (20 acres);
- the AU is within 5 km (3 mi) or an open field greater than 16 ha (40 acres);
- the AU has upland islands of at leas 10 square meters (108 square feet) surrounded by open water (the island should have enough vegetation to provide cover for nesting wetland-associated birds); and
- the AU has unvegetated mudflats.

**Rationale:** The suitability of an AU as habitat for wetland-associated birds is increased by a number of special conditions. Specifically, the proximity of an AU to open water or large fields increases its utility to migrant and wintering waterfowl. If there is strong connectivity between relatively undisturbed aquatic areas the

suitability as habitat is higher (Gibbs et al. 1991, Verner et al. 1986). In addition, islands surrounded by open water provide a protected nesting area for ducks if they have adequate cover. Mudflats are an important feeding area for migrating birds.

**Indicators:** No indicators are needed for this variable because the presence of the special habitat features can be determined on site, from maps, or aerial photos.

**Scaling:** If an AU has 2 or more of the 5 habitat features it is scored a [1]. AUs with one habitat feature score a [0.5] for the variable, and those with none score a [0].

$V_{pow}$ – The percent area of the AU that is covered by permanent open water.

**Rationale:** Permanent open water provides refuge for many species of waterfowl. The presence of open water allows for the establishment of aquatic vegetation beds, which also provides food for different species of waterfowl.

In addition, open water of varying depths provides greater diversity of foraging habitat for a greater variety of water birds (USDI 1978). Shallow water areas (less than 20 cm deep) provide habitat for rails and teal. The permanent open water should be present throughout the breeding season for maximum functional benefit (Eddelman et al. 1988). To simplify the models the Assessment Teams decided that the variable "permanent open water" is more appropriate than trying to determine whether the water is open during the breeding season. It is understood that some AUs may have open water during the breeding season, but then completely dry up in the late summer. It is too difficult however to establish the presence of open water only during the breeding season.

The extent of the permanent open water required for different scaled scores is based on an educated guess by the Assessment Team, reflecting the need to provide a rapid method. Areas of open water that are smaller than .1 hectare (1/4 acre), or less than 10% of an AU (if it is < 1 hectare), are difficult to determine from aerial photos.

**Indicators:** The extent of permanent open water in a AU can be easily determined during the dry summer months and no indicator is needed. There is a problem, however, in establishing the size during the wet season when the AU is flooded to its seasonal levels. The indicators that have been suggested to establish the extent of permanent inundation are the edge of emergent vegetation in the deeper portions of an AU, or the presence of aquatic bed vegetation such as *Nuphar spp*.

**Scaling:** AUs with 30%, or more, of their area covered in permanent open water are scored a [1] for this variable. AUs with a smaller area are scaled proportionally (%open water/30).

$S_{inverts}$ – The habitat suitability index from the "Invertebrate" function.

**Rationale:** The index is used to represent the availability of invertebrates as prey for birds.

**Indicators:** No indicators are needed. The variable is an index from another function.

**Scaling:** The index is already scaled and is re-normalized to 0 - 1.

$S_{amphib}$ – Habitat suitability index for the "amphibian" function.

**Rationale:** The index is used to represent the availability of amphibians as prey for birds.

**Indicators:** No indicators are needed. The variable is an index from another function.

**Scaling:** The index is scaled and re-normalized to 0 -1.

$S_{fish}$ – Habitat suitability index for the "fish" function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two scores is used in this model.

**Rationale**: The index is used to represent the availability of fish as prey for birds.

**Indicators:** No indicators are needed. The variable is an index from another function.

**Scaling:** The index is scaled and re-normalized to 0 -1.

$V_{canopyclos}$ – The percent of the AU with a canopy closure of woody vegetation in the AU that is >75%. **This variable reduces the suitability of an AU as bird habitat as it discourages access by certain wetland-associated birds such as herons.**

**Rationale:** A full canopy can limit access to any water in the AU because birds have difficulty flying in and out. This may be best illustrated by great blue herons *(Ardea herodias)*, which will be reluctant to fly down to a body of water if the tree canopy above is totally closed because rapid escape may be difficult or impossible (USDI 1978).

**Indicators:** No indicators are needed for this variable because the percent canopy closure can be estimated during the site visit or from aerial photos.

**Scaling:** AUs with a canopy closure greater than 70% have their suitability index reduced by a factor of 0.7.

## 6.12.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Wetland-associated Birds*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vbuffcond** | *Highest:* | Buffer category of 5 or AU > 6ha | If D1 > = 6 **or** If D42 = 5, enter "1" | |
| | *High:* | Buffer category of 4 | If D1 < 6 **and** D42 = 4, enter "0.8" | |
| | *Moderate:* | Buffer category of 3 | If D1 < 6 **and** D42 = 3, enter "0.6" | |
| | *Medium Low:* | Buffer category of 2 | If D1 < 6 **and** D42 = 2, enter "0.4" | |
| | *Low:* | Buffer category of 1 | If D1 < 6 **and** D42 = 1, enter "0.2" | |
| | *Lowest:* | Buffer category of 0 | If D1 < 6 **and** If D42 = 0, enter "0" | |
| **Vsnags** | *Highest:* | At least 6 categories of snags | If D31 > = 6, enter "1" | |
| | *Lowest* | No snags present | If D31 = 0, enter "0" | |
| | *Calculation:* | Scaled as # categories/6 | Enter result of calculation | |
| | If D31 < 6 calculate D31/6 to get result | | | |
| **Vvegintersp** | *Highest:* | High interspersion | If D39 = 3, enter "1" | |
| | *Moderate:* | Moderate interspersion | If D39 = 2, enter "0.67" | |
| | *Low:* | Low interspersion | If D39 = 1, enter "0.33" | |
| | *Lowest:* | No interspersion (1 class only) | If D39 = 0, enter "0" | |
| **Vedgestruc** | *Highest:* | High structure at edge of AU | If D41 = 3, enter "1" | |
| | *Moderate:* | Moderate structure | If D41 = 2, enter "0.67" | |
| | *Low:* | Low structure | If D41 = 1, enter "0.33" | |
| | *Lowest:* | No structure | If D41 = 0, enter "0" | |
| **Vspechab** | *High:* | AU has > = 2 of 5 special habitat features | If sum (D8.5 + D27 + D28 + D29 + D33) > = 2, enter "1" | |
| | *Moderate:* | AU has 1 of 5 special habitat features | If sum (D8.5 + D27 + D28 + D29 + D33) = 1, enter "0.5" | |
| | *Lowest:* | AU has no special habitat features | If sum (D8.5 + D27 + D28 + D29 + D33) = 0, enter "0" | |
| **Vpow** | *Highest:* | AU has > = 30% perm. open water | If D8.3 > = 30, enter "1" | |
| | *Lowest:* | AU has no permanent open water | If D8.3 = 0, enter "0" | |
| | *Calculation:* | Scaled as % open water/30 | Enter result of calculation | |
| | If D8.3 < 30 calculate D8.3/30 to get result. | | | |
| **Sinverts** | *Scaled score:* | Index for Invertebrates | Use (index of function)/10 | |
| **Samphib** | *Scaled score:* | Index for Amphibians | Use (index of function)/10 | |
| **Sfish** | *Scaled score:* | Index for Fish | Use higher of 2: (Anad. Fish/10) or (Res. Fish/10) | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **V%closure** | Canopy closure > 70% | | If D17 > 70, enter "0.7" | |
| | Canopy closure < = 70% | | If D17 < = 70, enter "1" | |
| | | | **Score for Reducer** | |
| ***Index for Habitat Suitability for Wetland-associated Birds = Total for variables x reducer x 1.20 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.13 Habitat Suitability for Wetland-Associated Mammals — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.13.1 Definition and Description of Function

**Habitat Suitability for Wetland-associated Mammals is defined as wetland features and characteristics that support life requirements of four aquatic or semi-aquatic mammals.** Mammalian species whose habitat requirements were modeled are the beaver (*Castor canadensis*), muskrat (*Ondatra zibethica*), river otter (*Lutra canadensis*), and mink (*Mustela vison*).

The model for this function is based on general habitat requirements for each of the four wetland-associated mammals. The model reflects the suitability of an AU to support mammal richness rather than individual species abundance. Habitat considerations in the model are restricted to the condition of the wetland buffer, and characteristics that can be found within the AU itself. It is assumed that wetlands that provide habitat for all four of the wetland-associated mammal species function more effectively than ones that meets the habitat needs of fewer species.

Wetlands that are found within urban or residential areas are modeled as having a reduced level of performance. Adjacent areas that are developed provide an avenue for humans, cats, dogs, and other domestic animals to harass mammal populations.

The SWTC and Assessment Teams decided to focus the model specifically on the aquatic fur-bearing mammals because these are wetland-associated species that are important to society, and they represent different types of mammals that use wetlands. Many terrestrial mammals will use wetlands, if they are available, to meet some of their life maintenance requirements. These species, however, do not need wetlands. It would have been too difficult to develop a mammal model that incorporates habitat features for all mammals using wetlands. Such models would have had to incorporate too much information about the surroundings uplands and expanded the scope of the assessment methods to the extent that they would no longer be considered “rapid.”

**If the AU is a habitat type that appears to be critical to a specific species, another method is needed in order to determine the habitat suitability of that AU** (e.g. USFWS Habitat Evaluation Procedures (HEP), USFWS 1981).

## 6.13.2 Assessing this Function for Depressional Outflow Wetlands

The suitability of wetlands in the depressional outflow subclass as mammal habitat is modeled by buffer conditions, water depths, presence of open water, connectivity of the site to other suitable habitat, interspersion of vegetation and open water, and the presence of characteristics important to each species modeled. The index for the fish habitat function is added as a variable to reflect the importance fish have in the diet of otters and, to a lesser degree, mink. Reduction in suitability is modeled based on the percentage of the surrounding landscape, within 1 km, that is developed ($V_{upcover}$).

## 6.13.3 Model at a Glance

### *Depressional Outflow — Habitat Suitability for Wetland-associated Mammals*

| Characteristics | Variables | Measures or Indicators |
|---|---|---|
| **Breeding, feeding, and refuge for beaver, mink, otter, and muskrat (applies to all variables)** | **Vbuffcond** | Descriptive table of buffer conditions |
| | **Vwaterdepth** | Number of water depth categories present |
| | **Vcorridor** | Categorical rating of corridor |
| | **Vbrowse** | Area of woody vegetation for beaver |
| | **Vemergent2** | At least .25 ha of emergent vegetation |
| | **Vwintersp2** | Diagrams of interspersion if AU |
| | **Vow** | % of AU in open water and aquatic bed |
| | **Vbank** | Banks present of fine material |
| | **Vpermflow** | Au has channel with permanent flowing water |
| | **Sfish** | Index for higher of two: Anadromous or Resident Fish |
| ***Reducers*** | | |
| **Development** | **Vupcover** | Land uses within 1 km of AU |

**Index:**

$$\frac{(Vbuffcond + Vwaterdepth + Vcorridor + Vbrowse + Vemergent2 + Vwintersp2 + Vow + Vbank + Vpermflow + Sfish) \times (Vupcover)}{\text{Score from reference standard site}}$$

## 6.13.4 Description and Scaling of Variables

***$V_{buffcond}$*** – Land-use patterns within 100 m of the edge of the AU.

**Rationale:** A relatively undisturbed buffer serves to minimize disturbance (Burgess 1978, Allen and Hoffman 1984), provide habitat for prey species and food sources for mammals (Brenner 1962, Dunstone 1978, Allen 1983), cover from predators

(Melquist et al. 1981), and den sites for resting and reproduction for wetland-associated mammals (Allen 1983). Both live standing vegetation and dead decaying plant material are important components of good buffer conditions.

**Indicators:** This variable is assessed using the buffer categorization described in the data sheets in Part 2.

**Scaling:** AUs with buffers that are vegetated with relatively undisturbed plant communities of at least 100 m around 95% of the AU (buffer category #5) are scaled a [1]. The categories between 0-5 are scaled proportionally as 0, 0.2, 0.4, 0.6, and 0.8 respectively.

$V_{waterdepth}$ – The varying depths of water present in a AU during the dry season.

**Rationale:** Adequate water depth is an essential criterion for beaver and muskrat. These aquatic rodents are vulnerable to predation when water depths are shallow. Declines in water level expose lodge or bank burrow entrances to predators. Further, permanent water conditions increase the potential for a resident fish population which serves as a stable food supply for mink and river otters.

**Indicators:** The variable is scored using a condensed form of the depth classes developed for WET habitat assessments (Adamus et al. 1987). These are 0-20 cm, 20-100 cm, and >100 cm.

**Scaling:** AUs with water depths greater than 1 m are scored a [1] for this variable. Those with water depths between 1-100 cm are scored a [0.5]; those with depths between 1-20 cm are scored a [0.3]; and those with water depths less than 1 cm, or no water, are scored a [0].

$V_{corridor}$ – The type of vegetated connections present between the AU and other nearby habitat areas.

**Rationale:** This variable characterizes the connection of the AU to other relatively undisturbed areas capable of providing mammal habitat. Adolescent mammals born and raised within an AU use natural riparian corridors to move from their natal area to unoccupied habitat. Riparian corridors that have relatively undisturbed vegetation cover ensure that dispersing animals are capable of reaching and populating or repopulating unoccupied habitat. Further, mink and river otter have a number of core activity areas within a larger home range. A loss of adequate travel corridors between core activity areas has potential to restrict or eliminate mammal use if the area of suitable habitat drops below required levels.

**Indicators:** This variable is determined using a modified corridor rating system developed in the Washington State Rating System (WDOE 1993.) Corridors are rated on a scale of 0-3 (Part 2).

**Scaling:** AUs rating a 3 for their corridor connections are scored a [1] for this variable. Those with a rating of 2 are scored [0.67]; those with a rating of 1 are scored [0.33]; and those with a rating of 0 are scored [0].

$V_{browse}$ – This variable characterizes the presence of woody deciduous plants that beaver prefer as a primary food source.

**Rationale:** Woody deciduous species commonly used by beaver include willow (*Salix spp*.), aspen (*Populus tremuloides*) cottonwood (*Populus spp.*) (Denney 1952) Trees and shrubs closest to the AU edge are generally used first (Brenner 1962). In a California study, 90% of all cutting of woody material was within 100 feet of the AU edge (Hall 1970). Red alder (*Alnus rubra*) is also a common food source in the lowlands of western Washington.

**Indicators:** This variable is determined by estimating the amount of alder, willow, aspen and cottonwood within the AU, and/or within a 100 m buffer around the AU.

**Scaling:** This is an "on/off" variable. AUs with more than 1 hectare (2.5 acres) of alder, willow, aspen, or cottonwood in them or in their buffer will score a [1]. AUs with less will score a [0]. The size is threshold based on the data collected during the field calibrations and the judgements of the Assessment Teams regarding suitable beaver habitat. Literature for areas outside the Pacific Northwest suggests that much larger areas are needed to sustain a beaver family (Denney 1952), but the Assessment Teams judged these numbers were not appropriate.

$V_{emergent2}$ – Emergent plants are present in the AU that cover more than 0.4 ha (1 acre).

**Rationale:** Muskrat and beaver use persistent emergent cover for security and feeding (Errington 1963, Jenkins 1981). Muskrats also use this vegetation as material for lodge construction (Wilner et al. 1980). Allen (1983) believes that beaver prefer herbaceous vegetation over woody vegetation during all seasons, if available.

**Indicators:** This variable is estimated using the Cowardin vegetation class "emergent" as an indicator of the amount of persistent emergent vegetation used by the mammals.

**Scaling:** This is an "on/off" variable. AUs with an area of emergent vegetation that is larger than 0.4 ha score a [1] for the variable. AUs that do not meet this criterion score a [0]. AUs need to have a minimum of 0.4 ha in emergent cover to score for this variable. Muskrats appear to prefer the greatest of aerial coverage in emergent cover. The size threshold is based on the judgement of the Assessment Teams. 0.4 ha is considered to be the minimum necessary to maintain a family of muskrats or beaver.

$V_{wintersp2}$ – The amount of interspersion present between vegetated areas of the AU and permanent open water if the AU is at least 0.4 ha (1 acre) in size.

**Rationale:** For muskrat and beaver, interspersion of vegetation and open water equates to the ease of access to feeding and lodge building sites, and food availability for mink and otter. A diverse mixture of open water and emergent vegetation distributed in a mosaic fashion is assumed to support the largest numbers of muskrats. Beaver colony territories are distinct and non-overlapping (Bradt 1938). High interspersion rates which optimize prey levels (i.e., muskrats, water birds, fish) optimize food abundance and availability for mink and river otter. King (1983) reported that habitat quality influences the distribution, density, and reliability of prey, which, in turn, directly affect mink population density and distribution. Food abundance and availability appeared to have the greatest influence on habitat use by river otter in Idaho (Melquist and Hornocker 1983). Classic muskrat studies by Dozier (1953) and Errington (1937) indicate that optimum muskrat habitat has approximately 66 to 80% of the AU in emergent vegetation with the remainder in open water.

A size threshold is included in this variable because the Assessment Teams assumed that very small AUs are not suitable habitat even if they have good interspersion between vegetated parts and the open water.

**Indicators:** The interspersion in an AU is assessed using a series of diagrams that rates the interspersion as high, moderate, low, and none. The size of the AU is estimated from maps or aerial photos.

**Scaling:** If an AU is less than 0.4 ha in size it is scored a [0] for this variable. If it is larger, then AUs with high interspersion are scored a [1]; those with moderate are scored [0.67]; those with low = [0.33], and those with no interspersion (i.e. no permanent open water) = [0].

***$V_{ow}$*** – The percentage of the AU that has open water. This includes the areas of permanent open water and that can be classified as "aquatic bed" vegetation using the Cowardin (1979) classification.

**Rationale:** For muskrat and beaver open water is needed for feeding and lodge building sites, and access to food for mink and otter. Beaver colony territories are distinct and non-overlapping (Bradt 1938). Classic muskrat studies by Dozier (1953) and Errington (1963) indicate that optimum muskrat habitat has approximately 66 to 80% of the AU in emergent vegetation with the remainder in open water. Beaver need an unknown, but lesser proportion, of open water.

A size threshold of 0.1 ha is included in this variable because the Assessment Teams assumed that very small areas of open water are not suitable for the mammals.

**Indicators:** The size of the area that is in permanent open water and aquatic bed vegetation is estimated during the site visit and from maps or aerial photos.

**Scaling:** If the area of permanent open water and aquatic bed vegetation is less than 0.1 ha (1/4 acre) the variable is scored a [0]. If it is larger, then AUs with at least

30% of their area in open water are scored a [1]; those with less are scored proportionally (% open water/30).

$V_{bank}$ – This variable identifies the presence of slope and soil conditions that are suitable for muskrat, otter, and beaver bank burrows.

**Rationale:** When studying bank burrowing muskrats, Earhart (1969) found that a minimum bank slope of 10° was required before burrows were consistently observed regardless of soil type. Gilfillan (1947) considered 30° or more slope as optimum conditions for muskrat bank burrows when the bank height exceeds 0.5 meters (1.6 feet). Muskrat and beaver are capable of constructing bank burrows in a wide range of soil conditions. Muskrat studies by Errington (1937) and Earhart (1969) note that clay soils provide the most suitable substrate for burrow excavation, but even soils with high sand content may provide suitable burrowing sites if dense vegetation exists (Errington 1937). Beaver are capable of constructing lodges against a bank or over the entrance of a bank burrow (Allen 1983) and appear to have less specific slope and soil type limitations for bank burrows.

**Indicators:** No indicators are needed to assess this variable. The presence of banks can be determined during the site visit. A steep bank that can be used for denning must be: 1) > 30 degrees; 2) more than 0.5 m (2 ft.) high (vertical); and 3) of fine material such as sand, silt, or clay.

**Scaling:** This is an "on/off" variable. AUs meeting the criteria for banks are scored a [1] for the variable. Those with no banks are scored a [0].

$V_{permflow}$ – There are channels or streams present in the AU that have permanently flowing water.

**Rationale:** This variable is included in the model because flowing water is an important characteristic for otters. In addition, the presence of permanent flowing water is an indicator that a surface water connection exists that will facilitate the dispersal of wetland-associated mammals living in the AU.

**Indicators:** No indicators are needed for this variable in the summer because the presence of flow in a channel can be established directly in the summer during the dry season. Indicators for the presence of permanent channel flow in the winter, during the wet season, may be more difficult to establish. Users may have to rely on aerial photographs (usually taken in the summer) or other sources of information to determine if the flows in a channel are permanent.

**Scaling:** This is an "on/off" variable. An AU scores a [1] if permanent channel flow is present, and a [0] if it is not.

$S_{fish}$ – Habitat suitability index from the "fish" function. The assessment methods have two functions to characterize habitat suitability for fish (anadromous and resident). The higher of the two indices is used in this model.

**Rationale:** This variable is specific to river otter and to a lesser extent for mink. Melquist and Hornocker (1983) found fish to be the most important prey of otters studied over a four year period. Annually, fish occurring in 93-100% of the 1,902 scats analyzed this Idaho study. Mink exhibit considerable variation in their diet, according to season, prey availability, and habitat type (Wise et al. 1981, Linscombe et al. 1982, and Smith and McDaniel 1982). In an Idaho study, fish occurred more frequently (59%) in the diet of mink than any other prey category. However, Eberhardt and Sargeant (1977) reported that mink in North Dakota AUs, which do not support fish, preyed heavily on birds and mammals.

**Indicators:** No indicators are needed. The variable is an index from another function.

**Scaling:** The index is scaled between 0 - 10. The higher of the two indices for fish (resident or anadromous) is used to characterize the potential for fish as a food source.

$V_{upcover}$ – The types of land uses within 1 km of the estimated AU edge. **This variable is used to indicate potential reductions in the level of performance for the function.**

**Rationale:** Human alteration to the AU buffer has direct impacts to the AUs habitat suitability for mammals. These alterations also include the associated negative impacts from harassment by humans and domestic animals. Loss or alteration of the natural areas around an AU has direct adverse impacts to feeding, loafing, and breeding habitat for mink, river otter, and muskrat and beaver. These mammals are vulnerable to harassment and predation by domestic pets (Errington 1937, Slough and Sadleir 1977, Burgess 1978, and Melquist and Hornocker 1983). This variable is in contrast to $V_{buffcond}$, which gives a positive value rating to buffers in good condition. Two variables were needed to represent upland conditions because $V_{buffcond}$ does not address the issue of disturbances to mammals from specific adjacent land uses.

**Indicators**: No indicators are needed to assess this variable. The amount and type of land uses within 1 km of the AU can be established from aerial photographs or site visits.

**Scaling:** AUs with at least 15% of their surrounding land in urban land uses, or at least 20% high density residential use, or at least 40% low density residential land use, have their index for the function reduced by a factor of 0.7.

## 6.13.5 Calculation of Habitat Suitability

### *Depressional Outflow – Habitat Suitability for Wetland-associated Mammals*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vbuffcond** | *Highest:* | Buffer category of 5 | If D42 = 5, enter "1" | |
| | *High:* | Buffer category of 4 | If D42 = 4, enter "0.8" | |
| | *Moderate:* | Buffer category of 3 | If D42 = 3, enter "0.6" | |
| | *Medium Low:* | Buffer category of 2 | If D42 = 2, enter "0.4" | |
| | *Low:* | Buffer category of 1 | If D42 = 1, enter "0.2" | |
| | *Lowest:* | Buffer category of 0 | If D42 = 0, enter "0" | |
| **Vwaterdepth** | *Highest:* | Water depths >1 m present | If D12.3 = 1, enter "1" | |
| | *Moderate:* | Water depths between 1-100 cm present | If D12.1 = 1 **and** D12.2 = 1, enter "0.5" | |
| | *Low:* | Water depths between 1-20 cm present | If D12.1 = 1, enter "0.3" | |
| | *Lowest:* | No surface water present | If all D10 are 0, enter "0" | |
| **Vcorridor** | *Highest:* | Corridor rating is 3 | If D43 = 3, enter "1" | |
| | *Moderate:* | Corridor rating is 2 | If D43 = 2, enter "0.67" | |
| | *Low:* | Corridor rating is 1 | If D43 = 1, enter "0.33" | |
| | *Lowest:* | Corridor rating is 0 | If D43= 0, enter "0" | |
| **Vbrowse** | *Highest:* | AU has more than 1 hectare (2.5 acres) of preferred woody vegetation for beaver in and within 100 m of AU | If D30 =1, enter "1" | |
| | *Lowest:* | AU does not have the above | If D30 = 0, enter "0" | |
| **Vemergent2** | *Highest:* | AU has cover of emergents that is > = 0.4 ha | If (D1xD14.5)/100 > = 0.4, enter "1" | |
| | *Lowest:* | AU has no cover of emergents or emergents < 0.4 ha | If (D1xD14.5)/100 < 0.4, enter "0" | |
| **Vwintersp2** | *Highest:* | If AU > 0.4 ha and interspersion between vegetation and open water is high | If D1 > = 0.4 and D38 = 3, enter "1" | |
| | *Moderate:* | If AU > 0.4 ha and interspersion is moderate | If D1 > = 0.4 and D38 = 2, enter "0.67" | |
| | *Low:* | If AU > 0.4 ha and interspersion is low | If D1 > = 0.4 and D38 = 1, enter "0.33" | |
| | *Lowest:* | AU < 0.4 ha **OR** no interspersion | If D38 = 0 OR D1 < 0.4, enter "0" | |
| **Vow** | *Highest:* | If Open Water (OW) > 0.1 ha and OW at least 30% of AU | If (D1 x D8.3) / 100 > 0.1 and D8.3 > = 30, enter "1" | |
| | *High:* | If OW > 0.1 ha and OW 10 - 29% of AU | If (D1xD8.3) / 100 > 0.1 and 10 < = D8.3 < 30, enter "0.8" | |
| | *Lowest:* | If OW < = 0.1 ha | If (D1xD8.3)/100 < 0.1, enter "0" | |
| | *Calculation:* | If OW > 0.1 ha scaled as % OW x 0.08 | Enter result of calculation | |
| | If (D1xD8.3)/100 > 0.1 and D8.3 < 10 calculate as D8.3x0.08 to get result | | | |

**Table continued on next page**

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vbank** | *Highest:* | Steep banks suitable for denning (>45 degree slope, fine material, >10 m long) | If D37 = 1, enter "1" | |
| | *Lowest:* | No steep banks present | If D37 = 0, enter "0" | |
| **Vpermflow** | *Highest:* | AU has channel with perm. water | If D4.1 = 1, enter "1" | |
| | *Lowest:* | No channel present | If D4.1 = 0, enter "0" | |
| **Sfish** | *Score is scaled* | Score for Habitat Suitability for Fish | Use higher of two indices: (Anadromous Fish)/10 or or (Resident Fish)/10 | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vupcover** | Land use within 1 km - > = 15% urban commercial, or > = 20% high density residential; or > = 40% low density residential | | If D3.4 > = 15 OR D3.5 > = 20 OR D3.6 > = 40, enter "0.7" | |
| | Land use criteria described above not met | | If above conditions not met, enter "1" | |
| | | | **Score for Reducer** | |
| ***Index for Habitat Suitability for Wetland-associated Mammals = Total for variables x reducer x 1.06 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.14 Native Plant Richness — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.14.1 Definition and Description of Function

**Native Plant Richness is defined as the degree to which a wetland provides a habitat for a relatively high number of native plant species.**

An AU is judged to provide habitat for native plants if it contains a diverse group of native plants. This function is the only one for which an actual estimate of performance can be made because the number of plant species can be estimated during a single site visit. Many native plants are persistent and can be documented in a rapid assessment method. The assessment of species richness during the site visit is used as a surrogate for the total richness. If an AU contains a diverse and mature assemblage of native plants it is assumed to perform the function at a high level. Those lacking diverse native plant assemblages and structure are assumed to perform the function at a lower level.

**Note:** The assumption is valid only if the AU has **not** been recently cleared or altered. If you find the AU has been recently cleared or cut, the index from the model will not provide an adequate assessment of the function.

The Assessment Teams considered using the list of native plant communities developed by Kunze (1994) for western Washington as the basis for the assessment. Attempts to identify the specific plant assemblages by name, however, proved to be too difficult for most investigators not specifically trained as botanists or plant ecologists.

The Assessment Teams also judged that AUs where one or more of the dominant species is non-native have lost some of their ability to support native plant assemblages. Non-native plants that become dominant tend to form monotypic stands that exclude native. **The percent of the AU dominated, or co-dominated, by non-native species is modeled as a reducer of habitat**.

**Note:** A variable representing the population of invasive **native** species was considered as a reducer. The Assessment Teams, however, decided that the impact of invasive native species was to some degree addressed in other variables ($V_{prichness}$, $V_{assoc}$, and $V_{strata}$). The presence of a native invasive species would be reflected in lower scores for those variables. The Assessment Teams judged the presence of non-native species as more detrimental to the performance of this function, and an element of the wetland ecosystem in need of highlighting.

## 6.14.2 Assessing this Function for Depressional Outflow Wetlands

Native Plant Richness in the depressional outflow subclass is assessed by the richness of the existing plant species and assemblages. Variables include the number of plant assemblages in the AU, the richness of plant species, and structural elements such as number of strata and the presence of mature trees. The presence of sphagnum bogs in depressional wetlands is used as an indicator of a potentially very rich native species assemblage that may not be captured by the other variables.

## 6.14.3 Model at a Glance

### *Depressional Outflow — Native Plant Richness*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Richness of native plant species and assemblages (applies to all variables)** | **Vstrata** | Number of strata present in any plant assemblage |
| | **Vassemb** | Number of plant assemblages |
| | **Vmature** | Presence/absence of mature trees |
| | **Vnplants** | Number of native plant species |
| | **Vbogs** | % of AU covered by sphagnum bog |
| ***Reducers*** | | |
| | **Vnonnat** | % of AU dominated by non-native plant species |
| **Index:** | | $\frac{(Vstrata + Vassemb + Vmature + Vnplants + Vbogs) \times (Vnonnat)}{\text{Score from reference standard site}}$ |

## 6.14.4 Description and Scaling of Variables

***$V_{strata}$*** – The maximum number of strata in any single plant assemblage. A plant assemblage can have up to 6 strata (layers: trees, shrub, low shrub, vine, herbaceous, moss). To count as a stratum, however, the plants of that stratum have to have 20% cover in the assemblage in which it is found.

> **Rationale:** Each stratum of a plant assemblage is composed of different plant species. AUs with more strata, therefore, have the potential to support more native plant species than ones with fewer. The number of strata is used as an indicator of plant richness that can be associated with each specific strata that may not be counted during the site visit. These include many mosses and other bryophytes that are not included in a species count.
>
> **Indicators:** No indicators are needed to assess this variable. The number of strata can be estimated directly at the site.

**Scaling:** AUs with 5 or more strata are scored a [1] for this variable. AUs with only one are scored a [0.2]. AUs with 2 - 4 strata are scaled proportionally as 0.4, 0.6, and 0.8 respectively. For this function, the vine stratum is not counted if it is dominated by non-native blackberries.

$V_{assemb}$ – The number of plant assemblages in the AU.

**Rationale:** Each plant assemblage represents a different group of plant species. Even if some plant species are the same between assemblages, the ecological relationships between the species within the assemblages are probably different, and represent potential differences in phenotypes. The number of assemblages, therefore, is one way to characterize the richness of plants in an AU. The procedures for collecting data described in Part 2 provide guidance on how to identify assemblages in the field.

**Indicators:** No indicators are needed to assess this variable. The number of assemblages can be determined in the field.

**Scaling:** Depressional outflow AUs with 10 or more plant assemblages are scored a [1]. AUs with fewer are scaled proportionally.

$V_{mature}$ – The AU has, or does not have, a stand of mature trees present.

**Rationale:** The model is giving a point for the presence of a stand of mature trees. A mature stand is used as a surrogate for stability, complexity and structure in plant assemblages that may not be captured by other variables. The presence of mature trees suggests the AU may contain native plant species that are intolerant of much disturbance and that might not be observed because of their scarcity.

**Indicators:** This variable is characterized by measuring the dbh (diameter at breast height) of the five largest trees of specific species (see Part 2 for list of species and size criteria). If the average diameter of the three largest of a given species exceed the diameters given in Part 2, the AU is considered to contain a stand of mature trees.

**Scaling:** This is an "on/off" variable. AUs with mature trees are scored a [1], those without are scored a [0].

$V_{nplants}$ – The number of native plant species present.

**Rationale:** The number of native plant species assessed during one site visit in an AU is one measure of how effective an AU is at providing a diverse habitat for native plants and maintaining regional plant biodiversity. It is not possible, however, to determine the total species richness in one visit and within a few hours. Some plants are annuals and grow for only a short time, others have a very limited distribution and may occupy a small and inconspicuous patch that is easily overlooked. For this reason the count of native species determined during the site visit is only an indicator of the actual number present.

**Indicators:** The indicator of overall native plant richness is the number of native species found during the site visit.

The Assessment Teams recognize that observations at a site made during the summer will usually result in a higher count of plant species than in the winter. We were unable to resolve this issue because most of our calibration occurred during the summer and fall. A different scaling may be developed for winter and summer if further data suggest that this is necessary.

**Scaling:** If the AU has 30 or more native species it is scored a [1]. AUs with a fewer number of native species are scaled proportionally ( # of native species/30).

$V_{bogs}$ – The percent area of the AU is covered by a sphagnum bog (defined as areas where sphagnum mosses represent more than 30% cover of the ground).

**Rationale:** Sphagnum bogs are often the habitat for many unique plant species (Mitch and Gosselink 1993). These plants are often small and hard to identify. Also sphagnum bogs often lack the physical structure of many other mature wetland plant communities. The presence of bogs is used as an indicator of a potentially very rich native species assemblage that may not be captured by the other variables.

**Indicators:** No indicators are needed for this variable since the % area of an AU covered by sphagnum bog can be determined directly.

**Scaling:** This is an "on/off" variable. AUs with 25% or more sphagnum bog are scored a [1]. Those with a bog cover <25% are scored a [0].

$V_{nonative}$ – The percent of the AU where non-native species are dominant or co-dominant (non-native species are listed in Part 2, Appendix L). **This is a variable of reduced performance.**

**Rationale:** The Assessment Teams judged that wetlands where one or more of the dominant species is non-native have lost some of their potential for maintaining native regional plant biodiversity. Non-native plants that become dominant tend to exclude many of the less common native plants.

**Indicators:** No indicator is needed for this variable. The areal extent of non-native species can be determined in the field.

**Scaling:** AUs in which non-native species extend over more than 75% of the AU have their index reduced by a factor of 0.5. Those with an extent of 50 – 75% are reduced by a factor of 0.7, and those with an extent of non-native between 25-49% are reduced by a factor of 0.9. AUs where non-native species are dominant or co-dominant on less than 25% of the AU do not have their index reduced.

## 6.14.5 Calculation of Index
## *Depressional Outflow – Native Plant Richness*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vstrata** | *Highest:* | 5 strata present (no blackberries) | If D21-D21.1 > = 5, enter "1" | |
| | *High:* | 4 strata present " | If D21-D21.1 = 4, enter "0.8" | |
| | *Moderate:* | 3 strata present " | If D21-D21.1 = 3, enter "0.6" | |
| | *Medium Low:* | 2 strata present " | If D21-D21.1 = 2, enter "0.4" | |
| | *Low:* | 1 stratum present " | If D21-D21.1 = 1, enter "0.2" | |
| | *Lowest:* | Only stratum = blackberries | If D21-D21.1 = 0, enter "0" | |
| **Vassemb** | *Highest:* | AU has at least 10 plant assemblages | If calculation > = 1, enter "1" | |
| | *Lowest:* | AU has 1 plant assemblage | If D20 = 1, enter "0.1" | |
| | *Calculation:* | Scaling based on the number of assemblages divided by 10 | Enter result of calculation | |
| | Calculate D20/10 to get result | | | |
| **Vmature** | *Highest:* | AU has mature trees present | If D22 = 1, enter "1" | |
| | *Lowest:* | AU has no mature trees present | If D22 = 0, enter "0" | |
| **Vnplants** | *Highest:* | Number of native plant species > = 30 | If calculation > = 1, enter "1" | |
| | *Lowest* | AU has 1 or less native species | If D19.1 < = 1, enter "0" | |
| | *Calculation:* | Scaled as # of native species/30 | Enter result of calculation | |
| | Calculate (D19.1)/30 to get result | | | |
| **Vbogs** | *Highest:* | AU is at least 25% bog | If D23.1 + D23.2 + D23.3 > = 1, enter "1" | |
| | *Lowest:* | AU is less than 25% bog | If D23.4 + D23.5 > = 1, enter "0" | |
| | | | **Total of Variable Scores:** | |
| *Reducer* | | | | |
| **Vnonnat** | >75% cover of non-native plants | | If D24.1 = 1, enter "0.5" | |
| | 50-75% cover of non-native plants | | If D24.2 = 1, enter "0.7" | |
| | 25 - 49% cover of non-native plants | | If D24.3 = 1, enter "0.9" | |
| | | | **Score for Reducer:** | |
| ***Index for Native Plant Richness = Total for variables x reducer x 2.04 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |

# 6.15 Potential for Primary Production and Organic Export — Depressional Outflow Wetlands

**Note**: Please read the introduction to the assessment models (Chapter 2) before using these models. It describes several basic assumptions used in modeling that will help you better understand how to use and apply the methods.

## 6.15.1 Definition and Description of Function

**The function of Primary Production and Organic Export is defined as wetland processes that result in the production of plant material and its subsequent export to surface waters.**

Wetlands are known for their high primary productivity (variously expressed as gm-Carbon/$m^2$ /year or as total biomass) and the subsequent export of organic matter to adjacent aquatic ecosystems (Mitch and Gosselink 1993). In some cases, wetlands may be highly productive, but most of the organic material produced is retained within the wetland where it originates (e.g. high salt marshes or coniferous forests). Alternatively, in some wetlands production may be lower, but most of it is exported (e.g. riverine marshes). **Performance of this function requires both that organic material is produced and a mechanism is available to move the organic matter to adjacent or contiguous aquatic ecosystems**. The exported organic matter provides an important source of food for most downstream aquatic ecosystems (Mitch and Gosselink 1993).

## 6.15.2 Assessing this Function for Depressional Outflow Wetlands

The potential of an AU in the depressional outflow subclass to produce and export organic matter is modeled as two separate processes: (1) production of organic materials, and (2) movement of organic material out of the AU.

Amount of production is most directly related to presence of plant cover ($V_{vegcover}$). Variables are then added to reflect type of vegetation ($V_{non\text{-}evergreen}$ *and* $V_{understory}$). The vegetation variables are not chosen to reflect higher rates of primary production, rather they reflect types of vegetation that decompose more readily. Although there seems to be a commonly held hypothesis that herbaceous vegetation is more productive than woody vegetation, the literature is inconclusive on this issue. For example, evergreen coniferous forests (e.g. hemlock) can be as productive as the most productive herbaceous sites (e.g. cattail marshes) (Franklin and Dyrness 1973, Mitch and Gosselink 1993). Other literature simply records high production for systems described as “marshes and swamps” without distinguishing based on vegetative cover type.

The principal reason for adding a variable to reflect vegetation type is to capture the variability in rate of decomposition of the organic matter produced, and, therefore, the ease of export. The model recognizes that herbaceous and deciduous plant material is easily decomposed and much of the above ground annual production is available for export as dissolved organic matter.

The equation is structured so that an AU receives a basic score based on the percent of the AU that is vegetated ($V_{vegcover}$). The score is increased if part of that total vegetation is either herbaceous, aquatic bed, or deciduous woody to reflect the less refractory nature of these vegetation types. The model assumes that non-deciduous (evergreen) coniferous needles are the most refractory and least usable by adjacent ecosystems (even toxic in some cases). Thus no additions to the score are made for presence of conifer cover. An additional variable is included to model the herbaceous understory that may be present in forested or scrub/shrub Cowardin vegetation classes, since the understory is an additional source of labile organic matter.

The second part of the model includes variables that model the ability of the wetland to move material to adjacent aquatic ecosystems. Depressional outflow AUs have a surface water outlet by definition, and therefore can export the organic matter produced. An estimate of how much of the organic matter produced within the AU can be exported is provided by the variable ($V_{effectarea1}$) that reflects the area of the AU that is seasonally inundated. Organic matter can be exported only where surface water is present that can carry the material away.

One indication that the export of organic matter is not very efficient in an AU is the presence of organics oils, and a variable is included to reflect this ($V_{org}$). AUs with less area covered by organic soils are judged to be better at exporting than those with more.

Some depressional wetlands such as sphagnum bogs are known to have low productivity (Mitch and Gosselink 1993). The presence of a sphagnum bog is used as an indication that the area has a low rate of primary production, regardless of its other characteristics. **The variable $V_{bogs}$ is used to reduce the index of performance for the function.**

## 6.15.3 Model at a Glance

### *Depressional Outflow — Potential for Primary Production and Organic Export*

| Process | Variables | Measures or Indicators |
|---|---|---|
| **Primary Production** | **Vvegcover** | % of AU with vegetation cover |
| **Primary Production** | **Vnon-evergreen** | % area of all non-evergreen vegetation |
| **Primary Production** | **Vunderstory** | % area of herbaceous understory in AU |
| **Export** | **Vorg** | Extent of organic soils in AU |
| **Export** | **Veffectarea1** | % of AU that is seasonally inundated |
| ***Reducers*** | | |
| **Bogs** | **Vbogs** | % of AU covered by a sphagnum bog |
| | **Index:** | $\frac{(\text{Vvegcover} + \text{Vnon-evergreen} + \text{Vunderstory}) \times (\text{Vorg} + \text{Veffectarea1}) \times \text{Vbogs}}{\text{Score from reference standard site}}$ |

## 6.15.4 Description and Scaling of Variables

$V_{vegcover}$ – The percent of the total area of the AU is covered by plants.

**Rationale:** The assumption made by the Assessment Teams is that the average amount of primary production per acre in an AU is most directly related to the amount of its total plant cover.

**Indicators:** No indicators are needed for this variable. The areal extent of vegetation can be determined from field visits or aerial photographs.

**Scaling:** An AU that is completely vegetated (100% of AU) is scored a [1]. AUs where the vegetated areas is less, because of open water or mudflats, are scored proportionally (%area/100).

$V_{non\text{-}evergreen}$ – The percent of the AU that is dominated by deciduous (non-evergreen) vegetation (emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed).

**Rationale:** This variable is chosen to reflect the types of vegetation that decompose more readily and are, therefore, more exportable.

**Indicators:** The indicator for this variable is the area that would be classified as emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed using the Cowardin classification (Cowardin et al. 1979).

**Scaling:** An AU that is completely vegetated with emergent, deciduous forest, deciduous scrub/shrub, and aquatic bed (100% of area when all are added together) is scored a [1]. AUs where the total area of these vegetation classes is lower are scored proportionally (total %area/100).

$V_{understory}$ – Percent of the AU where an herbaceous understory provides at least a 20% cover under areas of forest or scrub/shrub vegetation classes.

**Rationale:** An additional variable is included to model the herbaceous understory that may be present in a forested or scrub shrub Cowardin vegetation class. The understory is an additional source of labile organic matter that is not captured in the other vegetation variables.

**Indicators:** No indicators are needed. The % areal extent of herbaceous understory is estimated during the field visit.

**Scaling:** If 100% of the AU has an herbaceous understory it is scored a [1]. AUs where understory is less are scored proportionally (% area/100).

$V_{effectarea1}$ – The areal extent of seasonal inundation in the AU. This is also the area of the AU from which organic matter can be exported by the surface waters moving through the AU.

**Rationale**: To export organic matter, an AU needs to have a mechanism for collecting the material and bringing it to the outlet. Surface inundation provides such a mechanism. The presence of surface water can carry dissolved organic matter, and particulate organic matter, to the outlet. Areas in an AU that don't usually have any surface inundation have little chance to export their production.

**Indicators:** In depressional outflow wetlands the effective area of export is estimated as the area that is seasonally ponded or inundated.

**Scaling:** An AU that is inundated seasonally over 100% of its area is scored a [1]. AUs where seasonal inundation is less are scored proportionally (%area inundated/100).

$V_{org}$ – The area of the AU (as %) that is covered by organic soils.

**Rationale:** One indication that the export of organic matter is not very efficient in an AU is the presence of organic matter in the soils. The Assessment Teams have assumed that AUs with no organic soils are probably better at exporting than those with some.

**Indicators**: The extent of different soils types can be determined during the site visit.

**Scaling:** AUs with less than 1% area of organic soils score a [1]. Those with <50% organic soils score a 0.8; those with 51-95% score a [0.3]; and those with >95% organic soils score a [0].

$V_{bogs}$ – The percent area of the AU that is a sphagnum bog (defined as areas where sphagnum mosses represent more than 30% cover of the ground). **This is a variable of reduced performance.**

**Rationale:** The presence of a sphagnum bog is an indication that the area has a low rate of primary production, regardless of its other characteristics (Mitch and Gosselink 1993).

**Indicators:** No indicators are needed for this variable since the % area of AU that is a bog can be determined directly from the site evaluation or aerial photos.

**Scaling:** The variable is used to reduce the performance index for the function. AUs that are more than 75% sphagnum bog have their index for this function reduced by 0.5. Those with a bog cover of 50-75% are reduced by 0.7, and those with a bog cover of 25-49% are reduced to 0.9 of their original index. AUs with less than 25% bog are not reduced.

## 6.15.5 Calculation of Potential Performance

## *Depressional Outflow – Primary Production and Organic Export*

| Variable | Description of Scaling | | Score for Variable | Result |
|---|---|---|---|---|
| **Vvegcover** | *Highest:* | AU is100% vegetated | If calculation =1, enter "1" | |
| | *Lowest:* | AU has minimal vegetation cover | If calculation = <0.05, enter "0" | |
| | *Calculation:* | Scaling is set as % vegetated/100 | Enter result of calculation | |
| | Calculate [sum (D14.1 to D14.6)[ /100 to get result | | | |
| **Vnonevergreen** | *Highest:* | 100% of AU has cover of non-evergreen vegetation | If calculation = 1, enter "1" | |
| | *Lowest:* | AU has only evergreen vegetation | If calculation = 0, enter "0" | |
| | *Calculation:* | Scaled as a fraction based on % area | Enter result of calculation | |
| | Calculate (D14.2 + D14.4 + D14.5 + D14.6) / 100 to get result | | | |
| **Vunderstory** | *Highest:* | AU has 100% herbaceous understory | If calculation = 1.0 enter "1" | |
| | *Lowest:* | AU has no understory | If D16 = 0, enter "0" | |
| | *Calculation:* | Scaling based on understory as % of the total area of AU | Enter result of calculation | |
| | Calculate (0.01 x D16) x (D14.1 + D14.2 + D14.3 +D14.4)/100 to get result | | | |
| | | | **Total of Variables for Primary Production:** | |
| **Vorg** | *Highest:* | AU has no organic soils | If D47.1 + D47.2 = 0, enter "1" | |
| | *Moderate:* | AU has organic soils but < 50% | If D47.1 + D47.2< = 1, enter "0.8" | |
| | *Low:* | AU has > 50% and < 95% organic soils | If D47.1 **or** D47.2 = 2, enter "0.3" | |
| | *Lowest:* | AU has > 95% organic soils | If D47.1 **or** D47.2 = 3, enter "0" | |
| **Veffectarea1** | *Highest:* | 100% of AU is seasonally ponded or inundated | If D8.1 = 100, enter "1" | |
| | *Lowest:* | 0% of AU is seasonally inundated | If D8.1 = 0, enter "0" | |
| | *Calculation:* | Scaling = (% of AU inundated/100) | Enter result of calculation | |
| | Calculate D8.1/100 to get result | | | |
| | | | **Total of Variables for Export:** | |
| *Reducer* | | | | |
| **Vbogs** | Bog component > 75% of AU | | If D23.1 = 1, enter "0.5" | |
| | Bog component 50-75% of AU | | If D23.2 = 1, enter "0.7" | |
| | Bog component 25-49% of AU | | If D23.3 = 1, enter "0.9" | |
| | Bog component < 25% of AU | | If D23.4 + D23.5 = 1, enter "1" | |
| | | | **Score for Reducer** | |
| ***Index for Primary Production and Export = (Total for production x total for export) x Reducer x 2.22 rounded to nearest 1*** | | | | |
| | | | ***FINAL RESULT:*** | |