Guidebook for
Hydrogeomorphic (HGM)–based Assessment of Oregon Wetland and Riparian Sites:
Statewide Classification and Profiles

Oregon Division of State Lands

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Hydrogeomorphic (HGM)–based Assessment
of Oregon Wetland and Riparian Sites:

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Prepared for:
Oregon Wetland-Riparian Assessment Project
Oregon Division of State Lands

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SUMMARY

This guidebook describes a classification system for Oregon wetland and riparian areas based on their hydrogeomorphic (HGM) characteristics: their dominant water sources and setting in the landscape. This represents a regional refinement of a similar national classification. This guidebook provides narrative descriptions (profiles) for each of 14 HGM subclasses that occur in 10 regions of Oregon. The profiles address identification of the subclass, statewide distribution and variability, possible functions, and vulnerability to human-related and natural disturbances. The guidebook provides profiles for 13 natural functions that potentially are valued because they provide services to society. The guidebook documents the occurrence of these functions in wetland/ riparian systems of the Pacific Northwest, describes their potential values and services, and suggests variables and indicators that may predict the relative magnitude of the functions and values. Also included are (a) profiles of available regional information on sensitivities of algae, vascular plants, invertebrates, amphibians, and birds to human-related disturbances in wetland/riparian habitats, (b) a synopsis of commonly-used *classification* systems for Pacific Northwest wetland/ riparian systems, (c) a synopsis of *function assessment* methods for Pacific Northwest wetland/ riparian systems, (d) list of possible associations between Oregon wetland plant communities and HGM classes, and (e) lists of fish and wildlife species that use Oregon wetland/ riparian habitats. Existing literature, expert opinion, and databases are incorporated throughout the guidebook. Cited literature is primarily drawn from a database of 1600+ entries describing wetland, riparian, and aquatic research conducted in the Pacific Northwest.

This volume is intended to provide a framework for selection and classification of reference sites, and development of rapid methods for assessing functions, in each region of Oregon. Ultimately, the establishment of reference sites – when accompanied by development of refined classification systems, improved assessment methods, and associated performance standards -- is vital to meeting many management goals, including judging if ecological targets (benchmarks) for natural and restored wetland/ riparian sites are being met, and identifying sites that are most significant locally, regionally, and statewide.

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Section 1. Introduction and Background

This volume is one of 3 volumes that comprise a guidebook for classifying wetland and riparian sites in Oregon, based on their hydrogeomorphic (HGM) features, and assessing their functions (Adamus & Field 2001, Adamus 2001a, 2001b). The other two volumes deal exclusively with the Willamette Valley ecoregion, whereas this volume provides a statewide perspective. These guidebooks were prepared as part of a project, "Oregon Wetland and Riparian Assessment" (OWRA) funded jointly by the US Environmental Protection Agency (Region 10) and Oregon Division of State Lands. Most of this volume was prepared before the 2-volume regional guidebook for the Willamette Valley was developed. This "Classification and Profiles" volume was drafted first in order to provide a framework for classification, a broad context for methods development, and an aid for the selection of priority regions for guidebook development. Information presented in this volume influenced the decision to make the Willamette Valley the priority region for methods development during 1999-2000.

Indicators of wetland/riparian function that are appropriate for the Willamette Valley are not necessarily appropriate for all other parts of the state. For example, in the mainly mineral soils of the Willamette Valley, water level fluctuations are believed to indicate enhanced potential for nitrogen removal, whereas in mainly organic soils of the Klamath Basin, water level fluctuations are expected to facilitate the export of nitrogen to downstream areas. Thus, the development of a framework that is statewide and largely based on published, regionally-specific scientific literature – such as this volume is attempting -- is crucial to establishing a sound technical foundation upon which rapid methods can be developed for assessing particular wetland and riparian sites in each region of Oregon. And ultimately, the development of improved classification systems, assessment methods, and associated performance standards is vital for judging if ecological targets (benchmarks) for natural and restored wetland/ riparian sites are being met, and for identifying sites that are most significant locally, regionally, and statewide.

1.1 Why Classify?

The basic premise of classification is that sites belonging to the same class are more similar to each other than to sites belonging to another class. Scientists and resource managers classify and label natural systems to simplify the communication of knowledge about these systems, and to reduce the amount of natural variation that has to be dealt with when seeking to detect and characterize the effects of humans on these systems. Valid classification frameworks, when applied to individual sites at which data have been collected, allow statisticians to accurately extrapolate the data from those sites to entire populations of sites. For example, managers can avoid the high costs required to sample or assess every wetland in a watershed, by classifying all wetlands in the watershed and then assessing conditions at just a few. If those few are chosen according to a valid statistical design, true statements can be made about the probabilities of all other wetlands in the watershed sharing particular characteristics of the few.

Despite having many practical advantages, classifications are ultimately an artificial construct. As noted by Brinson (1995),

> "... classification is not intended to establish a rigorous hierarchy of a finite number of categories into which every wetland must conveniently fit. In reality wetlands are continua that often share characteristics of more than one class."

The validity of a particular classification framework depends ultimately on the choice of features used to characterize a natural resource, and the manner in which those features are interpreted and grouped.

1.2 Origins of HGM Classification

Vegetation typically has been used as the primary means of classifying and mapping wetland/ riparian systems. This has occurred largely because of the ease with which vegetation can be observed at many seasons. In contrast, *water* frequently is visible in wetland/ riparian systems for only for short seasonal periods, or may remain below the surface year-round. Nonetheless, water is a primary controller of what wetland and riparian systems do, i.e., their functions.

Seeking to recognize this more emphatically, Brinson (1993) proposed a national system for classifying wetlands according to their hydrogeomorphic (HGM) features, essentially meaning: pertaining to water, topography, and geological setting. Brinson's classification (Table 1) requires that factors external to a wetland (i.e., its "landscape setting" or "landscape position") be used to define classes of wetlands, and to assign individual sites to such classes. Landscape setting is considered because it is a significant predictor of a wetland's sources of water, and knowing the water sources reveals much about expected water level fluctuations, flow rates, periodicity, and chemistry. Such factors are responsible for maintaining most wetland functions. Wetland functions can in turn be related to a site's "designated uses" and "impairment" which are key elements specified in federal laws and programs.

After extensive peer review and revision, Brinson's HGM framework for classifying wetlands was widely adopted by scientists and wetland managers. Some of the impetus behind its adoption was the publication of a "National Action Plan" by the US Army Corps of Engineers, the federal agency primarily responsible for regulating development in wetlands[1]. The HGM classification has been used in wetland inventories (Tiner et al. 2000), for the design of wetland research and monitoring studies, for cataloging the extent and type of wetland alterations in a region (Gwin et al. 1999), and for focusing the development of regional methods for assessing wetland functions (e.g., Hruby et al. 1999, 2000). The Wetlands Program of the Oregon Division of State Lands has decided to use Brinson's classification as the primary framework for development of rapid methods for assessing wetland functions in each region of the state. However, as specified by Brinson (1993) and by the National Action Plan, individual states and regions should use the national HGM classification and its 7 major HGM classes as a starting point from which they define *subclasses* appropriate to their region. In developing a subclassification suitable for Oregon wetland/ riparian sites, the following assumptions have been made:

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[1] See: Federal Register 62(119):33607; internet address: http:/ / www.epa.gov/ OWOW/ wetlands/ science/ hgm.html

- The dividing of HGM classes into subclasses should be based primarily on hydrologic and geomorphic factors that relate most strongly to naturally-occurring wetland and riparian functions;
- The subclasses and the HGM classes from which they are derived should be viewed as parts of broader classifications of ecosystems that are hierarchical in terms both of geographic scale and effort;
- To the maximum extent feasible, the classification should be consistent with, or explicitly related to, various other frameworks now used for classifying these sites.
- Advanced technical skills should not be required to classify a site -- in most instances trained citizen volunteers (for example) should be able to distinguish the subclasses in the field or by using readily available data.
- By itself, the classification will not be used to assess the functions of sites. Rather, the classification will serve as a preliminary step in an overall method for assessing the functions (Smith 1993).

Table 1. Brinson's hydrogeomorphic (HGM) classes for wetlands, recognized at a national level (from Smith et al. 1995)

Hydrogeomorphic Class	Dominant Water Sources	Water Flow Direction
Riverine	Channel flow & overbank flow from channel	Unidirectional (channels) & Bidirectional (floodplain)
Depressional	Interflow, groundwater discharge	Vertical (seepage)
Mineral Soil Flats	Direct precipitation	Vertical (seepage)
Organic Soil Flats	Direct Precipitation	Vertical (seepage)
Slope	Groundwater discharge	Unidirectional, horizontal
Lacustrine Fringe	Interflow & surges from lake	Bidirectional, horizontal
Estuarine Fringe	Interflow & tidal surges	Bidirectional, horizontal

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1.3 Issues in Defining Subclasses

To develop the Oregon subclassification in a consistent, logical manner, several technical issues were addressed at the outset:

- How many subclasses should be defined for Oregon?
- To what extent should vegetation and human-caused site alterations be used to define subclasses?

- At what scale should the subclasses be applied?

Usually, the greater the number of subclasses, the more homogeneous each individual subclass tends to be. Internal homogeneity is desirable because it allows information from one site to be extrapolated to others with relatively great certainty, and allows information from other sites to be used to infer more precisely the function at a particular site. However, there is a cost to being precise. A large number of subclasses means that the effort required to characterize the features of one subclass must be multiplied many times if the objective is to characterize all or most of the wetland/ riparian sites in a region, as is often the case. Thus, practical considerations dictate that HGM classes not be split *ad infinitum*. Guidance from the Corps of Engineers states,

> "The number of regional wetland subclasses defined will depend on a variety of factors such as the diversity of wetlands in the region, assessment objectives, the ability to actually measure functional differences with the time and resources available, and the predilection towards lumping or splitting." (Smith et al.1995).

One approach for potentially defining an appropriate number of subclasses involves statistical analysis of a data set. This lends some degree of objectivity to the process of defining subclasses, because statistical analysis helps weed out random associations between sites, and focuses on associations that appear to occur with high probability. With the recent growth of "data mining" industries, powerful software once the sole domain of statisticians and researchers is increasingly available to resource managers for facilitating this process, and can be applied to establish objective numeric boundaries or thresholds between subclasses. However, the results are only as good as the choices made regarding factors on which to base the classification, and the accuracy and precision with which those factors are measured at a series of sites intended for classification. Moreover, statistically significant results may or may not be ecologically meaningful, so wetland experts should consider the reasonableness of the results.

Although Corps guidance suggests that the HGM subclasses be defined *within regions*, it does not specify how large or small a region should be. Efforts to date in other states have defined HGM subclasses of selected HGM classes across regions as large as New England and as small as about one-third of a state. None of these efforts rigorously examined whether their collected data could be extrapolated to a larger region, or whether initial choice of a different-sized region would have reduced the variability in their data significantly.

Another issue concerns what role, if any, vegetation should play as a basis for defining subclasses. In Oregon, Elmore et al. (1994) have noted,

> "...not all questions about a piece of land can be answered by a plant association classification. Therefore, geomorphic classification must be considered to effectively describe and manage riparian ecosystems."

Guidance from the US Army Corps of Engineers states,

> "The use of structural vegetative characteristics as the primary criterion for classifying wetlands may be inappropriate because it often places wetlands that are functionally very different into the same class" (Smith 1993).

Nonetheless, guidance from the Corps goes on to suggest,

> "The HGM classification does not explicitly include all factors that control how wetlands function.. variables such as climate or vegetation are not used as classification factors, but could eventually be

> included at lower levels of the classification hierarchy, or as variables in models for assessing specific functions."

Thus, vegetation is not to be neglected when defining HGM subclasses, but should play a secondary role to hydrogeomorphic factors. This may be a concern from a biodiversity conservation perspective if regional wetland gains and losses are expressed only in terms of HGM subclasses, because some rare plant and animal communities overlap several HGM subclasses (Christy & Titus 1997). There have been no regional studies to examine whether plant species assemblages, communities, or associations cluster (in a statistical sense) most strongly by HGM subclass, or by other environmental features.

No single classification, without being overly complex, can address all management needs. Depending on their needs, resource managers should therefore not rely on HGM or any other classification *exclusively*.

Human factors also strongly influence wetland/ riparian functions, even to the point of overwhelming the influence of natural factors. For example, statistical analyses of biological or soils data from a series of urban wetlands might show that some urban wetlands in one HGM subclass are more similar to urban wetlands in other HGM subclass, than to rural wetlands in the same HGM subclass. And in this example, one might just as easily replace "urban" with "constructed," "water-level controlled," or "grazed" -- there are inevitably many situations where human factors overwhelm the influence of hydrogeomorphic factors. However, it typically is undesirable to define subclasses based on human influence factors. As summarized in guidance from the Corps of Engineers,

> "A major reason for classification is to separate variation from natural sources that relate to functioning from variation due to disturbance, particularly disturbance caused by human activity." (Brinson et al.1996).

As an example of why basing subclasses on human influence factors is usually undesirable, consider a situation where one needs to know how well a constructed wetland is progressing toward maturity or stability. One could compare that wetland to naturally-occurring wetlands of that subclass in that region or to other, perhaps older, constructed wetlands of the same subclass in the same region. Such a comparison might indicate progress toward maturation. However, unless one could be sure how much that "yardstick" (the older constructed wetland) deviates from natural conditions, one cannot be assured that a goal of "no net loss of function" is being met.

Finally, one needs to consider spatial scales at which application of an HGM classification may be appropriate or necessary. Most wetland and riparian assessments focus on areas no larger than a few acres, or no larger than a stream reach (a "reach" being a length of channel delimited at its ends by the nearest two inflowing tributaries). Assessments are conducted at this scale because (a) many proposed alterations do not directly impact larger areas, and (b) making field measurements or even estimates of key variables over larger areas is too time-consuming for most regulatory needs. However, the mosaic of land covers, elevations, geologic strata, climate, and vegetation types across the broader landscape scale can profoundly influence wetland functions. Some riparian classification frameworks attempt to factor in the influence of surrounding land cover by using it as a subclassifier of the fundamental aquatic classes (Delong et al.1991, Haufler et al.1996). In the HGM approach, surrounding land cover can be accounted for to some degree by stratifying data collection by ecoregion, and by including land cover, elevation, and other landscape-level factors in models used to score individual functions.

1.4 Problem Sites

Inevitably, applying any classification to actual sites yields sites that seem to have characteristics of multiple subclasses, or seem to fit none of the described subclasses. That is because the purpose of classification is to simplify, and the complexity of wetland/ riparian systems resists simplification. Faced with a situation where a site does not fall neatly into a particular subclass, there are at least three paths that can be taken.

One approach is to collect more data. That can be as simple as reviewing aerial photographs and visiting the site at another season, or as involved as installing and checking groundwater monitoring devices. Unfortunately, for a high degree of certainty, hydrogeomorphic classifications at the subclass level sometimes require data collection efforts too intensive for practical use. The subclassification presented in this document attempts to base separations of the subclasses on features that are simple and rapid to observe, and do not require experience or training in hydrology. The diagnostic features will not be present in all sites, but they will be present in a majority of the sites that fit the subclass.

A second approach when a site fails to fit cleanly into a described subclass is to mentally divide the site into smaller, more homogeneous units and attempt to classify these. A drawback of this approach is that system function may be operating at a broader scale than what the small units encompass. Consequently, the resulting estimates of function and condition may be flawed.

A third approach takes an opposite path and aggregates the ambiguous subclass units into a mosaic which is assigned a compound name, e.g., a "riverine/ depressional" site. Although this may be closer to describing the reality of what exists, it is difficult to apply with much certainty the subclass-specific models and other information to help infer functions of such sites. Moreover, because of the large number of mosaics that are theoretically possible, a much expanded effort would be required to calibrate the reference conditions for each, and to extrapolate results to larger wetland populations.

Regardless of which approach one chooses to take in dealing with classification uncertainty, the very existence of uncertainty implies that a particular site may be atypical. Atypical-appearing sites often happen to be sites that have been poorly designed or heavily impacted by humans (Gwin et al. 1999), and this alone is very useful information to resource managers.

Section 2. An HGM-based Classification for Oregon

After reviewing the literature on wetland and riparian classification in the Pacific Northwest (Appendix A), and considering the issues above in the context of our project objectives, the following 14 HGM subclasses of Brinson’s national HGM classification were proposed:

Riverine
  Flow-through
  Impounding
Depressional
  Closed Permanently Flooded
  Closed Nonpermanently Flooded
  Outflow
  Alkaline
  Bog
Slope
  Headwater
  Valley
Flats
Lacustrine Fringe
  Headwater
  Valley
Estuarine Fringe
  River-sourced
  Embayment

Table 2 provides a key to these, and Table 3 describes a hierarchy of even finer-level divisions of the subclasses. All are based on HGM principles. Definitions and a key for these finer-level subclasses have not yet been prepared. Section 3.8 describes the likely geographic distribution of the subclasses.

Table 2. Key to Level-1 Wetland/ Riparian Hydrogeomorphic (HGM) subclasses of Oregon

> Note: Frequently, areas belonging to one HGM subclass will be situated within or adjacent to an area belonging to another HGM subclass. Normally, each area should be assessed separately. However, for practical purposes the areas may be combined into one site (assessment unit) if the smaller of the two areas comprises less than 20% of their total combined acreage. An example is a perennial channel (Riverine Flow-through subclass) that bisects an ash swale (Slope subclass) and which, even including the channel's 2-year floodplain, occupies less than 20% of their combined acreage. In this example, for most purposes the entire site should be classified as Slope.

1. Water levels visibly controlled by daily tidal cycles. Note that salinity is not considered in this determination.
   YES: **Estuarine** class, go to 2 (Note that salinity is not considered in this determination).
   NO: Go to 3

2. Water levels not visibly affected by 24-hour storm runoff events; usually fringes a bay; salinity always brackish or saline.
   YES: **Estuarine Fringe Embayment (EFB)** subclass
   NO: **Estuarine Fringe Riverine (EFR)** subclass

3. Closely associated with a channel or floodplain. Upland wetted edge of site expands at least once every other year (biennial flood) primarily as a result of overbank flow, channel inflow, or pumped water from a nearby and/or connected or bisecting channel. Includes active(2-yr) floodplain wetlands, sloughs, and riparian areas. On NWI maps, includes many sites labeled R or PUB, PEM, PSS, or PFO with –A, –C, -F, or -H water

regime codes appended, and others.
YES: **Riverine** class, Go to 4
NO: Go to 5

4. Water throughout most of site flows visibly during most of wet season. The site may be a channel, an island in a channel, or border a channel or ditch. It should include any channel to the 2 m depth. It often bisects or is bordered by a wetland in another HGM subclass.
YES: **Riverine Flow-through (RFT)** subclass, Figure 2
Includes scoured floodplains with no seasonal ponding of floodwater, wetlands that comprise entire islands within channels, and some ditches and channels.
NO: **Riverine Impounding (RI)** subclass, Figure 2
Includes sloughs connected (seasonally or permanently) to main channels, channels dammed by beavers or humans (such wetlands may be broader at their downhill/ outlet side), wetlands sustained primarily by water diverted or pumped from offsite channels, river alcoves with seasonally stagnant conditions, and depressions or temporarily ponded areas within active biennial floodplains.

5. Consists mostly of permanent or seasonal standing water with pH>8. Situated in a depression or lake basin without an outlet channel. Includes areas that are shallower than 2 m during annual maximum inundation.
YES: **Depressional Alkaline (DA)** subclass
NO: Go to 6

6. Located on margin of or within a lake, i.e., a body of permanent standing water that is deeper than 2 m over an area of >8 hectares (20 acres).
On NWI maps, includes most sites labeled "L" and others with –A, -C, -F, or –H water regime codes that border an L site.
YES: **Lacustrine Fringe** class, go to 7
NO: Go to 8

7. Located in headwater position (i.e., closer to a region's major drainage divides than to lowlands in the region) and usually higher than the mean elevation of the region[1].
YES: **Lacustrine Fringe Headwater (LFH)** subclass
NO: **Lacustrine Fringe Valley (LFV)** subclass

8. Consists of >10% cover of Sphagnum moss over an area of >0.25 acre, and has a mean annual water pH of <5.5. Usually situated in a depression with little if any standing water.
YES: **Depressional Bog (DB)** subclass
NO: Go to 9

9. Lacks permanent inlet channel. Has a surface water outlet that connects to a permanent river or lake less than once every 2 years. Not located on a noticeable slope. Water level fluctuations are mainly in response to runoff and direct precipitation.
YES: **Depressional Outflow (DO)** subclass
NO: Go to 10

10. Located on, or near base of, a slope, but the slope may be barely perceptible. Inlet channel absent or very short. Outlet channel frequently present. Downhill-flowing sheet flow may be visible at land surface, especially during wet months. Downhill side of site sometimes partly blocked by berm or dam (natural or manmade). Fed by runoff and precipitation but with a proportionally large (compared with other wetlands) component of lateral subsurface flow or discharging groundwater. Soil moisture (and surface water, if

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[1] Approximate mean elevations of regions (in ft.): Blue Mountains= 1351, Basin & Range= 1515, Columbia Basin= 539, Coast/Range= 256, East Cascades Slope= 1435, Klamath Mountains= 734, High Lava Plains= 1179, Owyhee Uplands= 1269, West Cascade Slope= 1037, Western Interior (Willamette) Valley= 191.

present and shallow) tends to persist more into the summer than in other wetlands of similar size, depth, climate, and soil type. Ratio of wetland surface area to area of the apparently contributing watershed is relatively large. Includes springs, seeps, sites sustained in summer mainly by seepage (not runoff) from upslope irrigated fields, some sites with water impounded seasonally by push-up dams at their downhill side, and some ash swales.
On NWI maps, includes many sites labeled PEM, PSS, or PFO with –B water regime codes, and less often with –A, -C, or –F codes.
YES: **Slope** class, Go to 11
NO: Go to 12.

11. Outlet channel is present (but may be small and partly dammed by beaver, roads, slides). Slope may be slight but is always noticeable. No inlet channel. Located in topographically high or intermediate positions such as stream heads, montane wet meadows, avalanche chutes. Usually closer to a region's major drainage divides than to lowlands in the region, and usually higher than the average elevation of the region.
YES: **Slope Headwater (SH)**
NO: **Slope Valley (SV)**

12. Fed mainly by direct precipitation, secondarily by lateral subsurface flow or surface runoff. Precipitation may be "ponded" at the site due to surrounding natural levees, ridge-swale topography, humocks or constructed dikes; and/or due to soils with subsurface layers that strongly impede infiltration; and/or due to high water table due to subsurface seepage from nearby river, lake, or irrigated fields. Usually in a shallow (<2 ft.) basin situated on a broad flat terrace. Includes wet prairie, wet wooded flats, some fens and some ash swales. On NWI maps, includes many sites labeled PUS, PEM, PFO, or PSS with –A, -B, or -C water regime codes.
YES: **Flats class**. No subclasses defined yet.
Many are inundated only seasonally. Altered (diked) flats sites may function similar to depressional class sites, but their only significant water comes from runoff from dike surfaces and precipitation.
NO: **Depressional class**, Go to 14
Fed mainly by overland runoff (sheet flow) which enters from all 3 or 4 compass directions, and/or by stormwater pipes, drainage ditches. Usually in a deep (>2 ft.) basin, which may have been deepened by excavation. Usually is inundated permanently. Often in natural depressions in rolling or mountainous terrain. On NWI maps, includes many of the sites labeled PUB or PAB, some L, and a few others.

14. More than 0.25 acre of standing water remains in the basin during the driest season of most years.
YES: **Depressional Closed Permanent (DCP)** subclass
NO: **Depressional Closed Nonpermanent (DCNP)** subclass

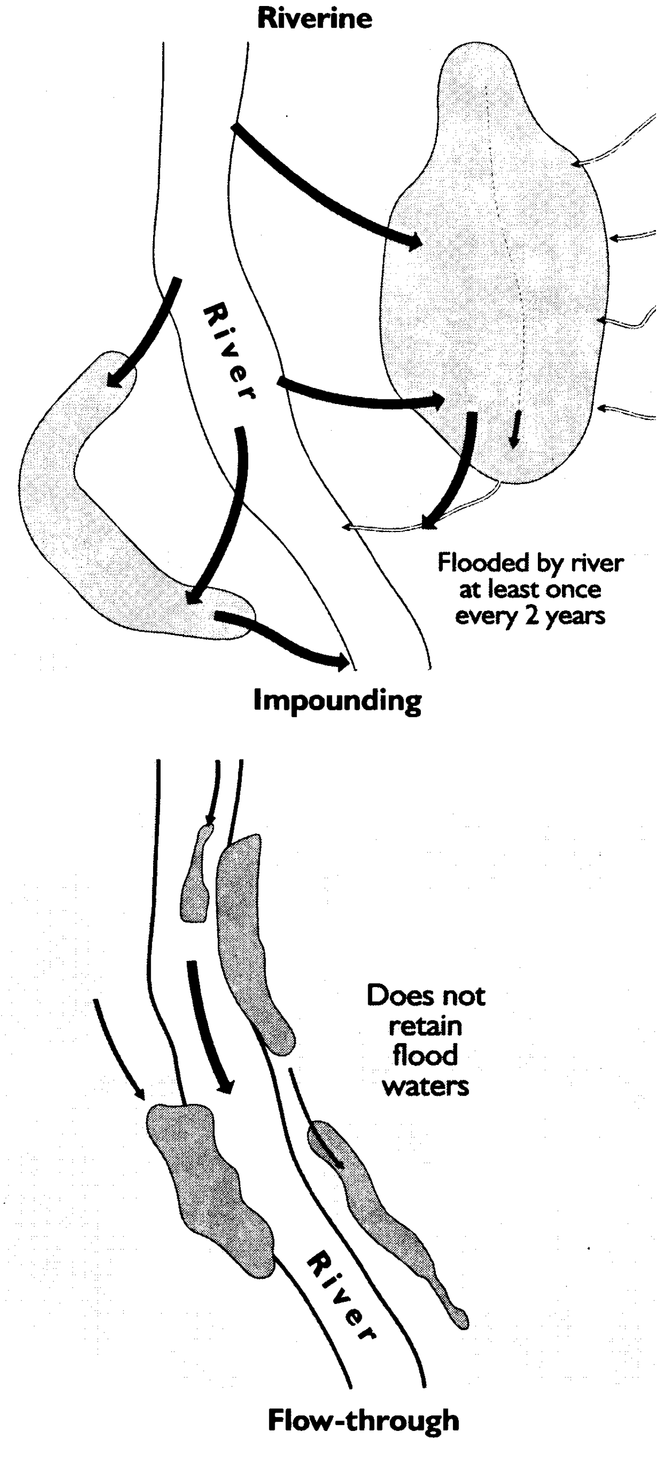


Figure 2. Riverine Impounding and Riverine Flow-through subclasses
(from Hruby et al. 1999)

Table 3. Proposed future (Levels II and III) divisions of HGM-based subclasses for Oregon

HGM Class	Level I Subclasses	Level II Subclasses	Level III Subclasses
Riverine	Flow-through	Low Gradient	Alluvial Fan channel Low Gradient Large Floodplain channel Low Gradient Medium Floodplain channel Low Gradient Small Floodplain channel Low Gradient Moderately Confined channel Moderate Gradient Moderately Confined channel Low Gradient Confined channel
	Impounding	Instream Floodplain	(none yet defined) (none yet defined)
Depressional	Closed Permanently Flooded	Organic/ clay Soil Other Soil	(none yet defined)
	Closed Nonpermanently Flooded	Organic/ clay Soil Other Soil	(none yet defined)
	Outflow	Permanently Flooded Nonpermanently Flooded	(none yet defined)
	Alkaline	Permanently Flooded Nonpermanently Flooded	(none yet defined)
	Bog	(none yet defined)	(none yet defined)
Slope	Headwater Slope	Thermal Nonthermal	(none yet defined)
	Valley Slope	(none yet defined)	(none yet defined)
Flats	(none yet defined)	(none yet defined)	(none yet defined)
Lacustrine Fringe	Headwater	Hardwater Softwater	(none yet defined)
	Valley	Hardwater Softwater	(none yet defined)
Estuarine Fringe	River-sourced	Regularly Flooded Irregularly Flooded Irregularly Exposed	(further split of each according to salinity: oligosaline subsaline)
	Embayment	Regularly Flooded Irregularly Flooded Irregularly Exposed	

Section 3. Profiles of the Hydrogeomorphic Classes and Subclasses

3.1 Introduction

In this chapter, each subsection begins with a description of one of the six geomorphic classes. Each class description then is followed with profiles of the subclasses that comprise that class. The subclass descriptions provide the following information:

Identification: How to recognize sites that belong in this subclass. Similar to the key to the subclasses, Table 2.

Distribution and Variability in Oregon: A preliminary synopsis of regional occurrence, and colloquial names of the kinds of sites that belong in this subclass. Distribution is summarized in terms of the regions shown in Figure 1. In addition, a summary of subclasses is presented by region in section 3.8. Note the lack of any existing databases that would allow for quantitative estimates of the acreage of HGM subclasses or classes by region.

Possible Functions: Examples of characteristics that typify sites of this subclass and which also have consequences regarding potential performance of functions. Also, a listing of functions that are or are not performed *generally* by the subclass. See Table 4 for list of functions and their definitions.

Vulnerability: Description of activities that historically may have impaired the quality or extent of sites of this subclass in Oregon, and/or which may do so in the future. Also a brief description of natural disturbance regimes that characterize the subclass, and any information on sensitivity of the subclass, relative to sensitivities of other subclasses. Table 5 presents a list of human-related factors that have degraded Oregon's wetlands.

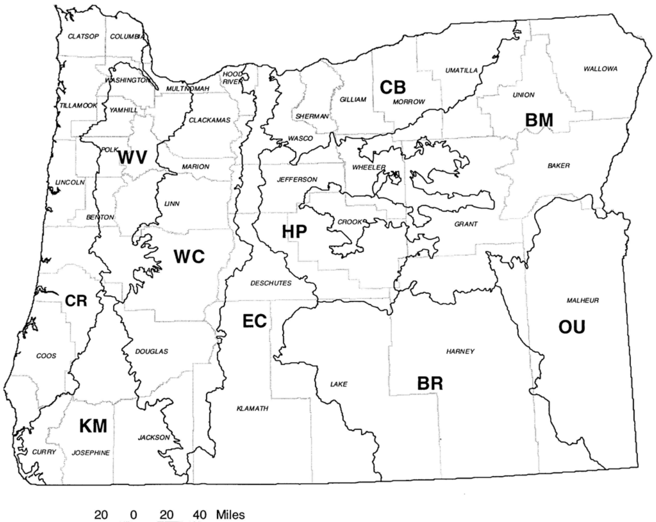


Figure 1. Regions of Oregon used in this Guidebook

CR = Coast and Coast Range; **WV = Willamette Valley**; **KM** = Klamath Mountains; **WC** = West Slope Cascades & Cascade Crest; **EC** = East Slope Cascades, Klamath Basin, Modoc Plateau; **HP** = High Lava Plains; **CB** = Columbia Basin; **BM** = Blue, Ochoco, Wallowa Mountains; **BR** = Basin & Range; **OU** = Owyhee Uplands

Table 4. Functions and their definitions, quantification, and associated values

Function	**Definition**	**Example of Quantification** (but not quantified by this guidebook)	**Associated Values**
Water Storage & Delay & Delay	capacity to store or delay the downslope movement of surface water for long or short periods	cubic feet of water stored or delayed within a wetland per unit time	Minimization of flood-related property damage in offsite areas
Sediment Stabilization & Phosphorus Retention	capacity to intercept suspended inorganic sediments, reduce current velocity, resist erosion of underlying sediments, minimize offsite erosion, and/or retain any forms of phosphorus	percent of the grams of total, incoming, waterborne phosphorus and/or inorganic solids (sediment) that are retained in substrates or plant tissue, per unit wetland area, during a single typical growing season	Water purification
Nitrogen Removal	capacity to remove nitrogen from the water column and sediments by supporting temporary uptake of nitrogen by plants, and by supporting the microbial conversion of non-gaseous forms of nitrogen to nitrogen gas	percent of the grams of total, incoming, waterborne nitrogen that are retained in substrates or plant tissue, per unit wetland area, during a single typical growing season	Water purification
Thermoregulation	capacity to maintain or reduce water temperature	decrease in temperature of water exiting a site via surface flow or infiltration, compared with temperature of the water when it enters the site via surface flow	Supporting fish and wildlife
Primary Production	capacity to use sunlight to create particulate organic matter (e.g., wood, leaves, detritus) through photosynthesis	grams of carbon gained (from photosynthesis) per unit area of wetland per year	Protecting water quality, supporting food webs
Resident Fish Habitat Support	capacity to support the life requirements of most of the non-anadromous (resident) species that are native to the ecoregion	sum of native non-anadromous fish recruited annually from within the site	Recreation, biodiversity
Anadromous Fish Habitat Support	capacity to support some of the life requirements of anadromous fish species	sum of native anadromous fish using the site annually for spawning, feeding, and/or refuge	Recreation, biodiversity
Invertebrate Habitat Support	capacity to support the life requirements of many invertebrate species characteristic of such habitats in the ecoregion	number of invertebrate species and guilds (functional feeding groups) per unit of sediment, soil, water, and colonizable vegetation within a wetland area	Biodiversity, supporting other wildlife

Function	**Definition**	**Example of Quantification** (but not quantified by this guidebook)	**Associated Values**
Amphibian & Turtle Habitat	capacity to support the life requirements of several of species of amphibians and turtles that are native to the ecoregion	sum of native amphibians and turtles that use the site annually for feeding, reproduction, and/or refuge	Biodiversity, supporting other wildlife
Breeding Waterbird Support	capacity to support the requirements of many waterbird species during their reproductive period in the ecoregion	sum of waterbirds that use the site during breeding season for nesting, feeding, and/or refuge	Biodiversity, recreation
Wintering & Migratory Waterbird Support	capacity to support the life requirements of several waterbird species that spend the fall, winter, and/or spring in the ecoregion.	sum of waterbirds that use the site during fall, winter, and/or spring for feeding, roosting, and/or refuge	Biodiversity, recreation
Songbird Habitat Support	capacity to support the life requirements of many native non-waterbird species that are either seasonal visitors or breeders in Oregon.	sum of native songbirds that use the site at any time of the year for breeding, feeding, roosting, and/or refuge	Biodiversity, recreation
Support of Characteristic Vegetation	capacity to support the life requirements of many plants and plant communities that are native to the ecoregion	dominance (relative to non-native species) of native herbs and woody plants that are characteristic of the ecoregion's wetlands	Biodiversity, water purification, supporting fish & wildlife

Table 5. Common stressors that affect functions of wetland/ riparian areas in the Pacific Northwest

Stressor	Definition	Typical causes or Associated activities	Examples from the Pacific Northwest
Enrichment/ Eutrophication	Increases in concentration or availability of nitrogen and phosphorus.	Fertilizer application, cattle, ineffective wastewater treatment systems, fossil fuel combustion, urban runoff	Recreation (McDowell 1980), cattle (Tiedemann et al. 1989), agriculture (Bonn et al. 1995, 1996)
Organic Loading & Depleted Dissolved Oxygen	Increases in carbon, to the point where an increased biological oxygen demand reduces dissolve oxygen in sediments and the water column and increases toxic gases (e.g., hydrogen sulfide, ammonia).	Ineffective waste treatment systems, urban runoff	
Contaminant Toxicity	Increases in concentration, availability, and/or toxicity of metals and synthetic organic substances	Agriculture (pesticide applications), aquatic weed control, mining, urban runoff, landfills, hazardous waste sites, fossil fuel combustion, wastewater treatment systems, and other sources.	Anderson et al. 1996, 1998, Wentz et al. 1998, Qian 1999, Marco 1999, Moran 1999, Thomas & Anthony 1999, Bonn 1999, Elliott et al. 2000, Black et al. 2000, Sytsma 2000
Acidification	Increases in acidity (decreases in pH).	Mining, fossil fuel combustion	
Salinization	Increases in dissolved salts, particularly chloride, and related parameters such as conductivity and alkalinity	Geothermal exploration, road salt used for winter ice control, irrigation return waters, seawater intrusion, & domestic/ industrial wastes.	
Sedimentation/ Burial	Increases in deposited sediments, resulting in partial or complete burial of organisms and alteration of substrate.	Agriculture, disturbance of stream flow regimes, urban runoff, ineffective waste treatment, deposition of dredged or other fill material, erosion from mining and construction sites.	
Turbidity/ Shade	Reductions in solar penetration of waters as a result of blockage by suspended sediments and/or overstory vegetation or other physical obstructions	Agriculture, disturbance of stream flow regimes, urban runoff, ineffective wastewater treatment plants, and erosion from mining and construction sites, as well as from natural succession, placement of bridges and other structures, and resuspension by fish (e.g., common carp) and wind.	Ivey et al. 1998

Stressor	Definition	Typical causes or Associated activities	Examples from the Pacific Northwest
Vegetation Removal & Thermal Alteration	Defoliation and possibly reduction of vegetation through physical removal, with concomitant increases in solar radiation	Grazing, logging, other agricultural and silvicultural activities, aquatic weed control, fire or fire suppression, channelization, bank stabilization, urban development, defoliation from airborne contaminants, natural herbivory (e.g., from muskrat, nutria, geese, insects), disease, and fire.	Beschta and Taylor 1988, Beechie et al. 1994, Maloney et al. 1999, Belsky et al. 1999
Dehydration and Restriction of Animal Movements	Reductions in wetland water levels and/or increased frequency, duration, or extent of desiccation of wetland sediments	Ditching, channelization of nearby streams, invasion of wetlands by highly transpirative plant species, outlet widening, channel downcutting, subsurface drainage, global climate change, and ground or surface water withdrawals for agricultural, industrial, or residential use.	Beechie et al. 1994, Wondzell & Swanson 1999
Inundation and Connecting of Hydrologically Isolated Basins	Increases in wetland water levels and/or increase in the frequency, duration, or extent of saturation of wetland sediments	Impoundments (e.g., for cranberry or rice cultivation, flood control, water supply, waterfowl management) or changes in watershed land use that result in more runoff being provided to wetlands.	Harr et al. 1975, Harris 1977, Beechie et al. 1994
Invasion by Widespread, Generalist Species	Increase in dominance of usually non-native species	Any of the above stressors	Daehler et al. 1996, Kilbride & Paveglio 1999
Other Human Presence	Alteration of wild animal behavior in response to human or domestic animal presence	Hiking, water sports, other outdoor activities, livestock, house pets	Bull & Hayes 2000

3.2 Class: Riverine

The Riverine hydrogeomorphic class includes sites that occur in topographic valleys such as canyons, floodplains, and riparian corridors -- always in association with channels of streams and rivers. As defined for Oregon, the Riverine class includes all vegetation that borders channels (riparian vegetation), whether the channels be intermittent or permanent, natural or manmade; and whether the vegetation be hydrophytic or not. The upland boundary of this subclass to the upland edge of the 2-year floodplain. Moving towards the center of the channel, the boundary extends to a low-flow depth of 2 meters. Thus, in most low-order streams this class will encompass the entire channel. Bars, flats, and islands within the channel are included if they meet the above criteria. If the associated channel is not permanently flooded, water should be present for at least 2 weeks during a majority of years in any 10-year period. Freshwater tidal channels are classified as Estuarine, not Riverine (this differs from Smith et al. 1995) because their salinity in Oregon shows tremendous variability and cannot be assessed visually. Not all sites classified as Riverine will contain wetlands or hydric soils as specified by current agency definitions and procedures.

Riverine sites are sustained primarily by direct inflow of surface water, either in channels or as overflow from channels. Some riverine sites receive appreciable amounts of water directly from precipitation, overland flow from adjacent uplands, or groundwater seepage, but unidirectional channel flow nonetheless remains the primary source. Riverine sites lose *surface* water by flow returning to the channel after flooding and saturation flow to the channel during prolonged rain or snowmelt. Riverine sites lose *subsurface* water by evapotranspiration, surface or subsurface discharge to the channel, or movement to deeper groundwater. On maps, most riverine sites can be recognized as channels, as aquatic areas intersected and strongly influenced by surface water in channels, as areas fed indirectly and predominantly by river water (e.g., via pump systems), or as active floodplain areas (e.g., oxbows, alcoves) that receive water mostly from a river or stream via channels or overbank flow.

Sites on floodplains are almost always assigned to the Riverine class, but only if there is evidence of flooding from frequent overbank events. Although this determination is necessary to separate some Riverine sites from Depressional/ Flat sites, it is difficult to make. Floodplain boundaries sometimes can be estimated from federal flood maps, soil surveys, topographic maps (valley shape and width), aerial photographs, and site visits (noting circumstantial evidence such as freshly deposited sediment and debris, natural levees, and terraces). However, annual frequency of inundation at any point in a floodplain can be difficult to determine without long term records. Techniques for identifying floodplains in Oregon are discussed and compared extensively by Reckendorf (1973). When applying the HGM classification to Oregon, a site within a floodplain should be classified as Riverine if ***either*** field evidence substantiates this ***or*** records show that during the last decade flooding primarily from channel overflow has occurred, on the average, more often than once every 3 years. Sites on alluvium that no longer are flooded (i.e., inactive floodplain or terrace) should not be categorized as Riverine. Also, sites whose water regime at all seasons is influenced *solely* by subsurface (hyporheic) water from a river or stream should not be considered Riverine.

This guidebook is initially proposing two subclasses of Riverine sites for Oregon:
- Riverine Flow-through
- Riverine Impounding

They are described in the following subsections.

***Riverine Flow-through*:**

Gravel bar in Willamette River near Coburg, Oregon

Subclass Profile: **Riverine Flow-through (RFT)**

Identification: In addition to meeting criteria for the Riverine class, sites in the Riverine Flow-through (RFT) subclass are distinguished by the fact that most of their surface water is visibly flowing (usually >5 cm/ s) during the wet season and is not substantially ponded (delayed) by natural or artificial constrictions. Many RFT sites have evidence of active erosion and deposition, and have a dynamic, fluctuating water regime that closely matches that of water in the contiguous channel.

Distribution and Variability in Oregon: The largest mileage of RFT sites (i.e., stream channels) probably occurs in the West Slope Cascade, East Slope Cascade, Blue Mountain, and Basin & Range regions. In general, a greater mileage of streams per unit area tends to occur in regions of Oregon with less permeable rock (e.g., granite) than in regions with more permeable rock (e.g., pumice of volcanic origin) (Grant 1997). Statewide, riverine sites comprise approximately 37% of the acreage of areas mapped by the National Wetland Inventory (SRI/ Shapiro 1995) and probably most of this is in the RFT subclass. The RFT subclass encompasses sites as diverse as shrub-lined gullies amid sagebrush desert, waterfalls on roaring streams, some riparian wet meadows, straight constructed ditches that bisect farmlands and flow only briefly in winter, and broad meanders and gravel bars of major rivers.

Possible Functions: Characteristics that typify RFT sites and have consequences for potential performance of functions include:

- more spatially dynamic than other HGM types, e.g., individual sites can change location as a result of channel meandering;
- a high degree of connectedness to other sites (via contiguous channels of water) which allows for frequent immigration and emigration of waterborne colonizing organisms—both beneficial and detrimental species;
- a linear alignment increases the chance an RFT site, with its normally younger vegetation, will intercept a more complex mosaic of upland land cover types, further enhancing possibilities for influx of diverse nutrients and organisms (Naiman et al. 1993);
- a linear alignment also increases the chance an RFT site will intercept diverse geologic strata, contact zones, and landforms, thus enhancing opportunities for localized inflow of ground waters;
- scouring by floods sometimes reduces herbaceous ground cover but replenishes soil nutrients;
- undisturbed vegetation is absent from nearly all sites due to natural influence of flooding; this makes the determination of expected “climax” vegetation conditions difficult or impossible at an individual site;
- substrates are often well-aerated by flowing water during all of the year, even below the ground surface;
- flowing water deposits a variety of sediment particle sizes, which in turn support diverse communities of plants, aquatic invertebrates, and fish.

RFT sites perform all the functions covered by this guidebook to some degree. Compared with all other subclasses, most RFT sites probably have lower capacity for Water Storage & Delay and Sediment Stabilization & Phosphorus Retention. They also may have higher capacity for Thermoregulation. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: The usual linear alignment of RFT sites also increases their probability of exposure to contamination invasion by upland (often weedy) plant species. Historically, many of Oregon's RFT sites have been diked, dammed, channelized, and polluted, or had their flows diverted intentionally (Sedell and Froggatt 1984, Grant 1997). Flows have also been altered indirectly by downcutting and channel widening resulting from land cover alterations, grazing, and groundwater exploitation. Among natural disturbances, major damage to vegetation at RFT sites from wildfires is rare, but common from floods, landslides, ice scouring, and other erosion.

Subclass Profile: **Riverine Impounding (RI)**

Identification: In addition to meeting criteria for the Riverine class, sites in the Riverine Impounding (RI) subclass are distinguished by the fact that most of their surface water during 2-year flood events is visibly and substantially ponded (delayed). Water flow is usually unidirectional, but during floods may become backed up and show no clear travel path. Ponding is caused by channel or floodplain constrictions, which may include artificial structures such as dams, undersized culverts, and water control mechanisms; earth movements (e.g., landslides); geologic formations; and beaver dams. Water passes more slowly through RI sites than in upstream and downstream (or connected) areas. However, RI sites are not merely slow or wide areas in a channel. Runoff added during major rainfall or snowmelt events passes through RI sites so slowly that the flooded water surface appears to be stagnant (currents of < 5 cm/ sec) during most of the time of flooding. Many RI sites are simply depressions within a 2-year floodplain, and have no inlet or outlet channels. Some RI sites have evidence of active erosion and deposition, and most have a dynamic, fluctuating water regime. During non-flood seasons, RI sites may receive some inputs from groundwater. Two RI wetlands studied in the Seattle area received 13 and 21% of their water inputs annually from groundwater (Reinelt and Taylor 1997).

The constrictions that cause riverine sites to be impounded are not always apparent during field visits. Large impounded channels (e.g., flood control reservoirs) are not classified as RI unless their deepwater (>2m) area is less than 8 hectares (20 acres). Diked wetlands and wetlands caused or expanded by constricted culverts are not classified as RI unless they have an inlet channel, are within a 2-year floodplain, or receive surface water from rivers by other means on a seasonal basis.

Distribution and Variability in Oregon: RI sites can occur wherever there are channels, whether natural or manmade. Because the largest mileage of riverine sites occurs in the Coast Range, West Slope Cascade, East Slope Cascade, Blue Mountain, and Basin & Range regions, this is probably where there are the most RI sites. They will be most common where there are many roads, where beaver populations are high because of minimal trapping or other causes, where slides occur extensively, or where floodplains are broad and dynamic. The RI subclass encompasses sites as diverse as seasonally flooded gravel pits in floodplains, headwater channels with functioning beaver dams, oxbows on major rivers, wet meadows on alluvium, intermittent desert channels that are constricted just before entering narrow canyons or road culverts, waterfowl impoundments fed mostly by piped-in river water, and backwater swamps behind natural levees that adjoin low-gradient channels. RI sites are probably the least temporally stable of the subclasses, changing to RFT and back to RI as beaver come and go or as rivers meander within their floodplain.

Possible Functions: Characteristics that typify RI sites and have consequences for potential performance of functions include:

- RI soils may be unsaturated for much of the year, but when flooded, they remain saturated for longer than RFT soils, so anoxic conditions typically develop and acidity is often greater than in RFT sites (Horner et al. 1997);

- water residence times are longer than for RFT sites so more sedimentation, accumulation of organic matter, and nutrient cycling occurs onsite in RI sites;
- current velocities during floods are slower than in adjoining channels, so that many aquatic organisms find refuge in these sites;
- physical constrictions that give rise to RI sites also can block fish access, with either positive or negative implications depending on function of interest.

As noted above, many RI sites are formed by beaver, and beaver dams play a key role in helping maintain stability of some channels. For building dams, beaver usually select sites with relatively large valley bottom width and extensive grass/ sedge cover, but relatively narrow channel width, low gradient, and low shrub cover (Bruner 1989, McComb et al. 1990, Suzuki 1992, Suzuki and McComb 1998). Specifically, sites with a channel gradient of <7% and constrictions of cross-sectional area <5 m^2 are preferred, assuming adequate browse is also present (McComb and Hagar 1992). Beaver-occupied sites in the Coast Range are not necessarily richer or more productive for small mammals or amphibians (Suzuki 1992).

RI sites perform all the functions covered by this guidebook to some degree. Compared with all other subclasses, most RI sites probably have high capacity for Fish Habitat and intermediate capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Many of Oregon's RI sites (particularly oxbows along major rivers) have been channelized out of existence, whereas many others have been created by road construction (e.g., particularly along the Columbia River) and increasing beaver populations. The duration of flooding and water level fluctuations at many RI sites has been altered indirectly by downcutting and widening of adjoining channels that has resulted from land cover alterations, grazing, water withdrawals for irrigation, groundwater exploitation, and other factors. As little as 0.5 m lowering of a streambed by downcutting can dramatically alter functions of adjoining wetland and riparian sites (Beschta 1997). By controlling river flows and paving over parts of floodplains, humans have robbed many Oregon river channels of their ability to migrate laterally. Such lateral migration is essential for creating RI sites. Among natural disturbances, major damage to vegetation at RI sites from wildfires is rare, but alteration is common from floods, channel erosion and deposition, and landslides. The historical distribution and patterns of open (unforested) patches in the Upper Willamette River is currently being documented by researchers at Oregon State University (Dr. Stan Gregory, *pers. comm.*).

Riverine Impounding:


Oregon Coast Range, beaver impoundment
photo by Bob Frenkel

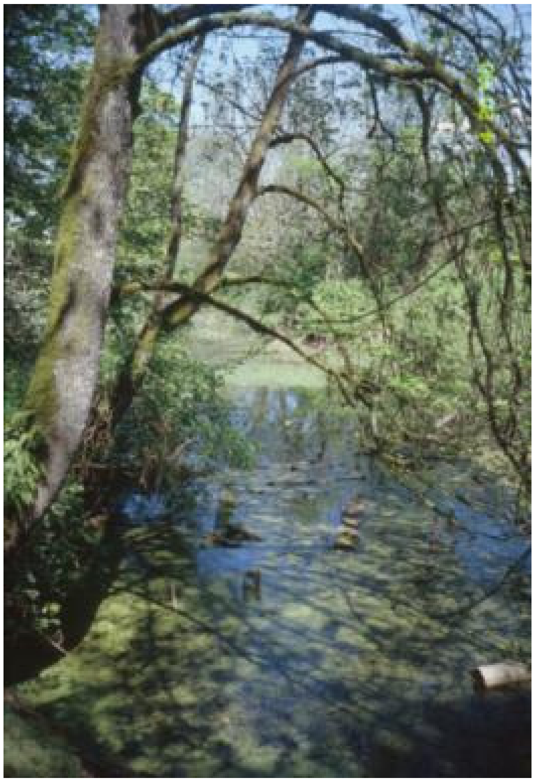

Slough along Willamette River near Coburg


Slough along Willamette River near Eugene


Slough along Willamette River near Coburg


Grande Ronde River, seasonally flooded oxbows
(with RFT's and Depressionals)
photo by Janet Morlan


Baskett Slough National Wildlife Refuge:
Impounded drainage canal


Slough along Willamette River near Coburg


Slough along Willamette River near Coburg

3.3 Class: Depressional

Depressional sites are located in topographic depressions and are fed primarily by overland flow (runoff) and interflow from surrounding uplands. The direction of the flow is typically from the uplands toward the center of the depression. Water movement within the site is primarily vertical, i.e., seasonal fluctuations in depth. Depressional sites lose water primarily via evapotranspiration and seepage to groundwater or interflow. Inlet channels may be present but are not diagnostic. Many Depressional sites could be characterized as "isolated" from navigable waters. Depressional sites are distinguished from Riverine sites by being isolated both from channels and from frequent overbank river flooding. If a site is flooded primarily by river water at least once every other year, it should be classified as Riverine regardless of whether it exists in a depression or lacks inlets and outlets. If the entire basin in which the depression resides is smaller than 8 hectares (20 acres) or is shallower than 2 m, then the entire basin is classified as Depressional (assuming it does not otherwise qualify as Riverine, Slope, or another class). If part of the basin is deeper than 2 m and the basin is larger than 8 hectares, the site should be classified as Lacustrine Fringe rather than Depressional, unless it is Alkaline (pH>8). Not all sites classified as Depressional will contain wetlands or hydric soils as specified by current agency definitions and procedures. This guidebook is initially proposing five subclasses of Depressional sites for Oregon:

Depressional Closed, Permanently Flooded (DCP)
Depressional Closed, Nonpermanently Flooded (DCNP)
Depressional Outflow (DOF)
Depressional Alkaline (DA)

Depressional Bog (DB)
They are described in the following subsections.

Subclass: **Depressional Closed, Permanently Flooded (DCP)**

Identification: In addition to meeting criteria for the Depressional class, sites in the Depressional Closed, Permanently Flooded (DCP) subclass are distinguished by having (a) at least 0.25 acre of standing water during the driest season of most years[1], (b) no outlet channel or connection to a permanent river or lake during a majority of years in any 10-year period, (c) a mean water column pH of less than 8 during most growing seasons, and (d) vegetation cover that is never more than 10% *Sphagnum* moss. Vegetation may be comprised largely of plants whose wetland indicator status is "obligate," and especially species that characteristically are submersed or floating-leaved.

Distribution and Variability in Oregon: Basins containing DCP sites arise from a variety of geological phenomena—such as landslides, glacial outwash, drifting sand dunes, accumulations of river sediments, and volcanic/ tectonic processes—that dam natural drainages. Some DCP sites are created by construction of no-outlet dikes to protect cropland or to create embankment or excavated ponds. These same processes can create RI sites as well, but when the processes are very efficient and runoff is relatively small, DCP or DCNP (nonpermanently flooded) sites are the result.

In western Oregon, runoff from an area of approximately 1 acre is sufficient to maintain a minimum annual water depth of at least 1 foot in a 1-acre DCP, whereas to create the same DCP site in eastern Oregon, runoff from an area of approximately 80 acres is required (NRCS 1982). Thus, as a very approximate guide, dammed drainages or excavations in eastern Oregon that have contributing watersheds *smaller than* 80 acres are likely to instead support DCNP sites (or no wetland at all). These figures will vary 25-50% depending on watershed soil type, expected local precipitation and groundwater input, subsurface drainage, vegetation type and density, and mean summer temperature and wind speed. Such variables might be modeled spatially within regions to predict occurrence and types of wetlands (e.g., Vorhauer and Hamlett 1996).

The DCP subclass encompasses sites as diverse as cutoff meanders on ancient river terraces, many farm ponds smaller than 8 hectares (20 acres), most interdunal and deflation plain wetlands (sites where wind has scoured sediments down to the water table level), some subalpine and glacial outwash basins, and some of the deeper depressions on top of clay lenses or on marine or alluvial terraces above existing floodplains. DCP sites can have mineral or organic soils, and groundwater discharge may be a major water source during some seasons. DCP sites are probably most common where there are many roads and landslides to dam headwater drainageways, as well as in some rangelands with a history of extensive grazing (where stock ponds were often

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[1] The Eastern Washington HGM method (Hruby et al. 2000) classifies Depressional sites as Long Duration or Short Duration, which are similar to Permanently or Non-permanently Flooded subclasses, except their definition of Long Duration sites includes sites that may be without surface water for as long as 2 months of the year. That definition was based on differences in invertebrate community structure between the defined subclasses, whereas our split is based on anticipated survival of resident fish.

excavated), and along the coast where salt marshes were sometimes diked to produce pastureland and hay.

Possible Functions: Characteristics that typify DCP sites and have consequences for potential performance of functions include:

- DCP soils remain covered by water for all of the year, so anoxic conditions typically develop in both the soil and the water column
- absence of outlets assures that little incoming sediment or organic matter will be exported
- absence of outlets also assures that aquatic organisms do not move freely into other water bodies during times of oxygen or thermal stress, and that colonization of the DCP site may be slower than if it were connected
- because outlets are lacking, water levels rise quickly and fall slowly in response to rain or snowmelt in the contributing watershed

DCP sites perform all the functions covered by this guidebook except Anadromous Fish Habitat and Thermoregulation (as defined here). Compared with all other subclasses, DCP sites have high capacity for Sediment Stabilization & Phosphorus Retention, and for Amphibian Habitat. They have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: DCP sites are vulnerable to sedimentation, which by filling in the DCP depression can cause an outlet to form, allowing runoff to pass through the site and essentially converting the site to a Depressional Outflow site. Biological communities of DCP sites are also very vulnerable to effects of overenrichment, salinization, and contaminants brought in by runoff which cannot easily exit a DCP site.

In western Oregon, several DCP sites have been constructed to compensate for permitted wetland losses, to provide habitat for migratory waterfowl, or during gravel extraction outside the usual floodplain. For example, in the Willamette Valley between 1982 and 1994, most of the 4.5 square miles of upland that were converted to wetland were probably converted specifically to Depressional sites, based on information given by Daggett et al. (1998). In addition, the conversion of 10.2 square miles of wetland to deepwater habitats during this period may also represent a substantial increase in Depressional and Lacustrine sites. In eastern Oregon, many DCP sites have been created by stock pond construction. In some regions, DCP sites have been converted to DCNP sites – that is, water now remains for shorter durations -- due to (a) irrigation withdrawals (direct or via groundwater exploitation), (b) downcutting of nearby unconnected channels (often from grazing) which lowers local water table levels, (c) invasion of the site or its contributing watershed by phreatophytes. Among natural disturbances, major damage to vegetation at DCP sites from wildfires is rare. Alteration is more common from severe storm runoff and periodic invasion by concentrations of herbivores (e.g., "eat-outs" by geese, muskrats, nutria).

Depressional sites:

Depressional Closed Permanent: constructed farm pond with fringing vegetation *(photo courtesy Tom Moser)*

Depressional Closed Nonpermanent, pasture between hills

Depressional Outflow: slough connecting to Willamette River less than once every 2 years

Depressional Closed Permanent: former gravel pit

Subclass: **Depressional Closed, Nonpermanently Flooded (DCNP)**

Identification: In addition to meeting criteria for the Depressional class, sites in the Depressional Closed, Nonpermanently Flooded (DCNP) subclass are distinguished by (a) being completely without surface water (or having <0.25 acre of surface water) for at least one day of most years, and have (b) no outlet channel or other water connection to a permanent river or lake more than once every 3 years, (c) a pH of less than 8 during most growing seasons, and (d) vegetation cover that is never more than 10% *Sphagnum* moss. Vegetation often is in concentric rings or zones that roughly parallel the perimeter of the wetland. Vegetation often contains a relatively high proportion of annual (as opposed to perennial) species, and a relatively small proportion of plants whose wetland indicator status is "obligate," e.g., species that characteristically are submersed or floating-leaved (Lippert & Jameson 1964). Similar to some Flats sites, but filled during the wet season more by runoff than by direct precipitation.

<u>Distribution and Variability in Oregon</u>: Some floodplain depressions that are inundated less than once every other year, all fall into this subclass. Also included are some interdunal and deflation plain wetlands, some diked (formerly tidal) wetlands, many snowmelt ponds, some bottomland and brush prairie sites, and various depressions on top of clay lenses or on marine or alluvial terraces above existing floodplains. Either woody or herbaceous vegetation may dominate. DCNP sites are formed by the same processes that form DCP sites, but generally have smaller contributing watersheds, more permeable underlying soils, and/or are located in more arid areas. Because eastern Oregon experiences major long term cycles in precipitation patterns, many sites which seem to be DCP sites during wet years there may actually be DCNP.

<u>Possible Functions</u>: Characteristics that typify DCNP sites and have consequences for potential performance of functions include:

- usually smaller mean wetland size, which affects capacity to perform all functions (e.g., Reinelt and Taylor 1997);
- absence of outlets, which insures that little incoming sediment or organic matter will be exported;
- absence of outlets also insures that aquatic organisms do not move freely into other water bodies during times of oxygen or thermal stress, and that colonization of the DCNP site may be slower than if it were connected;
- because outlets are lacking, water levels rise quickly and fall slowly in response to rain or snowmelt in the contributing watershed;
- because soils are sometimes flooded, they can become anoxic and thus lose nitrogen during these times from denitrification;
- because soils occasionally become unsaturated, organic matter does not accumulate to the degree that it does in most DCP sites, and may become compacted by frequent water level drawdowns;
- because soils occasionally are unsaturated there is more "dead storage" available for retaining runoff, so water residence times during storms may be longer than in some DCP sites;
- because soil aeration is better than in DCP sites, the productivity and richness of the DCNP plant community is often greater;
- the lack of permanent inundation is unfavorable for many aquatic bed species, but fosters increased density of woody plants;

- the lack of permanent inundation is unfavorable for fish and some aquatic invertebrates, but supports increased density of aquatic insects and a larger role for insectivorous amphibian predators.

DCNP sites perform all the functions covered by this guidebook except Fish Habitat and Thermoregulation. Compared with all other subclasses, DCNP sites have high capacity for Water Storage & Delay, Sediment Stabilization & Phosphorus Retention, Nitrogen Removal. They may have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: In agricultural lands and developing valleys, many tiny DCNP sites have been obliterated by "field leveling" activities designed to improve drainage and facilitate machinery movement. Perhaps even more have been deepened (converting them to DCP sites) or connected to other water bodies (converting them to Depressional Outflow sites) in order to enhance perceived values -- e.g., "real estate lakes," duck ponds, farm ponds, fish ponds. This has sometimes been carried out as compensation for permitted wetland losses. DCNP sites are also frequently subject to cultivation and logging.

Like DCP sites, DCNP sites are extremely vulnerable to sedimentation, which by filling in the DCNP depression can cause a conversion to non-wetland conditions (e.g., invasion by non-hydrophytic plants). Biological communities of DCNP sites are also very vulnerable to effects of overenrichment, salinization, and contaminants brought in by runoff which cannot easily exit a DCNP site. In some areas, DCNP sites have been converted to uplands due to irrigation withdrawals (direct or via groundwater exploitation), or due to downcutting of nearby unconnected channels (often from grazing) which lowers local water table levels. Historically, wildfires were probably a common natural disturbance at some DCNP sites. Other natural disturbances include severe storm runoff events, prolonged drought periods, and periodic invasion by concentrations of herbivores (e.g., "eat-outs" by geese, muskrats, nutria).

Subclass: **Depressional Outflow (DOF)**

Identification: In addition to meeting criteria for the Depressional class, sites in the Depressional Outflow (DO) subclass are distinguished by having (a) one or more outlet channels or other surface water connection to a permanent river, lake, or estuary more than once every 3 years, (b) a water column pH of less than 8 during most growing seasons, and (c) vegetation cover that is never more than 10% *Sphagnum* moss.

Distribution and Variability in Oregon: DOF sites may be permanently or nonpermanently flooded, and either woody or herbaceous vegetation may dominate. They are very common in most regions, and include many montane wet meadows, farmed and snowmelt wetlands that spill over and connect to larger water bodies during wet seasons, sloughs with outlets that no longer are flooded regularly by rivers, farm or stock ponds with outlets, and diked wetlands with outlets. They are formed by the same processes that form Depressional Closed (DCP and

DCNP) sites. Many are the result of partly successful attempts to drain DCP or DCNP sites by constructing outlet ditches.

Possible Functions: Depending on whether they are permanently or nonpermanently flooded, DOF sites share many characteristics of DCP or DCNP sites. However, because they are at least occasionally connected to more permanent water bodies, many DOF sites are less retentive of sediment and nutrients. DOF sites perform all the functions except Thermoregulation (as defined by this guidebook). Compared with all other subclasses, DOF sites are effective as Amphibian Habitat, and have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Although presence of an outflow in DOF sites ameliorates potential sedimentation and contaminant accumulation problems, if excessive sedimentation does occur it can convert DOF sites to DCP, DCNP, or upland. DOF sites also have been converted to uplands as a result of irrigation withdrawals (direct or via groundwater exploitation), or downcutting of nearby channels (often from grazing) which lowers local water table levels. Many of the intermittently flooded DOF sites are cultivated or grazed. Historically, wildfires were probably a common natural disturbance at some DOF sites. Beaver regularly dam the outlets of DOF sites. Other natural disturbances include severe storm runoff events, prolonged drought periods, and periodic invasion by concentrations of herbivores.

Subclass: **Depressional Alkaline (DA)**

Identification: In addition to meeting criteria for the Depressional class, sites in the Depressional Alkaline (DA) subclass are distinguished by having a mean water column pH of 8 or greater during most growing seasons. Many DA sites would be classified by the HGM national classification as Mineral Flat or Lacustrine Fringe.

Distribution and Variability in Oregon: DA sites may be permanently or nonpermanently flooded. They include alkaline springs and seeps, seasonally inundated salt flats, alkali lakes, and playas. DA basins vary greatly in size and salinity from year to year; in some years they may contain no surface water at all. They lack outlet channels but may have inlet channels. Precipitation and groundwater are the primary water sources, and water outputs are primarily via evaporation. They occur commonly in ancient lake bottoms in arid regions. In extreme cases, evaporation leaves mineral deposits that effectively prevent infiltration. In Oregon, most are located in the East Slope Cascades and Basin & Range regions. The Oregon Lakes Database lists 17 (of 204 sampled) lakes having a pH of 9 or greater. The Low Temperature Springs Database lists 20 (of 208 sampled) thermal spring wetlands that had such a pH

Possible Functions: Characteristics that typify DA sites and have consequences for potential performance of functions include:

- organic content of soils is sometimes limited due to the typically reduced production of vascular plants; trees are mostly absent but some shrubs (e.g., greasewood) flourish

- phosphorus is readily adsorbed to the concentrated cations and precipitated, increasing its retention within the DA basin
- at the most alkaline sites, nitrogen in the form of ammonia may convert to ammonium, which is toxic to many organisms
- because of the elevated salinity waters remain unfrozen slightly longer, and may thaw more quickly in springtime
- denser water (due to salinity) tends to buoy suspended sediments rather than allow rapid settling (although some settling may be accelerated by salt-related coagulation)
- although evapotranspiration rates are less than in fresher waters, site salinity usually increases as summer progresses, water evaporates, and water levels drop
- although microbial densities are often high at DA sites, the elevated salinity and alkalinity frequently restrict the rates of denitrification and perhaps decomposition
- algae and macroinvertebrate populations are typically enormous, and attract regionally significant concentrations of swallows, shorebirds (Jehl 1994, Oring & Reed 1997, Robinson & Warnock 1998), and bats[1]
- chemical conditions reduce species richness and restrict the floral and faunal communities mainly to a few specialist taxa
- in larger DA basins, restricted plant cover allows greater erosion and redistribution of sediments to occur from wind
- salinity is controlled by the frequency and extent to which the site overflows and connects to adjoining water bodies

DA sites perform all the functions except Thermoregulation (as defined by this guidebook) and Anadromous Fish Habitat. Some sites support rare fish species (USFWS 1998). Compared with all other subclasses, DA sites have high capacity for Phosphorus Cycling and Waterbird Habitat. They have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Most sites are relatively immune from major human influences (drainage, filling) because soil salinities restrict agricultural use. Many DA sites are grazed, often intensively where the site represents the only water source (spring) in an area. Geothermal energy development has been proposed at some locations. Alterations of water tables and drainage patterns at DA sites can increase salinity and alkalinity to an even greater degree, reducing vegetation cover and threatening some animal species.

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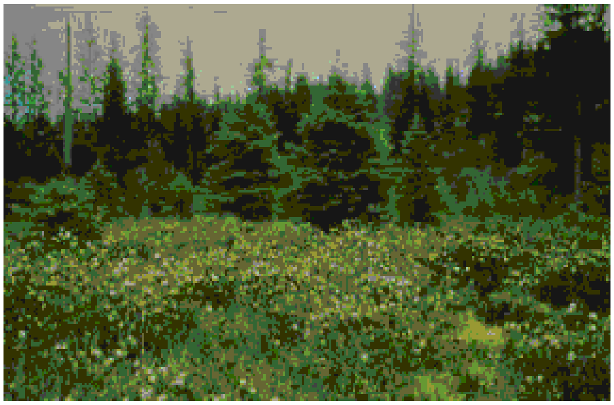
[1] The 3 largest alkaline sites in Oregon -- Goose, Summer, and Abert Lakes -- annually host over 300,000 shorebirds and meet Western Hemisphere Shorebird Reserve Network guidelines for designation as regionally important shorebird sites (Warnock et al. 1998).

Depressional wetlands:

Depressional Alkaline: Borax Lake, Oregon
(photo by Oregon Natural Heritage Program)



Depressional Bog in Washington
(photo courtesy of King County)

Subclass: **Depressional Bog**

Identification: In addition to meeting criteria for the Depressional class, sites in the Depressional Bog (DB) subclass are distinguished by having greater than 10% cover of *Sphagnum* moss over an area of at least 0.25 acre, and, a mean annual water pH of less than 5.5.

Distribution and Variability in Oregon: Relatively few peat bogs occur in Oregon. Most are small and are located in the Coast and West Slope Cascade regions. Some contain tiny temporary or permanent pools of open water, or adjoin lakes (in which case the lake area to a water depth of 2 m should be included in the assessment unit). Outlet and/or inlet channels may be present. When present, trees are often stunted and widely spaced. Very few of Oregon's bogs could be considered ombrotrophic (precipitation-dominated, sometimes dome-shaped), which are classified as Organic Flats by the national HGM classification (Brinson 1993). Many of Oregon's bogs are minerotrophic -- sustained primarily by groundwater and snowmelt runoff.

Possible Functions: Bogs form when plant litter accumulates faster than it decomposes. The accumulation can form a deep layer of peat. In some regions of North America peat accumulates to dozens of meters in depth (Chadde et al. 1998). Characteristics that typify DB sites and have consequences for potential performance of functions include:

- soil and water conditions are characteristically acidic (pH<5.5), which slows denitrification and decomposition, and potentially mobilizes some metals;
- water levels show less daily and seasonal fluctuation than in many other subclasses, in part because of water storage by peat;
- tannin (a natural substance leached from organic matter) stains whatever surface water is present, reducing light penetration and productivity of aquatic invertebrates and fish.

Bogs perform all the functions except Thermoregulation (as defined by this guidebook) and Anadromous Fish Habitat. Compared with all other subclasses, bogs have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Bogs form very slowly, at a rate of about one inch (peat depth) per 40 years in western Washington. Thus, human activities can cause impacts that are essentially irreversible. Declines in local water tables are particularly damaging because they may cause subsidence (settling and compaction) of peat. Limited cranberry cultivation has occurred at some coastal bogs in southwestern Oregon, but many bogs have been assigned special protective designations.

3.4 Class: Slope

The Slope hydrogeomorphic class consists of sites whose hydrology is dominated by groundwater inputs. The groundwater may originate from deep aquifers and be discharged into a site while under visible pressure (e.g., geysers, artesian springs) or may be discharged into a site as diffuse lateral flow from a confining clay layer just a few feet below the land surface. During some seasons groundwater inputs may be less than inputs from surface runoff and direct precipitation. Slope sites lose water via evapotranspiration, surface outflows, and subsurface interflow. Many (but perhaps not most) Slope sites might be characterized as “isolated” from navigable waters.

Recognition of Slope sites can be difficult because, except in extreme situations, the relative magnitude of groundwater input isn't directly recognizable during a single site visit. Sometimes the only approach is to assign sites to this class by default, when no other class "fits." Slope sites commonly occur as seepage at the toe of steep slopes (Suroweic 1989) or as seepage a short distance downslope from dams, reservoirs, and irrigated fields, but they occur in other situations as well. The ratio of wetland area to contributing watershed area is larger for Slope sites than for sites of other classes (Reinelt et al. 1997). Owing to the relatively great input of groundwater, the conductivity of waters at Slope sites is sometimes greater than at sites belonging to other subclasses. In the Willamette Valley, groundwater has a median conductance of 224 µmhos/ cm and normally ranges from about 169 to 326 µmhos/ cm among sites (Miller and Gonthier 1984). Comparable statistics for the other regions of Oregon are provided by the same source. Not all sites classified as Slope will contain wetlands or hydric soils as specified by current agency definitions and procedures. The distribution of named springs (a common type of Slope wetland) in Oregon, as mapped by the U.S. Geological Survey and reported in their Geographic Names Database, GNIS, is:

Region	% of all in Oregon
Blue Mountains	45%
East Slope Cascades	15%
Owyhee Uplands	13%
Basin & Range	9%
West Slope Cascades	6%
High Lava Plains	5%
Klamath Mountains	3%
Columbia Basin	3%
Coast/ Range	1%
Western Interior Valleys	1%

This guidebook is initially proposing two subclasses of Slope sites for Oregon:
Slope Headwater (SH)
Slope Valley (SV)
They are described in the following subsections.

Subclass: **Headwater Slope (SH)**

Identification: In addition to meeting the criteria for the Slope class, SH subclass sites typically (a) have an outlet channel but no inlet channel, (b) are visibly sloping, and (c) are located in topographically high or intermediate positions. SH sites may resemble Depressional Outflow sites. They may be permanently or nonpermanently flooded, but they have little or no surface water in pools or channels within the site, except when their outlets have been partly impounded (e.g., by beaver, road crossings, slides, geologic formations). Because they have no inlet channels, SH sites do not receive annual overflow from channels descending from higher elevations.

Distribution and Variability in Oregon: SH sites occur in avalanche chutes, on valley sideslopes, and at the head of streams above the point where water becomes spatially contiguous. They often include or are part of montane wet meadows. They occur most commonly in mountainous regions (Blue Mountains, West & East Slope Cascades, Klamath Mountains).

SH sites can originate from any of three types of situations:

1. *Contact*: A geologically permeable, water-bearing unit overlies a less permeable unit that intersects the ground surface.
2. *Fracture*: Cracks in bedrock emerge at the ground surface on slopes.
3. *Seep*: Numerous small openings in permeable soil discharge groundwater very slowly.

Seeps are commonly initiated where natural drainages are blocked, or in some cases by extensive logging (because removal of trees can reduce evapotranspiration losses, thus allowing the water table to rise to the surface for up to 20 years, until natural succession returns the system to its original state).

Possible Functions: Characteristics that typify SH sites and have consequences for potential to perform various functions include:

- groundwater usually has greater hardness, alkalinity, and/or conductivity, and lower dissolved oxygen than other surface water; this can strongly influence nutrient cycling;
- water levels (subsurface, and surface if present) fluctuate relatively little compared with sites in other HGM classes;
- water temperature is usually more constant throughout the year, being slightly cooler in summer and warmer in winter than other surface waters; this extends the effective growing season for hydrophytes. (This can aid identification: Sites visited in late autumn that are among the only ones in an area that remain ice-free are often Slope sites);
- although surface flooding is rare, soils of SH sites are almost constantly saturated and consequently are usually anoxic;

- especially in arid regions of Oregon, they serve as refugia for many regionally rare invertebrates (Myers & Resh 1999) and plants (Christy & Titus 1997), due to their persistent but shallow inundation.

SH sites potentially perform all functions, but support Anadromous Fish Habitat directly only if an outlet channel is present or they adjoin a stream, in which case their contribution can be considerable. Except where hot springs are present, SH sites have high capacity for Thermoregulation (Torgerson et al. 1999) and Amphibian Habitat. They have low capacity for Water Storage & Delay (depending on outlet constriction), Sediment Stabilization & Phosphorus Retention, Resident Fish Habitat, and Waterbird Habitat. Their capacity for other functions is probably moderate. However, to assess these functions accurately in an individual case, it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Probably the most common threat to SH sites in Oregon is downcutting of outlet channels as a result of excessive grazing or other erosive activities (Wondzell & Swanson 1999). This threat is greatest in mountain meadows and rangelands, where cattle in summer are naturally drawn to springs. Some SH sites may be dried out by falling water table levels associated with irrigation withdrawals, whereas others are sustained by irrigation return flows that support high water table levels late into the summer, e.g., in Snake River Valley. Particularly in arid regions of the state, many SH and SV sites have been converted to stock ponds and reservoirs (Depressional Outflow). Hot springs are potentially at risk from geothermal energy development. Scouring from floods is not important to SH sites, but some sites may be susceptible to natural disturbance from slides, fire, and herbivores.

Subclass: **Valley Slope (SV)**

Identification: These are perhaps the most difficult sites to recognize during a cursory visual inspection. They may or may not have any apparent gradient. They may or may not have an outlet channel. Inlet channels usually are absent. They may be permanently or nonpermanently flooded, but they always have little or no surface water in pools or channels within the site, except when their outlets have been partly impounded (e.g., by beaver, road crossings, slides, geologic formations). They differ from sites in the Slope Headwater subclass by being located in a topographically low position, often where there is a noticeable slope discontinuity, such as a sharp concave break in slope at the toe of a cliff or slope. However, they may also occur on seemingly flat ground such as adjoining the upper edge (<2-year flood return frequency) of lowland Riverine sites. There, they may greatly resemble Flats or Depressional Outflow sites, but if they are in a depression, the depression is quite shallow, and surface water typically persists longer into the growing season than in unimpounded Flats sites. Vegetation often consists of typical "fen" species assemblages. Water at SV sites is sometimes much cooler in summer than surrounding waters (hot springs are an exception) and this can be diagnostic.

Distribution and Variability in Oregon: SV sites occur in a wide variety of lowland settings. They occur commonly along the edge of small valleys within the Blue Mountains, East Cascade Slope, Basin & Range, and Owyhee Uplands regions in particular. SV sites originate in the three types of situations described previously for SH sites. In addition, many small SV sites develop below irrigated fields, as a result of lateral seepage from prolonged irrigation. They also can result from artesian springs (water released under pressure from a confined aquifer at the aquifer outcrop or through an opening in the confined unit).

Possible Functions: SV characteristics with potential consequences for various functions include all those described above for SH sites. In addition, where irrigation seepage is a primary water source of an SH site, maximum water table levels often occur in late summer rather than during the usual spring and early summer period.

SV sites can perform all functions to some degree, but when they do not adjoin a river and outlet channels are lacking, they do not directly support the Anadromous Fish Habitat function. Because of their topographic position, their capacity to support Waterbird Habitat and Resident Fish Habitat is somewhat greater than for SH sites. Other functional capacities are of about equal magnitude as those of SH sites. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Threats and natural disturbance regimes are similar to those described for SH sites.

Slope wetlands:

Malheur County, ungrazed

hot spring

Malheur County, heavily grazed

Skull Spring, Malheur County -- excavated

Austin, Grant County – excavated for gravel

Finley National Wildlife Refuge – excavated from upland to create seasonal wetland

3.5 Class: Flats

Identification: These are sites that are fed mainly by direct precipitation, secondarily by lateral subsurface flow or surface runoff. Many, and perhaps most, might be characterized as "isolated" from navigable waters. The Flats class includes many vernal pools, farmed wetlands, wet meadows, shallow ephemeral (seasonal, temporary, semipermanent) ponds, deflation plain ponds, and wet (e.g., tufted hairgrass) prairies. Precipitation may be "ponded" at these sites due to surrounding natural levees or dunes (ridge-swale topography) or constructed dikes; and/or due to soils with subsurface layers that strongly impede infiltration; and/or due to high water table due to subsurface seepage from a nearby river, lake, or irrigated fields. Flats are often in a shallow (<2 ft.) basin situated on a broad flat terrace (e.g., Calapooyia geomorphic surface, Reckendorf 1993). In their unaltered state, many Flats contain complex ("hummocky") microtopography and are inundated only seasonally. Altered (diked) Flats sites may function similar to Depressional class, but their only significant water comes from runoff from dike surfaces and direct precipitation.

Distribution and Variability in Oregon: Occur most widely in Western Interior Valleys, and elsewhere where terrain is level, especially at higher altitudes elsewhere where precipitation (often in the form of snow) is abundant.

Possible Functions: Similar to DCNP subclass (p. 27). Flats sites can perform all functions except Fish Habitat and Thermoregulation. They are particularly effective at providing Waterbird Habitat, Sediment Stabilization & Phosphorus Retention, and Nitrogen Removal. They have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Similar to DCNP subclass. In agricultural lands and developing valleys, many Flats have been obliterated by "field leveling" activities designed to improve drainage and facilitate machinery movement. Perhaps even more have been bisected by ditches or drained by subsurface tiles in order to expand agricultural use. In attempts to "enhance" production of waterfowl and to make water available later into the summer for farm use and stocked fish, dikes often have been built on and around Flats. Effects of these practices on native amphibians and prairie plants are largely undocumented.

Flats are extremely vulnerable to sedimentation, which by filling in the microtopographic depressions can reduce water-vegetation contact time. Biological communities of Flats are also very vulnerable to effects of overenrichment, salinization, and airborne contaminants. In some areas, Flats have been converted to uplands due to irrigation withdrawals (direct or via groundwater exploitation), or due to downcutting (often from grazing) of nearby unconnected channels, which lowers local water table levels. Historically, wildfires were probably a common natural disturbance at most Flats sites. Other natural disturbances include prolonged drought periods, and periodic invasion by concentrations of herbivores (e.g., "eat-outs" by geese, muskrats, nutria).

Flats wetlands:

Farmed, Willamette Valley – with water present

Farmed, Willamette Valley – with water absent

Wooded – E.E. Wilson Wildlife Area
photo courtesy of David Budeau

Montane pasture, Lake County

Wet meadow, Deschutes County
photo courtesy of Steve Shunk - Paradise Birding

Impounded by dikes, West Eugene

3.6 Class: Lacustrine Fringe

The Lacustrine Fringe HGM class consists of sites on the edge of lakes. The water table of Lacustrine Fringe sites is maintained primarily by the water elevation in the adjoining lake, which must be larger than 8 hectares, nonalkaline (pH<8), and not flooded more often than once every 2 years by overflow from an adjoining river. Lacustrine Fringe sites can include floating mats of vegetation, as well as underwater or emergent vegetation, woody vegetation, and the lake water itself to a depth (maximum annual) of 2 m. Surface water flow is seldom observable and is mainly bidirectional as represented by lake level fluctuations. Lacustrine Fringe sites may be partly fed by small streams and groundwater seepage but seldom (in their unaltered state) have internal channels. They may be permanently or nonpermanently flooded.

There are over 5280 named lakes, reservoirs, and ponds in Oregon according to the Geographic Names Database (GNIS) of the U.S. Geological Survey; this figure includes many oxbows and sloughs that are in the Riverine Impounded subclass, as well as many Depressional basins. Probably most of these 5280 lakes contain Lacustrine Fringe sites. The distribution of lakes, reservoirs, and ponds reported by the GNIS database is as follows:

	Percent of All in Oregon
Basin & Range	18%
Owyhee Uplands	17%
West Slope Cascades	17%
Blue Mountains	12%
Western Interior Valleys	12%
East Slope Cascades	7%
Klamath Mountains	6%
Coast/ Range	5%
High Lava Plains	3%
Columbia Basin	1%

Another way of approximating the regional extent of Lacustrine Fringe systems is to consider data from the systematic sample of all NWI maps for Oregon done by SRI/ Shapiro (1995). Based on acreage rather than number, this produces a somewhat different ranking:

	Percent of All in Oregon
Basin & Range	34%
East Slope Cascades	27%
West Slope Cascades	13%
Columbia Basin	8%
Owyhee Uplands	6%
Blue Mountains	4%
Western Interior Valleys	4%
Coast/ Range	3%
High Lava Plains	2%
Klamath Mountains	1%

Considering just those Lacustrine Fringe sites that are inundated year-round (permanently) gives a sequence that is almost identical, except for the rank of the Basin & Range region:

	Percent of All in Oregon
East Slope Cascades	32%
West Slope Cascades	22%
Columbia Basin	13%
Owyhee Uplands	9%
Blue Mountains	6%
Basin & Range	6%
Coast/ Range	5%
Western Interior Valleys	4%
High Lava Plains	3%
Klamath Mountains	1%

The morphology, watershed characteristics, and chemical compositions of 293 lakes are described in the *Atlas of Oregon Lakes* (Johnson et al. 1985). Characteristics of Oregon lakes are also summarized regionally by Newell and Bernert (1996):

> *Coast/ Range*: Most lakes here are in the 1.5 km-wide landward strip which extends the length of the coast. These lakes were formed by migrating coastal sands, by rises in sea level that have closed off streams from the ocean, and by interdunal movements. Larger lakes were formed by sand and beach deposits that blocked the lower portions of coastal valleys. Lakes in the mountains of the Coast Range are largely reservoirs or were formed by mass wasting (e.g., Triangle Lake). Coastal lakes have relatively high conductivity from airborne sea salt inputs, and have relatively shallow mean depths.
>
> *Western Interior Valleys*: The number of lakes per unit area is relatively high if those located in floodplains or near channels are included in the tally. Nutrient concentrations are relatively high. Detailed data on lakes by county are reported by Rinella et al. (1977, 1979); Shulters (1974, 1975, 1976); and Sanderson et al. (1973).
>
> *Klamath Mountains*. Lakes are relatively few and small. Many have moderately high alkalinities due to relatively high calcium concentrations. Most wetlands are located east of

Medford in the Rogue Valley, and many small lakes are present in parts of the Siskiyou Mountains.

Cascades: The number of lakes per unit area is higher in the East Slope Cascades than the West Slope Cascades. West Slope lakes are primarily reservoirs. The mean size of Cascade lakes is 3.4 hectares (8.4 acres), and the average maximum depth is 4.8 m (Landers et al. 1987). Many Cascade lakes were formed by volcanic activity (e.g., lava blocking stream channels, or water filling volcanic craters) or mountain glacial activity. Many Cascade lakes have very low nutrient concentrations -- the median conductivity is 11 µeq/ L (Landers et al. 1987). Conductivity and alkalinity are greater in lakes in the eastern and southern parts of the region.

Columbia Plateau. Similar to Western Interior valleys, in that many lakes are on floodplains, near channels, or constructed. The tablelands and dissected uplands have almost no lakes. Alkalinity and pH are moderately high.

Blue Mountains. Most of these numerous lakes are of glacial origin. Higher-elevation lakes have very low nutrient concentrations.

Basin & Range, Owyhee Uplands, High Lava Plains: Most of these lakes were formed by tectonic uplift, faults, landscape tilting, and humans (stock ponds and reservoirs). Many are classified as Depressional Closed or Alkaline.

This guidebook is initially proposing two subclasses of Lacustrine sites for Oregon:
Lacustrine Fringe, Headwater (LFH)
Lacustrine Fringe, Valley (LFV)
These are described in the following subsections.

Subclass: **Lacustrine Fringe, Headwater (LFH)**

Identification: In addition to meeting the criteria for the Lacustrine class, sites in the LFH subclass are located in lakes that are (a) in headwater positions (i.e., downslope of and closer to major drainage divides in their region than to lowlands in their region) and usually (b) higher than the mean elevation of their region.

Distribution and Variability in Oregon: No information available.

Possible Functions: Characteristics that typify LFH sites and have consequences for potential performance of functions include:

- shorter growing seasons (as compared with LFV sites) and thicker ice cover in winter
- lower nutrient concentrations and sometimes lower pH (as compared with LFV sites)
- more stable water levels and less human influence (as compared with LFV sites)

LFH sites perform all the functions except Thermoregulation (as defined by this guidebook) and Water Storage & Delay. They may or may not support Anadromous Fish Habitat, depending on whether their associated lake has an outlet channel accessible to fish. Compared with all other subclasses, most LFH sites in Oregon have high capacity for Resident Fish Habitat and Amphibian Habitat. They may have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Many LFH sites are on public lands and enjoy some degree of protection due to Oregon's Forest Practices Act and other regulations. Probably the most common threat to LFH sites is trampling of vegetation by livestock and recreationists. Erosion by waves and scouring by ice are common natural disturbance factors that affect LFH vegetation.

Lacustrine Fringe wetlands:

Winema National Forest

Kirk Ponds, Lane County – formerly riverine, this partly constructed wetland is not contiguous to Fern Ridge Reservoir but receives much of its water from it

Subclass: **Lacustrine Fringe, Valley (LFV)**

Identification: In addition to meeting the criteria for the Lacustrine class, sites in the LFH subclass are located in lakes that are (a) in valley positions, and/or (b) lower than the average elevation of their region.

Distribution and Variability in Oregon: Most LFV sites in Oregon are located on the margins of reservoirs, or have been created in large gravel pits outside of the 2-year floodplain. According to the GNIS database, the percentage of the total number of named lakes + reservoirs in each region that are reservoirs is:

	Lakes That Are Reservoirs
Owyhee Uplands	97%
High Lava Plains	90%
Columbia Basin	87%
Klamath Mountains	84%
Western Interior Valleys	78%

	Lakes That Are Reservoirs
Basin & Range	76%
East Slope Cascades	68%
Blue Mountains	68%
Coast/ Range	51%
West Slope Cascades	12%

Possible Functions: Characteristics that typify LFV sites and have consequences for potential performance of functions include:

- longer growing seasons (as compared with LFH sites) and thicker ice cover in winter
- higher nutrient concentrations and sometimes higher pH (as compared with LFH sites)
- less stable water levels and greater influence of human activities (as compared with LFH sites)

LFV sites perform all the functions except Thermoregulation (as defined by this guidebook) and Water Storage & Delay. They may or may not support Anadromous Fish Habitat, depending on whether their associated lake has an outlet channel accessible to fish. Compared with all other subclasses, most LFH sites in Oregon have high capacity for Resident Fish Habitat and Amphibian Habitat. They may have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Water level fluctuations from irrigation water withdrawals and reservoir management activities are the most typical alterations at LFH sites. Aquatic bed vegetation in LFH sites is often highly sensitive to turbidity originating from sediment runoff or erosion of shorelines from water level fluctuation. With their bottom-foraging habits, carp (*Cyprinus carpio*) -- an abundant and widespread nonnative fish that commonly inhabits LFH sites -- also aggravate the normal resuspension of sediments by wind and waves (Ivey et al. 1998). Many LFV sites have been intentionally filled or cut off from their adjoining lake to create recreational beaches, shoreline home sites, and boat launch areas. Along many lakes and sloughs, bank erosion from timber harvesting, flow diversion, grazing, and residential development has resulted in wetland loss. However, there also are instances where increased sediment inputs from these activities have lessened the shoreline gradient and nearshore depth sufficiently to allow wetland vegetation to become established for the first time (Hesser and Gangstad 1990). Natural disturbances that have been historically important to plant succession in LFV sites include wind and wave erosion and herbivore (e.g., muskrat) foraging.

3.7 Class: Estuarine Fringe

Estuarine Fringe sites are sites whose hydrodynamics are influenced mainly by the daily bidirectional movement of tides. They frequently adjoin Riverine sites. Their deepwater edge is defined by the 2 meter depth contour, estimated at mean daily low tide. Estuarine Fringe sites do not always contain surface water and vegetation. They can include mud and gravel tidal flats. They may receive runoff from adjoining uplands and some may seem dry at the surface. Nonetheless, their water tables are influenced primarily by tidal fluctuations.

The hydrology and chemistry of wetland sites in the Estuarine Fringe class is largely influenced by the geomorphic type of estuary in which they are situated (see Duxbury 1987 for classification and functional profiles of the types of estuaries found in the Pacific Northwest). Except for the Columbia River estuary and several small dune-associated estuaries in southern Oregon, nearly all Oregon estuaries are the "drowned river" type (Boule and Bierly 1987). Water within these estuaries is well-mixed, with wind and tidal currents playing a key role in determining how far upriver the higher-salinity waters penetrate at any given time. Water residence times are long and productivity is generally high.

Salt marshes, brackish sloughs, saltwater lagoons, lower tidal channels, salt ponds, and salt pannes are all assigned to the Estuarine Fringe class. Kelp and eelgrass beds and other aquatic bed vegetation situated deeper than 2 meters is not covered by this guidebook. Literature and data on salt marshes in the Pacific Northwest was compiled by Proctor et al. (1980) and Selisker and Gallagher (1983), and information on carbon, nitrogen, and phosphorus cycling in the region's estuaries was summarized by Wissmar et al. (1986).

Estuarine Fringe sites are of course located mainly along the coast, but extend inland dozens of miles, up to the head of tide. One source of information is the systematic sample of all NWI maps for Oregon done by SRI/ Shapiro (1995), which estimated 271,940 acres of tidal wetland (90% in the Coast/ Range region).

This guidebook is initially proposing two subclasses of Estuarine sites for Oregon:
  Estuarine Fringe, River-sourced (EFR)
  Estuarine Fringe, Embayment (EFB)
These are described in the following subsections.

Salt marsh, Tillamook County -- Estuarine Fringe, Embayment
photo courtesy of Bob Frenkel

Subclass: **Estuarine Fringe, River-sourced (EFR)**

Identification: In addition to meeting the criteria for the Estuarine class, sites in the EFR subclass receive most of their water inputs from rivers rather than the ocean. During rising tide the normally unidirectional, outflowing river currents collide with incoming tidal currents, causing a noticeable velocity reduction or even reversal of river currents at the site. Water level in most EFR sites also rises noticeably during seasonal runoff events and some individual storms. Salinity may vary from freshwater to slightly brackish (usually) to saline, depending on season, distance from the ocean, and monthly tidal magnitude. Many EFR sites are mapped by NWI as "Riverine Tidal." EFR sites can contain submersed aquatic bed vegetation, emergents, woody vegetation (uncommonly), and unvegetated tidal flats.

Distribution and Variability in Oregon: Most EFR sites are sloughs and marshes that border higher-order, low-gradient rivers such as the Columbia, before the rivers substantially widen into bays. Many are the result of tidal flows essentially damming the seaward flow of rivers. In the Columbia River, tidal influence extends upriver to the Bonneville Dam. The systematic sample of all Oregon NWI maps done by SRI/ Shapiro (1995) estimated that about 24% of Estuarine Fringe sites are EFR as would be defined by this guidebook.

Possible Functions: Characteristics that typify EFR sites and have consequences for potential performance of functions include:

- an extremely stressful environment: plants and animals must cope with strong shifting currents, sudden presence/ absence of surface water, and nutrient concentrations, temperatures, turbidities, and salinities that shift hourly and sometimes by orders of magnitude;

- rapidly shifting water chemistry promotes rapid cycling (adsorption, remobilization) of some nutrients;
- turbidity is typically high, thus limiting some submersed aquatic plants and aggravating dissolved oxygen deficits;
- denitrification rates are probably lower than in freshwater nontidal situations;
- although perhaps historically important in EFR channels and important to maintaining their structure, submersed wood is now much rarer than in most non-estuarine subclasses;
- in Oregon, ice is almost never present;
- sedimentation rates may be lower than in EFB sites; for example, in the Columbia Estuary silt accumulates in only about 10% of the estuary (Hubbell et al. 1972).

EFR sites perform all the functions except Thermoregulation and Water Storage & Delay (as defined by this guidebook). They often have exceptionally high capacity for Anadromous (wintering salmon) and Resident Fish Habitat (Aitkin 1997). Although substantial sediment deposition occurs, sediments can easily be eroded and resuspended by changing coastal currents. EFR sites have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Being located at the terminus of most river basins, these sites are typically surrounded by development and/or are subjected to high loads of contaminants. Many EFR sites in larger estuaries have been converted into deepwater harbors, or have been diked, drained, and thus converted to freshwater Depressional sites or to upland in order to provide land useful for agriculture (Boule and Bierly 1987). Many have been partly or completely filled during the development of transportation facilities. Along the Columbia River, the acreage of estuarine wetlands declined by 25% between 1948 and 1991, partly due to extensive channelization (Allen 1999). Along fresher reaches of the tidal river below Bonneville Dam (reaches mapped as "riverine tidal," wetlands registered a 37% decline between 1948 and 1991, mainly as the result of urban development (Allen 1999). Major storms are the primary natural disturbance factor, although herbivores can cause some locally important alteration of vegetation.

Subclass: **Estuarine Fringe, Embayment (EFB)**

Identification: In addition to meeting the criteria for the Estuarine class, sites in the EFB subclass usually receive more of their water inputs from the ocean than from rivers. EFB sites may be fed by input channels and contain internal channels. Water level in most EFB sites does not rise noticeably during seasonal runoff events or in response to individual storms. Salinity is usually brackish to saline. Probably all EFB sites are mapped by NWI as "Estuarine" EFB sites can contain submersed aquatic bed vegetation, emergents, and unvegetated tidal flats.

Distribution and Variability in Oregon: Most EFB sites are sloughs and marshes that border bays and estuaries, outer parts of Alsea estuary. The systematic sample of all Oregon NWI maps done by SRI/ Shapiro (1995) estimated that about 76% of Estuarine Fringe sites are EFB as defined by this guidebook. Distinct productivity differences exist among different estuaries and coastal waters in Oregon (Thom 1987, and B. Menge, Oregon State University, *pers. comm.*) and these subregional differences might be reflected at EFB sites.

Possible Functions: Characteristics that typify EFB sites and have consequences for potential performance of functions include:

- a moderately stressful environment: plants and animals must cope with sudden presence/ absence of surface water (tides), and with nutrient concentrations, temperatures, and salinities that shift hourly;
- rapidly shifting water chemistry promotes rapid cycling (adsorption, remobilization) of some nutrients;
- denitrification rates are probably lower than in freshwater nontidal situations;
- in Oregon, ice is almost never present;
- wind and waves are important stressors at some times of the year.

EFB sites perform all the functions except Water Storage & Delay and Amphibian Habitat. They often have exceptionally high capacity for Anadromous and Resident Fish Habitat, as well as Waterbird Habitat. They have intermediate or low capacity for the other functions. However, to assess the functions accurately in an individual case it is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA.

Vulnerability: Many EFB sites, particularly in the larger estuaries, have been diked and thus converted to freshwater Depressional sites or to uplands used for agriculture. Some have been partly or completely filled during the development of transportation facilities and harbors. Major storms are the primary natural disturbance factor, although herbivores can cause some locally important alteration of vegetation. Excessive input of sediments and reduced scour at some sites can result in gradual reduction in tidal inundation frequency and eventual conversion of the site to upland. Additions of sediments also can create new substrates that allow existing marshes to grow outward (e.g., Johannessen 1973).

Table 6. Summary: possible functions of HGM subclasses in Oregon

Note: This table is based entirely on the author's judgments, inasmuch as very few scientific studies have compared functions across multiple wetland classes. To assess the functions accurately in an individual case it also is essential to visit the particular site, consider its larger watershed context, and use methods such as contained in Volume IA. Information in the table below should not be used as the sole justification for exchanging one wetland type for another.

Legend
3= one of the more important subclasses for this function
2= function present in *many* sites of this subclass; capacity usually *greater* than in several other subclasses
1= function present in *some* sites of this subclass; capacity usually *less* than in several other subclasses
0= function is minimal or absent in typical sites of this subclass

Subclasses: FT= flow-through, I= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	HW		V	HW	R	B
Water Storage & Delay	1	2	2	3	2	2	2	1	1	1	0	0	0	0
Sediment Stabilization	1	2	3	3	2	2	2	1	1	1	2	1	1	1
Phosphorus Retention	1	2	2	3	2	3	1	2	2	2	2	2	2	2
Nitrogen Removal	1	2	2	3	2	1	1	2	2	2	2	2	2	1
Thermo-regulation	3	2	0	0	0	0	0	3?	3	0	0	0	2	1
Primary Production	3	2	1	1	2	1	1	2	2	1	2	2	2	2
Anadromous Fish	3	3	0	0	1	0	0	1?	0	0	2?	1?	3	3
Resident Fish	3	3	1	0	2	1	1?	2?	1?	0	3	3	3	3
Amphibian Habitat	1	2	3	2	3	1	2	3	3	2	3	3	0	0
Waterbird Habitat	2	3	3	2	2	3	1	2	1	3	3	2	2	3
Biodiversity Support	2	2	2	2	2	2	2	2	2	2	2	2	2	2

3.8 Summary of HGM Classes by Region

The narrative following Table 7, below, describes the geographic distribution of each of the six HGM classes in Oregon. These descriptions are based entirely on published sources and the author's experience. No spatial data capable of defining distributions of HGM classes were available for analysis at this time. The regions are shown in Figure 1.

Table 7. Geographic occurrence of HGM subclasses in Oregon

Legend:
blank = sites of this subclass are probably absent from this region
U = present but less extensive than many other subclasses in this region
C = present and one of the more extensive subclasses in this region
***** = present, and geographically this region is one of the more important for this subclass
1, 2, etc.= see corresponding footnotes below table

Regions: C/ R = Coast and Coast Range; **WV** = Western Interior Valleys; **KM** = Klamath Mountains; **WC** = West Slope Cascades, **EC** = East Slope Cascades & Klamath Basin; **HP** = High Lava Plains; **CB** = Columbia Basin; **BM** = Blue Mountains; **BR** = Basin & Range; **OU** = Owyhee Uplands

Class	**Subclass**	**C/ R**	**WV**	**KM**	**WC**	**EC**	**HP**	**CB**	**BM**	**BR**	**OU**
Riverine	Flow-through	C*	C	C	C*	C	C	C	C*	C	C
	Impounding	C*	C	C	C*	C	C	C	C*	C	C
Depressional	Closed, Permanently Flooded	U**2**	U	U	U	C	U	U	U	C **4**	U
	Closed, Nonperm. Flooded	U**2**	U	U	U	U	U	U	U1	C **4**	C
	Outflow	C	U**3***	U	U	U 7	C	U	C**13**	C	U
	Alkaline					C	U	U**19**	U**10**	C **4***	C
	Bog	U **6***	U9		U**20**	U			U**12**		
Slope	Valley	U	U**17**	U	U	C**14**	U	U	C	U **14**	C **14**
	Headwater	U	U	U	C	C*	U	U	C**11**	U	U
Flats	--	U	C*	U1	U**15**	C	U				
Lacustrine Fringe	Valley	C	C **8***	U**16**	U**16**	C **5***	U	U	U	U	U
	Headwater	U		C	C	C	U		C	U	
Estuarine Fringe	River-sourced	C*	U**18**								
	Embayment	C*									

NOTES (correspond to numbers above):
1. e.g., vernal pools, in Rogue Valley and elsewhere
2. e.g., diked former tidal marshes
3. e.g., some oxbows formerly within the 2-year floodplain
4. e.g., many Warner Basin and Alvord Basin wetlands
5. e.g., many Klamath Basin marshes
6. e.g., Gearhart Bog, Woahink Bog, Sandlake Bog, Pond Lily Lake, upper Neskowin Marsh, Hunter Creek Bog
7. e.g., much of Sycan Marsh
8. e.g., Fern Ridge Reservoir marshes, some oxbow lakes near Willamette River
9. Peach Cove Bog
10. e.g., some Artemesia cana/ Poa cusickii playas
11. e.g., some avalanche tracks
12. e.g., some Kalmia polifolia shrub swamps
13. e.g., many mid- to high-elevation wet meadows
14. e.g., many desert springs, including non-alkaline hot springs
15. e.g., many subalpine snowmelt pools and wet meadows
16. e.g., reservoir fringe marshes
17. e.g., part of Labish Plains complex south of Woodburn (at least formerly)
18. e.g., parts of Columbia Slough wetland complex
19. e.g., greasewood flats, playas with annual forbs and grasses
20. e.g., Gold Lake Bog

Coast/ Range[1]

Estuarine Fringe sites within this region occur, logically, nearest the coast. Riverine sites often are situated in areas of accumulated sediment near mouths of rivers that have cut through the mountains. Flats, Depressional, and Lacustrine Fringe sites occur partly as wind-scoured interdune areas, sometimes with tributary streams, especially where the Coast Range front is distant from the ocean. These interdune wetlands are most prevalent in the Clatsop Plains area (Columbia River to Gearhart); from Heceta Head to Coos Bay; and between Bandon and Cape Blanco. More restricted areas of interdunal wetland occur between Tillamook Bay and Waldport. Slope sites are uncommon and occur mostly along the eastern edge of the region, where foothills join the Western Interior Valleys region.

Along the Columbia River, the acreage of estuarine wetlands declined by 25% between 1948 and 1991, partly due to extensive channelization (Allen 1999). Little information is available on trends of riparian/ wetland systems elsewhere in the Coast/Range region. Changes in forest cover are reported by Ripple et al. (2000). Using various techniques, Kagan et al. (1999) estimated a 96% decline in the region's freshwater marshes, an 89% decline in salt marshes, an 81% loss of riparian habitat, and a 34% increase in open water since the mid-1800's. Wetland mitigation outcomes in the Coos Bay watershed were examined by Shaffer (1999), and individual restoration projects have been examined by Morlan (1991), Pinit (1999), and others. Many areas in the Coast/Range region have been affected at least temporarily by diking, drainage, fires (e.g., Tillamook burn), and the alterations of water flow and sediment that accompany agriculture, logging, and urbanization. The Lower Columbia River and estuary receive measurable loads of contaminants from the industrialized Portland area (McCarthy & Gale 1999), but ecological effects have seldom been investigated. In addition, a significant source of nitrogen to water bodies was (at least historically) the annual immigration of spawning salmon. Wetlands closer to the coast have always been exposed to significant quantities of nitrogen from precipitation moving landward from the nitrogen-richer ocean.

Data on the characteristics of woody debris in Coast Range RFT sites has been reported by Froelich (1973), Swanson et al. (1982), Veldhusien (1990), and probably others. A survey of 2300 miles of channels in coastal Oregon watersheds found large woody debris to be at "desirable" levels in 25% of the forested streams and 2% of the agricultural streams (Oregon Plan, 1998 Annual Report). Stream shading was found to be "adequate" on 90% of the stream miles in forested watersheds but on only 60% of the stream miles in agricultural watersheds. In forested watersheds, shrubs and grasses comprised 27% of the streamside cover whereas in agricultural watersheds they comprised 50% of the cover (Oregon Plan 1998 Annual Report).

Even in Coast Range riparian areas that had not been logged or burned for 145 years, shrubs rather than trees dominated in 52% of such areas. In areas not subjected to significant disturbances, tree recruitment is so limited that stands of trees seldom become dominant or self-sustaining in the riparian zone (Nierenberg & Hibbs 2000). In particular, the recruitment of

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[1] Throughout this guidebook, the region is termed Coast/ Range instead of Coast Range, to emphasize the fact that it includes all lowland coastal areas as well as the Coast Range itself.

coniferous trees in Coast/ Range riparian sites appears to be declining while stands of nearly monotypic red alder are becoming more prevalent (Taylor and Adams 1986, McComb and Hagar 1992, Hibbs and Giordano 1996, Hayes et al. 1996, Hess 1999, Pabst & Spies 1998, 1999). Large conifers were dominant at only 10% of the 2300 stream miles surveyed since 1990 (Oregon Plan 1998 Annual Report). Nonetheless, some trees persist in Coast Range riparian areas due to bank sloughing and debris avalanches, which create seed beds where trees become established and dominate (Hayes et al. 1996). Such natural disturbances may occur in this region at a rate of 2.6 events per km of stream per century (Nierenberg & Hibbs 2000).

Western Interior Valleys

Estuarine Fringe (River-sourced) sites are uncommon within the region and occur mainly along the Columbia River. Slope sites also are uncommon, and are likely to exist mainly below impoundments, along geologic faults on the Valley floor, and along the foothill edges of the region. Most of the Lacustrine Fringe sites have been constructed as reservoirs, e.g., Fern Ridge near Eugene.

Riverine and Flats sites predominate, but have been extensively altered compared with their historical levels. It is likely that alteration has increased the proportional area of Depressional and RFT (Riverine Flow-through) sites, at the expense of RI (Riverine Impounding) and Flats sites. Many Flats sites have been converted to Depressional or have been eliminated altogether.

Historically, wet prairie was the most extensive wetland type in the region (see Section 3.5). Swales, sometimes with scattered ash thickets, were also common. Large, willow-dominated beaver swamps occurred regularly along channels. River floodplains contained extensive networks of wooded sloughs (see Section 3.2). Using a review of General Land Office records and other techniques, Kagan et al. (1999) estimated a 19% decline in the region's freshwater marshes, an 81% loss of riparian habitat, and a 120% increase in open water since the mid-1800's. Wetland and riparian areas undoubtedly receive significant quantities of pesticides, excessive nutrients, and other chemical contaminants from agricultural and urban parts of the region (Bonn 1999, Qian 1999), but effects on biological community structure and processes are largely unstudied.

Klamath Mountains

Riverine sites likely predominate. Estuarine Fringe sites are absent, and Depressional sites are uncommon in this mountainous region. A major but declining concentration of wetlands is in the Rogue Valley near Medford, where wetlands classified mostly as Flats (e.g., vernal pools) are present. Because of the region's rugged terrain, Slope sites may be more common than in most other regions. Lacustrine Fringe sites occur along higher-elevation lakes in the Siskiyou Mountains, and along some reservoirs. Little information is available on trends. Using various techniques, Kagan et al. (1999) estimated a 96% decline in the region's freshwater marshes, an 89% decline in salt marshes, an 94% loss of riparian habitat, and a threefold increase in open water since the mid-1800's. Many sites have been affected by filling, drainage, and the alterations of water flow, sediment, and nutrients that accompany agriculture and logging. For example, one survey of 21 streams in part of this region (upper South Umpqua Basin) found that changes in low flow channel width (1937 to 1993) were statistically correlated with timber harvest and road density (Dose and Roper 1994). Declines in invertebrate taxonomic richness have been linked to impacts from logging (Fore et al. 1996). Several public wetlands that hosted rare plants recently have been methodically vandalized.

West Slope Cascades

Riverine sites likely predominate. Depressional and Flats sites are uncommon in this mountainous region, existing mainly as wet meadows and snowmelt basins. Because of the region's rugged terrain, Slope sites probably are relatively common, particularly where logging roads with undersized culverts have partially dammed the outlets of montane meadows and snowmelt basins. Lacustrine Fringe sites occur along some of the higher-elevation lakes and foothill reservoirs.

Using various techniques, Kagan et al. (1999) estimated a 47% loss of riparian habitat, 63% increase in open water, and net increase of 9890 acres of marsh in the region since the mid-1800's. Particularly in lower elevations of the region, reservoirs constructed in the 1940's through 1960's inundated some wetlands but presumably created others of different hydrogeomorphic types. Regulated flows issuing from these reservoirs impose a more East Slope Cascade type of flow regime on West Slope Cascade streams. That is, water is colder and more seasonally attenuated (Grant 1997). Timber harvest and accompanying access roads have extensively altered drainage networks, creating wetlands in some areas and eliminating them (directly or indirectly) in others. Up to 25% of mid-elevation public forest lands and 100% of some low-elevation private lands have been harvested (Grant 1997). Road networks potentially have increased the number of channels per unit area by up to 40%, thus increasing the amount of water input to existing wetlands and channels (Wemple 1994, Grant 1997, Thomas & Megahan 1998).

East Slope Cascades

Wetland acreage is concentrated mostly in the Klamath Basin, where Lacustrine Fringe sites occupy large areas around Upper Klamath Lake and Klamath Marsh. Lacustrine Fringe sites also occur in the Three Sisters area. Depressional sites occur as snowmelt basins and are uncommon in this mountainous region. Flats exist mainly as wet meadows. Because of the region's rugged terrain, Slope sites probably are relatively common, particularly where logging roads with undersized culverts have partially dammed the outlets of montane meadows and snowmelt basins. Large riverine sites occur primarily along the Deschutes, Sprague, and Williamson Rivers. Areas with porous volcanic rocks act as geologic reservoirs, storing groundwater during the melt season and releasing it slowly during the low flow summer months (Grant 1997).

Except for the Klamath Basin part of the region, little quantitative information is available on wetland and riparian trends. Some sites have been affected at least temporarily by the alterations of water flow, sediment, and nutrients that accompany agriculture, logging, and urbanization (Adams & Cho 1998, Sytsma 2000). Enormous efforts were undertaken in the early 1900's to drain vast acreages of wetlands in the Klamath Basin, with consequent pollution of lakes with excessive nutrients (Snyder & Morace 1997). A few major restoration projects are now underway at a local scale. Excessive nutrient and pesticide runoff imperils the biotic integrity of many of the remaining sites in the Klamath Basin. Frequencies of natural patches in the forest canopy have been documented for part of the East Slope Cascades in Washington (Hessburg et al. 1999).

Columbia Basin

Flats and Depressional sites are uncommon, whereas Riverine, Slope, and Lacustrine (reservoir) Fringe sites predominate. Many Riverine sites were inundated by construction of Columbia River dams in the mid-20th century. Some RI and DOF wetlands developed at sites mined for gravel (used in dam construction), and in areas impounded by access roads. Loess (wind-blown sediments) are more common in this region than elsewhere in Oregon. Groundwater levels in the region have been declining by as much as 20 feet per year, and surface waters are becoming increasingly saline (Vaccaro 1986). Little information is available on recent trends. Using a review of General Land Office records and other techniques, Kagan et al. (1999) estimated a 95% decline in riparian habitat, a 1% decline in open water, and a net addition of 262 acres of marsh in the region since the mid-1800's. Some sites have been affected at least temporarily by the alterations of water flow, sediment, and nutrients that accompany agriculture and logging in this region (Douglas et al. 1998, Matheussen et al. 2000). From a sample of eastern Oregon subwatersheds, the ICBEMP project (Quigley and Arbelbide 1997) reported that many riparian areas show a reduction in the shrub and large tree components between the pre-1950 period and the post-1980 period.

High Lava Plains

Riverine sites predominate. Some Depressional sites may exist on the outer fringes of the floodplain of the Crooked River and its larger tributaries. Lacustrine Fringe sites are restricted almost entirely to reservoir margins. Slope sites may be moderately common at the margins of valleys. Few unlatered Flats remain. Areas with porous volcanic rocks act as geologic reservoirs, storing groundwater during the melt season and releasing it slowly during the low flow summer months. Little information has been compiled on trends. Using various techniques, Kagan et al. (1999) estimated a 100% decline in the region's wet meadows and 100% decline in playa, but a 55% increase in riparian habitat, a 103% increase in open water, and a net addition of 5866 acres of marsh in this region since the mid-1800's. Some sites may have been affected at least temporarily by the alterations of water flow, sediment, and nutrients that accompany agriculture and logging activities in this region.

Blue Mountains

Riverine, Slope, and Lacustrine Fringe sites are all present in substantial numbers. Wetlands are largely concentrated in intermountain basins such as those of the Silvies, Grande Ronde, Snake, and Powder Rivers. The relatively few Flats and Depressional sites that occur in the region are probably concentrated in these valleys as well. Some of Oregon's few glacially-derived montane basins are located in this region.

Little regionwide information has been compiled on trends. Using various techniques, Kagan et al. (1999) estimated a 98% decline in the region’s wet meadows, 100% decline in playa, and 83% decline in marshes, but threefold increases in riparian habitat and open water in this region since the mid-1800’s. Along the Middle Fork John Day River, McDowell (2000) commented that human activities have resulted in “loss of channel sinuosity, loss of riparian woody vegetation, probable loss of large woody debris and pools, and reduced potential for adjustment because of bank stabilization projects.” Similar changes were noted along the Grande Ronde (Lytjen 1998). Changes have been wrought by alluvial gold mining, dredge mining, beaver trapping, livestock grazing, haying, irrigation, logging, road and railroad building, and placing of bank stabilization structures.

Basin & Range

Lacustrine Fringe and Depressional sites predominate, especially in the Warner Basin, Silver/ Summer Lakes area, and Malheur/ Harney Lakes area. Water levels can show enormous variation from year to year and decade to decade. Most sites were formed where fault lines cross ancient lake sediments, but some (e.g., Harney Lake) were formed by lava flows that blocked ancient outlets. Riverine sites are relatively uncommon and often are not permanently flooded. Playas (Depressional Alkaline sites) are relatively common, as in the Alvord Basin. Depressional and Slope sites in this region are often the result of construction of small ponds for irrigation and livestock watering, and return flows from irrigation. Flats sites were probably never common, and few if any remain.

Little information has been compiled on trends. Using various techniques, Kagan et al. (1999) estimated a 100% decline in the region’s wet meadows and 61% decline in marshes, but a threefold increase in riparian habitat, 34% increase in open water, and 5% increase in playa in this region since the mid-1800’s. Some wetland/riparian sites may have been affected at least temporarily by the alterations of water flow, sediment, and nutrients that accompany agriculture (mostly grazing and irrigation diversion) activities in this region.

Owyhee Uplands

Acreage of wetland/ riparian sites currently is very limited. Riverine sites probably predominate, being located mainly along the Owyhee, Malheur, and Snake Rivers. Tiny pockets of Lacustrine Fringe wetland occur along the Owyhee Lake (Reservoir). Many Depressional and Slope sites in this region are the result of construction of small ponds for irrigation and livestock watering, and return flows from irrigation.

Little information has been compiled on trends. Using various techniques, Kagan et al. (1999) estimated a 100% decline in the region’s playas, but a 18% increase in riparian habitat, 104% increase in open water, and a net increase of 5866 acres of marsh in this region since the mid-1800’s. Some wetland/riparian sites have been affected at least temporarily by the alterations of water flow, sediment, and nutrients that accompany agriculture (mostly grazing and irrigation diversion) activities.

3.9 Processes Controlling the Regional Distribution of Wetlands

By understanding the environmental factors and processes that support the natural creation and evolution of wetlands in landscapes, we can better predict where wetlands presently occur and where, if not already present, they will be most viable if constructed or restored. This knowledge is key to establishing performance standards for wetlands at a landscape level (see Section 9 of Volume IB for discussion). Fundamentally, wetlands occur as a result of interactions between topography, watershed water yield (precipitation minus evapotranspiration), and soil attributes. Wetland water regimes reflect the seasonality and source of water inputs (Table 8). In Oregon, digital data describing topography are available at fairly coarse vertical scales, limiting their usefulness for discerning wetlands. Water surplus values (ratio of annual evapotranspiration to precipitation) have been modeled for every 4 km^2 area of eastern Oregon, and evapotranspiration calculations with even finer resolution (200 m) are available from Martinez-Cob (1990) for parts of the Western Interior Valley, Western Slope Cascade, Columbia Basin, Blue Mountains, High Lava Plains, Basin & Range, and Owyhee Uplands regions. Soils have been mapped digitally for most of the state at a coarse scale (1:250,000) and at finer scales in a few regions (e.g., southern Willamette Valley).

Table 8. Usual response of selected water regime variables as a function of a wetland/ riparian site's water source

Hydrologic Attribute	Primary Water Source			
	Groundwater Dominated	Snowmelt Dominated	Rain-On-Snow Dominated	Winter Rain Dominated
Baseflow (or Baselevel) Index	Highest	High	Low	Moderate
Coefficient of Flow (or Water Level) Variation	Lower	Lower		
Predictability of Daily Flow or Daily Water Level	Higher	Higher		
Flood frequency	Lower	Higher	Higher	Higher
Seasonal Predictability of Flooding		Highest		
Flood Initiation Date	Most variable	Latest (May)	Mid (March-April)	Earliest (Dec. - Jan.)

Section 4. Profiles of Functions and Their Potential Value

This section presents profiles of nine functions that typify wetland and riparian systems of Oregon. As used in an HGM programmatic context, "profiles" are hydrogeomorphic descriptions of ecosystems, and can be narrative or in tabular form as quantitative data (Brinson 1993). The development of profiles has involved examination of regional scientific literature, expert opinion, review of existing assessment methods and models, compilation and analysis of available spatial data, and ultimately a synthesis of this information. The descriptions are somewhat technical and are written for persons with a background in wetland science. Some of the terms are defined in Appendix A of Volume IA.

The particular functions presented here were limited to nine, but there are potentially dozens. These nine functions are all compatible with a wetland/ riparian site being self sustaining in the long term, and are recognized widely by scientists and the Clean Water Act. These functions go by slightly different names in different publications, some describing them more inclusively or in more value-laden terms than others, but the principles described remain similar.

- Hydrologic Functions:
  - Water Storage & Delay
- Water Quality Functions:
  - Sediment Stabilization & Phosphorus Retention
  - Nitrogen Removal
  - Thermoregulation
- Biological Functions
  - Primary Production
  - Fish Habitat:
    - Anadromous Fish Habitat
    - Resident Fish Habitat
  - Wildlife Habitat Functions:
    - Amphibian Habitat
    - Waterbird Habitat
  - Support of Characteristic Native Vegetation

Each of these subsections begins with a description of the function and examples of published studies that have supported its existence in Oregon wetland/ riparian systems. A footnoted table is then presented which lists variables that might predict the function, as it is defined in this guidebook. For some functions, a second table is presented which lists variables that might predict the function's values. Definitions and procedures for estimating these variables are not specified because that may change somewhat with ecoregion. However, some that are pertinent to the Willamette Valley are addressed in Appendix A (Glossary and Procedures) of Volume IA. Where available, regional literature that supports use of each variable is cited in the footnotes below the table, but in many instances the variables should be viewed more as hypotheses than as facts. The lists of variables are not comprehensive and should be viewed simply as "starting points" for the development of HGM-based assessment methods appropriate to each ecoregion. They do not by themselves constitute an assessment method.

4.1 Water Storage & Delay

This function is similar to and includes at least in part:

- from OFWAM (Roth et al. 1996), the "Hydrologic Control" function
- from Hruby et al. (1999, 2000), the functions:
  - Reducing Peak Flows
  - Maintaining Seasonal Low Flows to Streams
  - Decreasing Downstream Erosion & Flooding
- from Gersib (1997), the functions:
  - Flood Flow Storage & Desynchronization
  - Base Flow Maintenance
  - Groundwater Recharge

- from Smith et al. (1995), the functions:
    - Short-term Storage of Surface Water
    - Long-term Storage of Surface Water
    - Storage of Subsurface Water
    - Moderation of Groundwater Flow or Discharge

Function Documentation, Processes, and Variables

Wherever a landscape contains a constriction, a relatively flat surface, or a depression (i.e., a "basin"), water falling on or running off the land surface will be temporarily stored and its total volume reduced by evaporation. In Oregon, wetlands are mostly synonymous with natural depressions and constrictions. Thus, wetland basins are positioned to delay, and sometimes store and remove, water as it flows downgradient across the landscape. Wetland/ riparian sites in good condition dissipate hydraulic energy from wind, waves, currents, and/or overland runoff. They also are able to hinder the percolation of water sufficiently to allow the development of hydrophytic vegetation. Sites that occupy only 0.05% of the watershed above a floodable area may reduce downstream flood peaks by about 0.1%; sites that occupy 2.7% of a watershed may reduce downstream flood peaks by 5% (Suter 1995). Reductions in flood peaks that are as slight as these can translate into avoidance of thousands of dollars in property and resource damage.

The amount of water that wetlands delay, evaporate, or transfer into long term storage in unconfined aquifers can represent most of a watershed's runoff or only a barely measurable fraction. The capacity of a watershed's floodplains and wetlands for delaying or removing runoff depends fundamentally on the balance between the volume of input to each basin, relative to the empty storage volume available in each basin. Large volumes of runoff arriving in a short time can quickly overwhelm the storage capacities of basins, making them virtually irrelevant as mitigators of downstream flood peaks. Likewise, even small volumes of runoff can overwhelm the storage capacities of basins if the capacities already have been saturated by recent runoff. Logically, the larger is the ratio of wetland area to watershed area, the greater is the contribution of wetland basins to their watershed's hydrologic processes. Five factors or mechanisms primarily determine the amount of storage space available in wetland basins at a given moment:

1. Morphology. Basins that are large and deep will have the greatest space potentially available for storing runoff. Basins that normally are free of ice during heavy runoff events will have more storage space available then. Basins that lack an outlet will store or remove nearly all the runoff that enters them. Basins whose outlets are constricted (very narrow) relative to basin width and volume are almost as effective as closed basins at delaying the downslope passage of runoff. Constriction can be the result of natural morphology of a watershed, or of narrowing caused by landslides, beaver dams, dense vegetation (floodplain "roughness"), or human structures (culverts, dams, water control structures).

2. Evaporation (including evapotranspiration, i.e., water loss via transpiring plants). The more rapidly the detained water in a basin is removed by evaporation, the greater will be the space available for storing runoff from the next storm. Basins that are shallow and wide have more of their water exposed to evaporation, and higher evaporation rates due to better air circulation and more complete warming of the water column. Regionally, basins in warmer, more arid climates have higher evaporation. Saline waters also evaporate more slowly. At a landscape scale, a larger portion

of total runoff is likely to be evaporated if it is distributed among many small basins as opposed to a few larger ones.

Basins with a dense plant cover can lose substantial water by transpiration. But, they also have less evaporation. This is due to the vegetation shading and cooling the water, facilitating infiltration, blocking wind, and maintaining a moisture-conserving layer of plant litter on the soil. Canopies and root systems of wooded sites can also be important for intercepting and temporarily storing moisture, e.g., condensation or "fog-drip," temporary storage via capillary action, and interception of blowing snow (Harr 1982, Berris and Harr 1987). The role of vegetation in regulating the upward discharge of groundwater into wetland/ riparian sites also is variable. Water uptake by plants creates unsaturated conditions in sediments, which helps groundwater flow upward (or infiltration flow downward). Plants also trap fine suspended particles from the water column; when particles are deposited they can gradually reduce the transmissivity of the wetland/ riparian sediments and thus reduce the upward movement of groundwater or downward movement of infiltrating water.

In basins with particular types of deep-rooted plants (phreatophytes), water loss via transpiration is the overriding net effect. In basins with other plants, the primary effect often is water conservation (storage, infiltration, and/or facilitation of groundwater discharge into the basin)(e.g., Ponce and Lindquist 1990, Li et al. 1994). Whether water loss or conservation predominates depends not only on the type of vegetation, but on the extent, density, and height of the plant community (foliage biomass), watershed aspect, prevailing wind direction, and runoff amount during the May-August period. In 2 wetlands that Reinelt and Taylor (1997) studied in the Seattle area, evapotranspiration and infiltration removed only 1% annually of the water inputs to wetlands; most outputs were via surface flow.

3. <u>Infiltration and Subsurface Storage</u>. In basins where incoming runoff or flow is rapidly evaporated or infiltrates quickly through sediments, the sediments in extensive parts of the basin may become seasonally unsaturated. While unsaturated, the pore space within these sediments provides a minor amount of additional storage space for runoff. When the sediments become saturated, they uncommonly become conduits for water that travels downward to recharge unconfined aquifers. Sediments that are naturally permeable or are made more permeable by extensive, deep root networks are more likely to become seasonally unsaturated or serve as conduits for recharge during late fall and winter when vegetation is dormant. Basins underlain by thick layers of impermeable material (e.g., clay layer), or that are the discharge points for groundwater (e.g., perennial springs), or that remain frozen for long periods will seldom allow much infiltration or have significant subsurface space available for storing runoff. Basins associated with loess (deposited wind-borne sediment) or other coarse-grained soils such as alluvium and glacial outwash are more likely to support infiltration and groundwater recharge (e.g., Dinicola 1993, Gee et al. 1992). Measurements of infiltration in a wooded wetland on the Oregon coast indicated 60-85% of the surface water inputs were lost to infiltration (Franklin and Frenkel 1987).

4. <u>Basin Relative Morphology</u>. Basins that are large relative to the upslope areas that provide runoff to them (i.e., their drainage areas) will control runoff to a greater degree than basins that are proportionately small. However, even small areas of upland can generate large volumes of runoff (high water yield) under some circumstances. Upland water yield is likely to be greater, and storm hydrographs sharper, where the watershed area upslope of most of the wetland basins is elongate in

shape, relatively steep, comprised of clayey or similar less-permeable soils (including pavement and bedrock), has few other wetlands and depressions, and is channelized or artificially drained. Conversely, as the watershed area upslope of a basin becomes more rounded in shape and dominated by permeable soils that are not artificially drained, the runoff inputs to downslope wetlands become diminished. This has the same effect as a proportional decrease in drainage area. Regional differences also are important. Basins located in regions where precipitation or snowmelt does not have an extreme seasonal pulse are more able to control runoff.

5. Channel Roughness. In wetlands that contain flowing water, objects (such as large flooded trees) that increase resistance to the flowing water can, by delaying the water, decrease the likelihood that the peak flows from tributaries will coincide (synchronize) with peak flows in the mainstem. Thus, if located where they will intercept currents, trees can sometimes help reduce downstream flood peaks.

The above factors and mechanisms may be represented somewhat by variables listed in Table 9 on the next page.

Table 9. Variables possibly associated with capacity for Water Storage & Delay

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to each region. They do not by themselves constitute an assessment method.

Legend:

A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses

B = less important

*** = no variables necessary because this function usually occurs in all sites of this subclass

blank = usually not relevant

light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.

dark shade = no variables necessary because this function usually minimal in all sites in this subclass

Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region			***	***										
2/ HGM subclass			***	***										
3/ Valley bottom or channel type	A	A	***	***										
5/ Basin proportionate size	A	A	***	***	A	A	A	A	A	▨	A	A	▨	▨
6/ Evapotrans-piration potential		A	***	***	B	B	B	A	A	▨	A	A	▨	▨
8/ Outlet constriction		A	***	***	A		B	A	A	▨			▨	▨
11/ Water level fluctuation	A	A	***	***	A	A	A	A	A	▨	A	A	▨	▨
12/ Non-permanently flooded area	A	A	***	***	A	A	A	A	A	▨	A	A	▨	▨
13/ Duration of flooded connection		A	***	***	A			A	A	▨			▨	▨
16/ Dominant depth class		A	***	***	A	A	A	A	A	▨			▨	▨
25/ Woody flooded area	A	B	***	***	B					▨			▨	▨

NOTES:

1/ *Region*. In Oregon, region may be correlated with HGM subclass and evapotranspiration potential, which in turn influence this function. Storage function (actually, water residence time) during high, moderate, and low flow conditions was measured and reported for many stream reaches in the Willamette Valley by Harris (1968) and Harris and Sanderson (1968).

2/ *HGM subclass*. Clear differences exist among HGM subclasses with regard to their capacity for storing water and facilitating infiltration and evapotranspiration. Depressional Closed sites are particularly important because all runoff that enters them is retained or lost only via infiltration and evapotranspiration. In Oregon, HGM subclass may be correlated regionally with the following variables that in turn can influence capacity of this function: duration of flooded connection, water level fluctuation, surface flow gradient, outlet constriction.

3/ *Valley bottom or channel type.* Wide, flat, nontidal, lowland channels probably contain proportionately more bank storage than headwater channels. Thus, for storage and infiltration, channel types (Denman 2000) might be ranked:

1. Alluvial Fan, Floodplain, Low Gradient Outflow
2. Moderate Gradient Outflow or Moderately Outflow
3. Steep Narrow Valley Channel, Estuarine Channel

5/ *Basin proportionate size.* As measured by the ratio of wetland area to area of the wetland's contributing watershed. Proportionately larger wetlands are more important because they intercept more of the runoff. However, a basin can be abnormally large due to water subsidies from groundwater (Reinelt et al. 1997) or irrigation runoff, in which case its capacity to store runoff may be equal or less than the capacity of proportionately smaller basins. In the central Coast Range, contributing watersheds must be 2825-6140 sq. ft. in size to support 1 foot length of channel, and runoff generally moves downslope 0.2-0.5 mile before jointing a channel (Niem 1976). Geology influences runoff quantity: volcanic strata often are highly fractured and support greater discharge of groundwater into wetlands and channels. However, at least in the Coast Range, the density and pattern of stream channels is independent of geology (Niem 1976).

6/ *Evapotranspiration potential.* High evapotranspiration in a wetland implies that water is quickly removed, so sediments are likelier to be unsaturated some of the time and thus able to store new runoff.

8/ *Outlet constriction*. Wetlands whose outlets have smaller cross-sectional area (are constricted) are more able to detain runoff long enough for some infiltration and evaporation to occur. Constriction may be due to geologic factors, beaver, culverts, or control structures. Water levels within such sites usually fluctuate more than sites without constrictions (Reinelt and Taylor 1997).

11/ *Water level fluctuation*. If caused by natural factors, muted water table fluctuations (fluctuations smaller than expected from a given precipitation event) at a basin outlet can imply that storage, evaporation, and/or infiltration is occurring. However, muted fluctuations can also be due to groundwater being the dominant water source for a basin (Taylor 1993). The magnitude of water level fluctuation in a series of Seattle-area wetlands was attributed mainly to relative imperviousness of the contributing watershed, its vegetation cover, and characteristics of a site's outlet; an equation is presented for estimating fluctuation, given data on those variables. For example, a mean water level fluctuation of >0.30 m was associated with sites that comprised <4% of the contributing watershed, whereas a smaller mean fluctuation (<0.13 m) was associated with sites that comprised a larger percentage of a contributing watershed (Reinelt and Taylor 1997).

12/ *Nonpermanently flooded area*. Basins that lack surface water are likelier to have sediments that are periodically unsaturated. Unsaturated sediments are more able to accept and detain new runoff long enough for some infiltration and evapotranspiration to occur.

13/ *Duration of flooded connection*. Basins that outflow only briefly to other water bodies are likelier to store water than those that are permanently connected.

16/ *Dominant depth class.* Deeper basins, if not permanently flooded, can store the most runoff.

25/ *Woody flooded area.* In wetlands exposed to flowing water, increased cover of dense, flooded, woody vegetation suggests increased channel roughness and thus increased capacity for slowing runoff long enough for some infiltration and evapotranspiration to occur. Vegetation can also trap coarse sediments that themselves store and release water slowly. However, woody vegetation also can occupy space otherwise available for storing runoff, can trap so much sediment that storage space is reduced, and can shade the water from wind and sunlight, thus reducing evaporation. Increased vegetation cover, regardless of type, appears to increase infiltration and this can result in significant removal of surface runoff. For example, in the Idaho portion of the Columbia Basin, one study measured significant springtime recharge of groundwater where dense root mats developed below grassy surfaces (Williams and Allman 1969). In a Willamette Valley study, tree roots and rodent holes greatly enhanced infiltration during large storms (Hammermeister et al. 1982).

Potential Values of the Water Storage & Delay Function

There are potentially great social consequences -- both positive and negative -- of altering the volume and timing of even small amounts of runoff:

Benefits of Storage and Evaporation:

- If large volumes of runoff were to otherwise move farther downslope in a short time, floods and erosion might result, with consequent damage to property.
- Long delays in runoff timing, as potentially caused by storage and slow release of accumulated runoff from wetland/ riparian sediments, can sustain aquatic habitats and fish (Hicks et al. 1991), maintain water temperature (sometimes), and provide water for agriculture during the driest times of the year (i.e., base flow augmentation).

Detriments of Storage and Evaporation:

- Large floods are essential to some ecosystem processes, and lessening of their frequency or magnitude can impair landscape function.
- Attenuation of runoff, as occurs when runoff is stored, can limit economic use of otherwise dry land located downslope.
- Storage in shallow, unvegetated basins sometimes can raise water temperatures.
- Rapid evaporation or transpiration of stored water can reduce water tables, flows, and water quality downstream.

Beneficial values of Water Storage & Delay should be assessed, in part, by considering variables in Table 10.

Table 10. Variables potentially influencing values of the Water Storage & Delay function

1/ Region
2/ HGM subclass
3/ Valley bottom/ channel type
50/ Contributing watershed: Slope
51/ Contributing watershed: Narrowness
52/ Contributing watershed: Imperviousness
53/ Contributing watershed: Precipitation or snowmelt intensity
54/ Contributing watershed: Precipitation amount
55/ Contributing watershed: Frequency of rain-on-snow events
56/ Contributing watershed: Vegetation type and density
60/ Contributing watershed: Dams or water-diverting features
61/ Contributing watershed: % wetland + lake acreage
80/ Downslope: Developed land uses
81/ Downslope: Highly erodible soil types and activities
82/ Downslope: Number of floodable properties
83/ Downslope: Other important flood-vulnerable resources
84/ Downslope: Flood-dependent ecological resources
85/ Capacity of reservoirs and diversions located between wetland and downslope floodable properties

NOTES:
1/ *Region*. Runoff is much greater in some regions than others, thus providing greater opportunity for storage. The timing of runoff is important. Regions in which much precipitation occurs during the mid-to-late growing season, and/or where runoff is associated with intense storms, are likelier to have situations where wetlands are able to store the intense runoff because wetland water tables are usually lower then. Watersheds in regions where soils are frozen late into the spring yield large quantities of runoff to channels and wetlands at that season (e.g., Wilcox et al. 1991). In regions where snowmelt is a major source of runoff, the percentage of the mean annual runoff that occurs in any month can be estimated (if not known from gauging records) using data on elevation, latitude, area of the contributing watershed, and a regression equation developed by Copp (1981).

2/ *HGM subclass*. Sites that receive most of their water from groundwater will have less opportunity to influence runoff than sites that receive most of their water from precipitation directly, or from overbank or overland flow.

3, 50/ *Valley bottom/ channel type, Contributing watershed: Slope.* Steep-sloped watersheds delivery a higher percentage of precipitation to channels and wetlands. Thus, channel types (Denman 2000) could be ranked as follows:

1. Steep narrow valley channel
2. Moderate gradient moderately constrained
3. Moderate gradient constrained
4. Low gradient constrained
5. Alluvial fan, Floodplain, Estuarine

51/ *Contributing watershed: Narrowness*. Narrow, elongate watersheds deliver a higher percentage of precipitation to channels and wetlands than do watersheds that have a rounded shape.

52/ *Contributing watershed: Imperviousness.* Watersheds in which soils are relatively impermeable either naturally or due to pavement are likelier to deliver a higher percentage of precipitation to channels and wetlands.

53/ *Contributing watershed: Precipitation or snowmelt intensity*. Watersheds in which precipitation or snowmelt is intense are likelier to deliver a higher percentage of precipitation to channels and wetlands. The normally expected intensity of rainfall is expressed by the R factor. The R factor is based on the long term average intensity of a 30-minute storm. For eastern Oregon, R values have been summarized for all 54 subwatersheds by the ICBEMP project (Quigley and Arbelbide 1997).

Precipitation or snowmelt intensity is sometimes viewed as affecting the magnitude of peak flows to a greater degree than is storage of runoff in wetlands and lakes. However, an analysis of data from 485 storms affecting 13 small watersheds in the Blue Mountains region found that rainfall intensity and duration were statistically less important than antecedent moisture conditions and total storm rainfall in predicting stream peak flows (Higgins et al. 1989).

54/ *Contributing watershed: Precipitation amount*. Watersheds in which annual precipitation inputs are larger will obviously have more opportunity to store that precipitation. Mean annual precipitation has been summarized for all 54 subwatersheds of eastern Oregon by the ICBEMP project (Quigley and Arbelbide 1997). Statewide, mean annual precipitation ranges from <16 inches for most of eastern Oregon to >100 inches for parts of the Coast/ Range and West Slope Cascade regions.

55/ *Contributing watershed: Frequency of rain-on-snow events*. Watersheds in which precipitation is often in the form of rain falling on snow or frozen soil will have a greater proportion of this runoff delivered to wetland/ riparian sites (Rothacher 1973, Fowler et al. 1987). This is one of the most important variables for predicting erosion potential (Washington Forest Practices Board 1994). In the West Slope Cascades region, rain-on-snow events are most frequent at elevations of 1000 - 4000 ft elevation (Grant 1997).

56/ *Contributing watershed: Vegetation type and density.* In the Blue Mountain region for example, watersheds dominated by Western Larch-Douglas Fir vegetation tended to provide less water annually to streams and wetlands, but also have lower peak flows, higher low flows, and longer flow durations than watersheds dominated by other conifers or mountain meadows (Higgins et al. 1989). The same study measured no effect of either of 4 levels of grazing on stream peak flows, low flows, or flow duration. Pinyon-juniper vegetation also is widely known to deplete total annual runoff.

60, 61/ *Contributing watershed: Dams or water-diverting features, % wetland + lake acreage.* The absence upslope of dams, diversions, and sizable lakes and wetlands suggests that a site farther downslope will have increased opportunity for storing runoff.

80/ *Downslope: Developed land uses*
81/ *Downslope: Highly erodible soil types and activities*
82/ *Downslope: Number of floodable properties*
83/ *Downslope: Other important flood-vulnerable*

resources
84/ *Downslope: Flood-dependent ecological resources*
When valuable resources are located downslope or downstream, the storage function of wetland/ riparian sites located upslope becomes particularly significant.

85/ *Capacity of reservoirs and diversions located between wetland and downslope floodable properties.* An individual wetland/ riparian site is more significant when it is the only one that can potentially store runoff that otherwise could flood properties located farther downslope.

4.2 Assessment of Functions: Water Quality

This chapter deals with the capacity of wetland/ riparian sites to alter the physical and chemical characteristics of surface and ground water. The first subsection (4.2.1) addresses the ways in which wetland/ riparian sites alter the concentrations or form of suspended sediment (turbidity), phosphorus, nitrogen, and a few toxic substances that otherwise could damage aquatic function. A second subsection (4.2.2, Thermoregulation) addresses a strictly physical attribute.

4.2.1 Processing of Sediments, Nutrients, Toxicants

These functions are similar to, and include at least in part:
- From OFWAM (Roth et al. 1996), the function "Water Quality" (in part)
- From Hruby et al. (1999, 2000), the functions:
  - Removing Nutrients
  - Removing Metals and Toxic Organics
- From Gersib (1997), the functions:
  - Shoreline Stabilization
  - Phosphorus Retention/ Transformation
- From Smith et al. (1995), the functions:
  - Cycling of Nutrients
  - Removal of Elements and Compounds

Function Documentation, Processes, and Variables

Sediment Stabilization & Phosphorus Retention
In this guidebook "Sediment Cycling" deals with the mobilization and (especially) the deposition of suspended sediments. Particularly in Riverine sites, cycles of mobilization and deposition provide a dynamic stability to wetland and riparian sites, allowing them to support other functions. If wetland/ riparian sites are in good condition, they usually retain (temporarily or permanently) incoming sediment particles that are suspended in the water or air, but do so at a season or rate that does not cause permanent or severe damage to other wetland/ riparian functions (Naiman et al. 1992). Sites in good condition have vegetation with well-developed root masses capable of quickly colonizing newly deposited sediments and protecting them from excessive erosion.

The capacity of wetland/ riparian sites to retain and stabilize sediments is largely related to their ability to store water. As particles of suspended sediment enter a site via surface flow or runoff, several processes cause the particles to be retained. Those processes include entrapment, agglomeration, physical concentration, filtration, settling, burial, and anchoring. These processes are partly related to the fact that most wetlands (as described in Section 4.1) reduce or displace the energy (velocity) of channel flow or runoff, allowing gravity settling to occur.

Suspended sediments are further detained by stems and leaves of plants and woody debris that filter the incoming water. Among woody species, the zone within which individual plants effectively maintain soil stability generally extends laterally as far from the trunk as does the crown of the tree or shrub. Roots from some types of vegetation can very gradually stabilize much of the new sediment that is deposited, especially if sediments do not become tightly compacted or anaerobic (both of which inhibit root growth). In fact, sediment-stabilizing capacity of wetland plants is often correlated with their root biomass. Thus, streambank stability is less influenced by riparian zone width as by the density of fine-rooted plants within the zone. Plants with root densities of greater than 2 mm of roots per cubic mm of soil are particularly effective in increasing soil resistance to erosion (Kleinfelder et al. 1992).

Sediment deposited in nonpermanently flooded parts of channels can be removed permanently from the water column by being incorporated during the dry season into larger soil particles that are less prone to resuspension (Dieterich 1992). Thus, it cannot be assumed that all seasonally-deposited sediments will be resuspended as soon as flows increase.

Chemical precipitates and fine organic matter that mix with the incoming sediment can hasten its deposition and make it more resistant to erosion, once deposited. Brackish waters can either hasten sediment deposition by processes of agglomeration and flocculation (in well-mixed waters), or keep sediments suspended longer (in stagnant waters) due to the greater density of the saline underlayer. Much deposition occurs in estuaries, as outgoing sediment-laden river waters encounter incoming tidal currents, slow down rapidly, and deposit their sediments. However, the finer of these sediments remain deposited for only a short time. Rates of sedimentation also are influenced by particle size (coarser particles settling faster) and temperature (particles settle faster in warmer water).

Even in instances where little water or sediment is being retained, partly submersed vegetation slows the rate of erosion that might otherwise occur on-site and perhaps a short distance downstream. A wetland's capacity for reducing downstream erosion is related largely to its capacity to provide short-term storage of excess runoff during storm events.

An urban detention pond in Oregon retained 47% of incoming suspended sediment (Miller 1987), and one in Bellevue, Washington retained 50% (Comings et al. 2000). A wetland constructed to treat dairy wastes in Oregon removed 55%. In summer-dry channels in western Oregon, nearly all of the incoming suspended sediment was trapped within 36 - 105 meters of its source (Dieterich 1992). In central Oregon, a 3.5 mile stretch of RFT sites in good condition removed 79% and 48% of the suspended sediment load entering the area during February of two successive years (Winegar 1977). In Washington, grassy swales constructed to retain sediment retained about 80% of the sediment input, provided the slope was not so great that flows within the swale became channelized during storms (Horner and Mar 1982).

Phosphorus retention is often correlated with sediment retention. As defined in this guidebook, phosphorus retention is the result of processes that remove more of the incoming phosphorus than is exported to groundwater and any outflowing channels, at least in the short term. Wetland/ riparian sites in good condition temporarily or permanently remove phosphorus from incoming runoff, surface water, or groundwater, but do so without causing severe eutrophication of the wetland. Phosphorus is often adsorbed onto incoming sediments. Constructed wetlands in Bellevue, Washington, retained 20-50% of incoming phosphorus (Comings et al. 2000), and one in Oregon retained 42% (Niswander 1997).

While phosphorus is being retained within a basin, it can be converted from one form to another, e.g., from organic to inorganic form, or from oxidized to reduced form. This has important ecosystem consequences. Not all wetlands retain phosphorus, nor do so without adverse consequences to the wetland. Evidence of phosphorus retention in wetland/ riparian environments is stronger for seasonal than for long-term retention, and stronger for retention of inorganic than organic forms.

Phosphorus commonly adsorbs to inorganic sediments, perhaps more so in western Oregon than does nitrate (Simmons 1981, Aumen et al. 1990, Miller 1987). Thus, it would seem that the proven ability of most wetland/ riparian sites to retain sediment (as described above) would usually result in retention of phosphorus. However, net retention of phosphorus in individual wetland/ riparian sites appears to be far from a universal phenomenon. This is because only some types of sediments readily adsorb phosphorus, and the phosphorus they do adsorb in many cases is easily released again to the water column. Factors that usually control this release include the dissolved oxygen levels and pH in the water column and sediments, the chemical characteristics of the water column and sediments, the phosphorus loading rate, and the distribution and type of plants present in the wetland. As evidence of the variable nature of phosphorus retention in four RFT watersheds in the Pacific Northwest, Feller and Kimmins (1979) reported annual phosphorus budgets ranging from a net retention of 0.1 kg/ ha/ yr to a net export of 0.3 kg/ ha/ yr. Perhaps least likely to retain phosphorus are montane RFT sites that are subject to frequent snow-on-rain events.

Nitrogen Removal

Wetlands/ riparian sites in good condition also temporarily or permanently retain or permanently remove dissolved forms of nitrogen (primarily nitrate) from incoming runoff, surface water, or groundwater, and do so without causing severe eutrophication of the wetland. There probably are more sites that can permanently remove nitrogen from incoming waters than there are sites that can retain incoming phosphorus for long periods. Wetland/ riparian sites are among the most effective ecosystems for removing nitrogen, and are clearly more effective than terrestrial systems. A national-scale analysis (Nolan 2001) determined that groundwater contamination with nitrate can be predicted with 97% accuracy from knowledge of (a) depth to the seasonally high water table (deeper = greater contamination risk), (b) extent of soils that are classified as well-drained (higher % = greater contamination risk), (c) extent of cropland and pasture, (d) population density, (e) fertilizer loading, and (f) presence of a fracture zone within the aquifer (= greater risk). The importance of agricultural land cover as a predictor of aquifer contamination specifically in the Pacific Northwest was demonstrated by Tesoriero & Voss (1997).

Nitrogen is removed when microbes convert dissolved nitrate or ammonium to a gas by a process known as denitrification, which can occur when water-holding capacity of a soil exceeds about 60%. No comparable removal mechanism exists for phosphorus. Wetland/ riparian sites generally support greater rates of denitrification than do other ecosystems. Even ombrotrophic bogs can retain 65% of the nitrogen they receive, mainly from precipitation. In contrast to the limited assimilative capacity of wetland/ riparian sites for phosphorus, the ability of such sites to remove nitrogen via denitrification does not diminish noticeably with time or sustained loading.

Wetland/ riparian plants also can take up nitrogen (in nitrate or ammonium form) and incorporate it into their tissue. Conversely, some plants add nitrate to wetland/ riparian sites by converting gaseous nitrogen to nitrate during the process of nitrogen fixation. Thus, nitrogen retention/ removal is governed mostly by denitrification rate, nitrogen loading rate, nitrogen fixation rate, and the distribution and type of plants in the wetland. A study of a spring-fed (Slope) wetland in the East Cascades region reported that nitrogen fixation (primarily due to the blue-green alga *Nostoc pruniforme)* accounted for 4% of the nitrogen inputs -- small compared with inputs from inflowing water, woody debris, and beaver excrement (Dodds 1986, Dodds and Castenholz 1988).

A few studies in the Pacific Northwest have studied the capacity of riparian and wetland plants and soils to remove nitrogen. Summertime nitrate removal was in a stream in the West Cascades region was much higher than in a stream in the eastern United States (Munn and Meyer 1990). The stream seemed to remove nitrate the most where woody debris dams were present. However, studies by Aumen et al. (1985, 1990) found that although woody debris and its associated algae and microbes retained nitrogen, the effects were too small to be measurable at the scale of a stream reach. A detention pond in Salem was found to have no measurable effect on nitrogen runoff in a dissolved organic form (Miller 1987). In contrast, an Oregon wetland constructed for treating dairy wastes removed 41% of dissolved organic nitrogen (Niswander 1997). Plant uptake and infiltration reduced the nitrate concentrations in summer-dry streams in western Oregon, especially in relatively sunny reaches where filamentous green algae were prevalent (Dieterich 1992). Retention or removal of nitrate was greater in nonpermanently than permanently flowing streams, and averaged 1% per meter of channel.

Denitrification potential in some red alder-dominated floodplain soils (3 - 24 ng N/ g/ hr) in the West Cascades was greater than in upland soils (Griffiths et al. 1998), and McClelland (1987) attributed this to greater moisture levels, higher pH, and larger nitrate inputs in riparian sites. Seasonal variation within the growing season was not significant, but spatial variation within sites was very great (also noted by Dodds 1986, and Baumeister 1992). Denitrification in Oregon red alder stands also was reported by Bollen (1967), Bormann and DeBell (1981), Gregory et al. (1991), Cromack et al. (1999), and Binkley et al. (1992), who mostly found very low rates. Denitrification was measured in groundwater by Koegler et al. (1989) at a site in the Columbia Basin. In Washington, denitrification potential measured in a valley was greater than on a ridge (Geyer et al. 1992), and valley nitrate concentrations were smaller (Kafka-Todd 1995). Levels of soluble nitrogen were lower in two Willamette Valley hydric soil series than in two non-hydric soils (Laurent 1979), presumably as the result of greater denitrification in the hydric soils. Denitrification rates in a hydric Willamette Valley soil to which manure had been applied were 33 kg/ N/ yr, and were highest during late fall and early winter (Baumeister 1992). Denitrification in Willamette Valley soils is highly correlated with soil water content (Myrold 1988). Drainage of fields with subsurface tile undoubtedly shortens nitrogen contact time with soil and minimizes the nitrogen removal role of farmed wetlands and riparian areas; nitrogen moves quickly in subsurface tiles directly into streams, which may thus experience greater nitrogen loading. Conditions in nonpermanently flooded sites in the Willamette Valley are adequate to cause the hydric soils to become anaerobic (and thus supportive of denitrification) beginning in late December and persisting into at least April of most years (Huddleston and Austin 1996). However, complete anoxia can inhibit denitrification by minimizing the rate at which nitrate diffuses into the soil or sediments (Niswander 1997).

Processing of Toxicants

Many toxic organic substances are readily volatilized (exported as a gas) or oxidized by sunlight in the shallow, microbe-rich, exposed topography of wetlands. However, the naturally high concentrations of dissolved organic matter and low oxygen levels that prevail in wetland/ riparian sites (e.g., Horner et al. 1997) can increase the mobility and bioavailability of a few of the most insoluble contaminants such as PCB (Smith et al. 1988). The detoxification capacity of a wetland, then, depends on characteristics of the contaminant and the concentration of microbe-supporting organic matter, as well as sediment chemistry, oxygen conditions, pH, and salinity.

Detoxification processes have received only a little attention in natural aquatic systems in Oregon. Limited data from one wetland constructed for this purpose in Oregon (Carnevale 1995) and from a riparian system loaded with atrazine and 2,4-D (Entry et al. 1995, Entry & Emmingham 1996) both indicate wetlands are capable of processing some contaminants. In the Willamette Valley, pesticides found most often in surface water are atrazine, deselthylatrazine, simazine, metolacholor, and diuron (Anderson et al. 1998). The role of Oregon wetland/ riparian sites for possibly detoxifying these compounds is poorly known, but it may be assumed that wetland/ riparian sites in good condition are able to permanently reduce the toxicity of some contaminants (certain pesticides and other synthetic organics), sometimes without harming the wetland/ riparian site itself. Unfortunately for wetland plants and animals, wetland/ riparian sites under some conditions also retain, accumulate, and/or mobilize other toxic substances (particularly heavy metals such as mercury). Because of the high potential for damage to other wetland/ riparian functions, and lack of good indicators, this function is not included in the assessment methods in Volume IA.

Table 11. Variables possibly associated with capacity for Sediment Stabilization, Phosphorus Retention, Nitrogen Removal

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to an ecoregion. They do not by themselves constitute an assessment method for this function.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
*** = no variables necessary because this function usually occurs in all sites of this subclass
blank = usually not relevant
shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
Subclasses: FT= flow-through, I= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region			***	***										
2/ HGM subclass			***	***										
3/ Valley bottom or channel type	A	A	***	***										
7/ Growing season length	A	A	***	***	A	A	A	A	A	A	A	A	B	B
17/ Soil or sediment adsorptive capacity	A	A	***	***	A	B	A	A	A	A	A	A	B	B
19/ Soil or sediment organic content	A	A	***	***	A	A	A	A	A	A	A	A	A	A
25/ Submersed cover: Woody/ emergent	A	A	***	***	B	A	A	A	A	B	A	A	A	A
28/ Sheltering	B	B	***	***	B	B	B	B	B	B	A	A	A	A
101/ Water Storage	A	A	***	***	A	A	A	A	A	A	A	A		

NOTES:
1/ *Region*. In Oregon, sites in different regions differ somewhat in their capacity to remove suspended sediment and nutrients from runoff or groundwater. This is partly because regions differ with regard to geology and consequently the adsorptive capacity and organic content of soils/sediments (#17, 19).

2/ *HGM subclass*. Different HGM subclasses have somewhat distinct capacities to remove suspended sediment and nutrients. For example, Estuarine, Depressional Alkaline, and Depressional Bog sites would be expected to have the least capacity to remove nitrogen because their salinity or acidity generally inhibits the denitrification and plant nutrient uptake processes. In contrast, dissolved phosphorus is readily precipitated and retained when waters are saline or alkaline.

3/ *Valley bottom or channel type.* Valley bottom or channel type also can be used to generally predict some water quality functions. For example, in Riverine sites of the West Cascades region, sediment storage associated with instream woody debris is generally greater in mid-sized and larger channels (third order or larger) than in small channels (Nakamura and Swanson 1993). Retention of ammonium (a form of nitrogen) in broad unconstrained reaches was more than double that in narrow constrained reaches (Lamberti et al. 1989).

7/ *Growing season length.* Longer growing seasons may be associated with greater root development (important to stabilizing sediments and taking up nutrients), reduced ice scour of deposited sediment, and more active microbial communities (important to denitrification and detoxification). However, the freezing of basins all the way to their bottoms also can force phosphorus into sediments, where it may be retained. Microbial communities in hydric soils of western Oregon remain active year-round regardless of soil temperature and calendar date (Huddleston and Austin 1996).

12/ Proportion of basin lacking permanent surface water. The portion of a site that is flooded only seasonally is often the most effective part for retaining suspended sediment carried in during floods (Dieterich 1992). Soils/sediments in such sites are also likely to be more weathered, thus enhancing the potential for adsorbing phosphorus.

17/ *Soil or sediment adsorptive capacity.* Important particularly to phosphorus retention, this variable is related strongly to increased sediment concentrations of particular forms of aluminum, iron, and calcium. These are typically associated with high clay content of soils/sediments. Based on a analysis of extractable aluminum and iron among 7 Oregon soil series (Spycher 1973), the soils would be ranked from most-to-least retentive of phosphorus as follows: Hembre> Knappa> Quillayute> Nehalem> Jory> Woodburn.

19/ *Soil or sediment organic content.* Organic matter supports prolific microbial communities that are the key to most nutrient cycling. Organic carbon (at least, the water soluble component) is essential to denitrification and detoxification processes, although the level below which it limits these processes in Oregon wetlands is not known, and it may be a relatively unimportant limiting factor in wetland (as opposed to upland) soils. Organic matter further supports water quality functions by developing anaerobic conditions that support denitrification, provided sediments do not become too acidic. Even acidic sediments can favor phosphorus retention, as phosphorus adsorbs more readily to clay at low pH (Simmons 1981). Accumulated soil organic matter also indicates depositional conditions that usually imply sediment and nutrient retention. Microbial biomass carbon is relatively low in some Oregon soils that have been intensively cultivated (Ndiaye 1998). Finally, organic matter can increase soil porosity and thus facilitate oxygen exchange between water and sediments. This can increase plant uptake and temporary storage of nutrients.

However, oxygen deficits and associated acidity created by excessive levels of organic matter can mobilize some toxicants and phosphorus. Too much carbon can also inhibit denitrification if it creates constant and homogeneous anaerobic, acidic conditions, especially if such conditions increase the concentration of sulfide (Knowles 1982), restrict plant growth, or inhibit the decomposition and release of nitrate stored in plant tissue. Denitrification is sometimes greater in wetlands that have been recently burned or moderately grazed, because root growth frequently is rapid and extensive following such disturbances. Denitrification is especially likely to decline if the decomposition of plant litter slows to the point where a buildup of organic matter decreases the pH to below about 3.5 (Knowles 1982). Excess carbon may also enhance a process known as dissimilatory nitrate reduction which competes with denitrification but does not permanently remove nitrogen from a wetland.

25/ *Submersed cover: Woody/ emergent*. Increased vegetation density and wider vegetation zones may increase water quality functions of wetlands because of increased seasonal uptake and processing of nutrients and toxicants by plants and microbes, filtration and deposition of incoming suspended sediments, and sheltering from wind and waves that otherwise would resuspend sediments. However, shading from plants may diminish the rate of photo-oxidation of some toxicants, and by reducing water temperature may slow beneficial chemical and microbiological processes. Plants also take up nutrients and toxicants from sediments and, following senescence and decomposition, can subsequently release them into the water column.

In a stream in the West Cascades region, nitrate losses were greatest where woody debris dams were present (Munn and Meyer 1990). However, studies by Aumen et al. (1990) found that the effects of instream wood on both nitrate and phosphate concentrations were too small to be measurable at the scale of a stream reach. Another West Cascades stream study documented extensive retention of suspended sediment by instream woody debris, but sediments were retained only temporarily (Nakamura and Swanson 1993).

28/ *Sheltering*. Wind-driven resuspension of sediment can be an issue, particularly in lacustrine and estuarine sites. Sites that are sheltered from wind by vegetation or topography will have fewer problems with resuspension of sediments. However, shaded sites may take up and retain nitrate less than unshaded sites (McIntire and Phinney 1965, Dieterich 1992).

101/ *Water* s*torage*. Sites having a relatively great capacity to remove runoff via storage, infiltration, or evapotranspiration will also be more likely to alter suspended sediment and nutrient loads, because hydraulic residence and processing times are longer. Thus, variables identified as important to the Water Storage & Delay function are also important to the water quality functions. For example, when water is very deep, bottom current velocities are slow and deposited sediments are less likely to be resuspended by wind or animal activity. Periodically anoxic conditions that support denitrification (but may mobilize phosphorus) are more likely to develop in deep basins. Also, basins in which a large portion of the area is inundated only seasonally (or intermittently) have more space to store incoming sediment- and nutrient-laden runoff. Soils/sediments in the periodically exposed parts of these basins are likely to have more weathered surface horizons, with consequently greater potential for adsorbing phosphorus. Fluctuating anoxic/oxic conditions, which are important to denitrification, are likely to be present in basins with a proportionally large zone that is flooded only seasonally. However, such fluctuations sometimes cause the compaction of upper sediment or soil layers, reducing the pore space available for colonizing denitrifiers. Also, the anoxic, acidic conditions sometimes associated with water level fluctuations can mobilize a large portion of the adsorbed phosphorus, particularly when reflooding occurs or if soils/sediments are tilled during the unflooded period.

Potential Values of Sediment Stabilization, Phosphorus Retention, and Nitrogen Removal

As is true of the hydrologic functions, there are potentially great social consequences -- both positive and negative -- of altering the loading rate, form, and seasonal timing of nutrients and sediments that are transported through a watershed. For example, detention basins are commonly recommended for treatment of stormwater (e.g., Edwards 1994), but vegetation that grows in such basins can accumulate metals and potentially harm other aquatic life within the detention basin.

Although deposited sediments are crucial to maintaining floodplains and to ensuring the geomorphic stability and productivity of many wetlands, excessive amounts of sediment reduce aquatic productivity by blocking light, smothering seeds and benthic invertebrates, blocking groundwater exchange, and taking up water storage space. Phosphorus, which often is adsorbed to suspended sediments, is an essential nutrient in aquatic ecosystems and is usually more limiting in freshwater than saltwater systems. Phosphorus retention may be more important to aquatic ecosystems in regions whose soils are predominantly of volcanic origin, because phosphate concentrations in such soils are often great (i.e., low N:P ratios suggest aquatic life is limited more by nitrogen there). And indeed, phosphorus is not considered limiting to forest growth in much of Oregon (MacDonald et al. 1991). However, excessive amounts of phosphorus during the growing season in any freshwater systems can potentially stimulate plant growth to such a degree that subsequent decay of algae deprives the water of oxygen. Phosphorus concentrations have been measured to be routinely in excess of EPA standards (for protecting waters from eutrophication) in the Pudding River watershed of the Willamette Valley (Bonn et al. 1995).

Nitrate is another essential plant nutrient that often appears to limit primary production in estuarine and montane waters of the Pacific Northwest. For example, eelgrass production has been demonstrated to be nitrogen-limited over the usual range of ambient concentrations (Williams and Ruckelshaus 1993). Stream communities in foothills of the Willamette Valley appeared to be nitrogen-limited (Dieterich 1993) as are algae in streams of the basalt-dominated areas of the Cascades (Gregory 1980). Like phosphorus, nitrate in excess can trigger algal growths so dense that oxygen in the water is depleted, but this depends on characteristics of the receiving water body. In densely shaded waters, nitrate additions are less likely to trigger heavy growths of algae (McIntire and Phinney 1965, Gregory 1980). For example, a study of a well-shaded, oligotrophic wetland in the East Slope Cascades region (Dodds 1986) found little obvious biological response when nitrate was added briefly. Some researchers have suggested that runoff-borne phosphorus and nitrate should be of limited concern in Oregon because most runoff occurs during the winter when light levels are low and blooms of oxygen-depleting algae are least likely to occur (Miller 1987, Bonn et al. 1996, Park et al. 1970). However, when present at high levels in drinking water, nitrate also is a human health hazard. Excessive levels have been measured in Oregon groundwater, e.g., Willamette Valley (near Pudding River and Junction City), La Pine area, Prineville area, lower Malheur River Basin. Nitrate in shallow ground water beneath urban Portland reaches levels as high as 5.4 mg/L, a level found in Nebraska to be associated with increased risk of non-Hodgkin's lymphoma (Nolan & Stoner 2000).

The value of a particular wetland/ riparian site's nutrient and sediment processing functions can be assessed by considering its opportunity for receiving large loads of nutrients and suspended sediments and the significance of resources located downslope from site which potentially are affected by water quality processes occurring within the site (Table 12).

Table 12. Variables potentially influencing values of the Sediment Stabilization, Phosphorus Retention, and Nitrogen Removal functions

1/ Region
2/ HGM subclass
3/ Valley bottom or channel type
42/ Watershed water quality rating
57/ Contributing watershed: Proximity & percent of area containing nutrient sources
58/ Contributing watershed: Proximity/ % area of soil-disturbing activities on erodible soils
59/ Contributing watershed: Soil fertility
80/ Downslope: Proximity to waters not meeting nutrient criteria
83/ Downslope: Proximity to areas experiencing sedimentation problems, e.g., harbors
83/ Downslope: Other important nutrient- or sediment-sensitive areas
110/ Water storage opportunity

NOTES (numbers refer to the above table):
1/ *Region.* Polluted runoff is more prevalent in some regions than others, providing greater opportunities for wetland/ riparian sites to play a role in retaining suspended sediments and nutrients in those regions.

2/ *HGM subclass*. For example, although Depressional sites are very effective at retaining whatever sediments and nutrients they intercept, Riverine and Estuarine sites generally receive larger annual loads of suspended sediment and nutrients, so have greater opportunity to perform these functions.

3/ *Valley bottom or channel type.* For example, low gradient channels and valley bottom types, because they mostly occur at topographically low elevations, are likely to have larger contributing watersheds and greater amounts of sediment and nutrients washed in, as compared to higher elevation sites. However, higher elevation channels can receive large inputs from their surrounding steeper, more landslide-prone slopes. Many pesticides also tend to concentrate to a greater degree in smaller channels than in larger channels (Anderson et al. 1998).

42/ *Watershed water quality rating*. Sites located in watersheds that are listed under Section 303(d) due to nutrient or turbidity issues are likely to have greater opportunity to perform the water quality improvement functions. In Oregon, 75% of the watersheds that have substandard water quality have such condition mainly as a result of agricultural or forestry activities (Oregon DEQ 305b report).

57/ *Contributing watershed: Proximity & percent of area containing nutrient sources.* Includes fertilized lands, livestock areas, areas with shallow septic systems, urban and suburban areas, and areas with erodible soils having high phosphorus or nitrate content. These source areas will provide more opportunity for wetland/ riparian sites to perform water quality functions, when the sources are in the site's contributing watershed, are extensive, and located nearby. The season during which fertilizers or pesticides are applied also influences the chance of these substances entering wetlands

(Simmons 1981). In Oregon, several studies have documented the importance of urban land as a source of suspended sediment (e.g., Miller 1987). Depending on the landscape setting and grazing regime, livestock may or may not (Tiedemann et al. 1989) significantly affect stream nutrient concentrations. A survey of 19 Seattle-area wetlands (Horner et al. 1997) found a strong relationship between percent forest cover in the contributing watershed, and a wetland's lack of excessive phosphorus concentrations.

58/ *Contributing watershed: Proximity and percent of area occupied by soil-disturbing activities on erodible soils*. Eroding cropland, scoured stream banks, stormwater runoff, natural mudslides, and other sources of suspended sediment will provide more opportunity for wetland/ riparian sites to perform water quality functions, when these sources are in the site's contributing watershed, are extensive, and located nearby. For example, planting of a bare Willamette Valley soil with a continuous grass cover reduced soil erosion one hundred fold (Simmons 1981). Orchards, vineyards, and row crops in the Pacific Northwest produce about 50 times more sediment than soils vegetated with natural forests or permanent pastures (Dunne and Leopold 1978). However, removal of forest cover and construction of road networks does not inevitably correlate with long term increase in suspended sediment at watershed outlets (Sullivan 1985). Regardless of the surrounding land use, slides and debris torrents can provide major episodic inputs of sediment to channels in Oregon's Coast Range and Cascade regions (Hurley 1990). The intrinsic erodibility of a soil is expressed by the K factor. The K factor of each mapped soil series is listed in county soil surveys. In general, soils derived from volcanic ash or loess (wind-blown sediments) are most erodible. Soil erodibility has been summarized for all 54 subwatersheds in eastern Oregon by the ICBEMP project (Quigley and Arbelbide 1997), taking into account not only the K factor, but also the rainfall intensity (R) and existing vegetative cover. When combined with data on slope, the K factor can be used to approximate erodibility as follows (Washington Forest Practices Board 1994):

Slope Class	K<0.25 (soil not easily detached)	K = 0.25-0.40 (moderately detached)	K>0.40 (easily detached)
<30%	low	low	moderate
30 - 65%	low	high	high
>65%	moderate	high	high

59/ *Contributing watershed: Soil fertility*. Excessive nutrient loads in parts of Oregon are partly attributable to naturally fertile soils and their underlying aquifers. For example, riparian soils in the Tualatin River Basin were found to be a significant potential source of phosphorus to streams and groundwater (Abrams and Jarrell 1995). Even in relatively undisturbed watersheds of the West Slope Cascades, groundwater can be rich in nitrate compared to streams and enriches streams during both storm and baseflow periods. On an annual basis, groundwater discharging from floodplain forests along a large mountain stream in the West Slope Cascades contributed 1.9g/ m^2 nitrogen, of which more than half was inorganic nitrogen. This was sufficient to support instream primary production and exceeded the amount from leaf inputs (Wondzell and Swanson 1996).

120/ *Water storage opportunity*. Sites whose contributing watersheds have large water yields are likely to also be receiving large inputs of nutrients and suspended sediment because loads correlate strongly with flow volume (e.g., Tiedemann et al. 1989).

4.2.2 Thermoregulation

Thermoregulation is the capacity of a site to maintain the range of water temperatures that would naturally be present in its basin and in connected downstream waters. This function concerns not only the ability to maintain a particular temperature, but also to maintain the diurnal, daily, and monthly variation that occurs naturally. In summer this function may involve the capacity of a site to maintain or (rarely) reduce the temperature of inflowing surface water. This function is similar to and includes the following from other assessment methods used in the region:

- From OFWAM (Roth et al. 1996), the function "Water Quality" (in part)
- From Gersib (1997), the function "Thermoregulation"

This function was not addressed explicitly in function assessment methods by Hruby et al. (1999, 2000) or Smith et al. (1995).

Function Documentation, Processes, and Variables

Wetland/ riparian sites can help maintain water temperature primarily by providing shade and by serving as a conduit and temporary holding area for discharging groundwater (which normally in summer is cooler than surface waters). Although the shading role of wetland and riparian plants is obvious, their role in mediating the discharge of groundwater is unclear. Transpiring plants can create a hydrologic gradient around their root systems that attracts lateral and upward movement of groundwater. In some situations the suspended sediments and organic matter that plants trap and deposit in a site also can temporarily retain and gradually release discharging groundwater. However, retention and deposition of fine sediments and organic matter can also clog interpore space and reduce the release rate of discharging, cool groundwater. Plants that partly block the outlet of a wetland can slow the velocity of surface waters, allowing solar warming to occur if much of the water is unshaded.

Table 13. Variables possibly associated with capacity for Thermoregulation

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to an ecoregion. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
dark shade = no variables necessary because this function usually minimal in all sites in this subclass
Subclasses: FT= flow-through, I= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	I	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
15/ Maximum summer depth	A	A					A	A	A					
16/ Dominant depth class	A	A					A	A						
27/ Shading	A	A					A	A	A					
101/ Storage rating	A	A					A							

NOTES:
1/ *Region*. Regional differences exist in the capacity of wetland/ riparian sites to maintain or reduce summer water temperatures. For example, sites in western Oregon are more likely to be heavily vegetated with shading vegetation. Sites in regions of rugged topography are more likely to contain springs that discharge cooling groundwater.

2/ *HGM subclass*. Depressional Closed and Lacustrine Fringe sites do not have channel inflows and outflows, so are not situated to effectively maintain or reduce water temperatures. Depending on their proportionate size and vegetation, sites in other subclasses may have a small or large effect on temperature of groundwater and runoff. Many Estuarine sites receive little or no groundwater input due to their relatively flat gradient, fine-particled soils, and hydraulic counterpressure from tides. Sites belonging to the Slope HGM class normally have much greater capacity to maintain or reduce summer water temperatures because such sites are dominated by groundwater input, which (except in the case of hot springs) is cooler in summer than most waters.

3/ *Valley bottom or channel type*. Steep-walled valleys (especially north-facing ones) provide shade directly as a result of their topography. Broad valleys also are important because they provide more favorable sites for establishment of dense shading vegetation (Hicks et al. 1991).

15/ Maximum summer depth
16/ Dominant depth class
Deeper water is cooler due to less solar warming and increased influx of cool groundwater

27/ *Shading.* The effect of shade on water temperature in channels has been widely researched in Oregon and quantitative predictive models are available (Levno and Rothacher 1967, Brown and Krygier 1967, 1970, Brown et al. 1971, Adams and Sullivan 1990, Beschta and Weatherred 1984). For documentation of the link between shade and water temperature, see (for example) Beschta et al. 1987, Beschta and Taylor 1988, Li et al. 1994, Tait et al. 1994.

Shade generally has a minor effect on water temperature when low-flow channel width exceeds about 100 feet. Clearcut logging in Coast/ Range and West Slope Cascades watersheds generally increases the mean monthly maximum water temperature about 3 to 8 degrees C (Beschta et al. 1987). Shade reduces solar radiation to such a degree that light intensities are only 7-15% of total solar radiation in a 40-year old deciduous stand and 5% in an old-growth coniferous stand, as compared with 30-100% in a recently clearcut stand (Gregory et al. 1991). Following logging, vegetation regrowth creates 50% canopy cover on small channels in the Coast/ Range within 5 years, and within 15-25 years in the West Slope Cascade region (Summers 1983).

Although vegetation nearly always helps cool water or maintain water temperature, there may be rare instances (e.g., some shallow lakes) where wind and associated evaporative processes could be effective, but are thwarted by dense surrounding vegetation. And although unshaded channels warm up rapidly during the day, at night they can lose heat more rapidly than shaded channels, perhaps causing increased ice buildup in winter (MacDonald et al. 1991). No evidence of this has been reported from Oregon, however (Brown and Krygier 1970).

101/ *Storage rating*. Substantial solar warming of detained water can occur in wetland/ riparian sites that have a relatively large capacity for the water storage function. However, if much of the detention is actually the result of infiltration, warming may not be great.

Potential Values of the Thermoregulation Function

Maintaining or reducing the temperature of surface waters is of paramount importance to the survival of salmon and many other aquatic animals. Wetland/ riparian sites have the greatest opportunity to perform this function when incoming runoff or channel flow has been warmed by lack of shade (a predictive variable would be "#56 Contributing watershed vegetation type and density"). Significance is greatest when downslope waters are known to contain sensitive species or to have potentially harmful summer water temperatures (a predictive variable would be "#42 Watershed Water Quality). Thus, significance of this function may be generally greater in desert areas such as the Owyhee Uplands and less in higher-elevation regions such as the West Slope Cascades.

4.3 Primary Production

Primary Production includes the production of carbon by photosynthesis (i.e., plant productivity) and its subsequent consumption, re-use, and decomposition by animals and microbes. It also includes physical and biological processes that minimize excessive concentration of organic matter at the location where it is produced, e.g., by decomposition. Primary production is relevant both to water quality functions and life support/ habitat functions. This function is similar to and includes the following from other assessment methods used in the region:

- From Hruby et al. (1999, 2000):
    - Primary Production and Organic Export
    - Supporting Local Food Webs
- From Gersib (1997), the function "Food Chain Support"
- From Smith et al. (1995), the functions:
    - Cycling of Nutrients
    - Export of Organic Carbon

Function Documentation, Processes, and Variables

Primary Production in wetland/ riparian sites involves three key processes: production, decomposition, and dispersion. A balance among these processes appears to be critical to sustaining long-term productivity in many wetlands and waters to which they may be connected.

Production. This involves the ability of vascular plants and algae, through photosynthesis, to produce carbon as they grow. Production is influenced by genetic characteristics of a plant species, as well as soil fertility and structure, moisture, growing season length, light, temperature, and sediment oxygen regime. Estimates of vascular plant production at Oregon wetland/ riparian sites have been published by Naiman & Sedell (1980), Kibby et al. (1980), Mitchell (1981), Boss (1983), Frenkel and Morlan (1990, 1991), and others. Productivity rates for coastal diatoms were reported by McIntire and Ampoker (1986), and other studies have measured riverine and estuarine phytoplankton productivity in near the mouth of the Columbia River (Small et al. 1990, Lara-Lara 1990, Frey 1993, 1994).

Decomposition. This involves the leaching, fragmentation, and conversion of particulate carbon to dissolved carbon, as done primarily by invertebrate (Anderson et al. 1978) and microbial communities. These processes accelerate with increasing temperature, nutrient concentration, water circulation, aerobic conditions, and circumneutral pH. Few data on decomposition rates of wetland/ riparian plants are available for Oregon. Among 4 Oregon streams, decomposition rates (as a percent of initial weight of the organic matter) varied from 0.0029 to 0.0057% per m^2 per day (Naiman and Sedell 1980). As organic matter decomposes, it is converted into gas (methane or carbon dioxide), and is consequently removed from aquatic systems through oxidation or diffusion processes. Carbon dioxide in wetland/ riparian waters and sediments is converted to methane primarily when conditions are anoxic and little sulfur is available.

Dispersion. Before it is fully decomposed, organic material can be transferred from riparian to aquatic environment (e.g., tree fall, litter fall). Dissolved or particulate carbon may be leached from the organic matter, diluted, and moved into connected surface waters and lands, as a result of current, wind, and wave energy, or of transport by consumers (e.g., grazing animals).

Table 14. Variables possibly associated with capacity for Primary Production

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to an ecoregion. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
7/ Growing season length	A	A	A	A	A	A	A	A	A	A	A	A	B	B
18/ Soil nutrient levels	B	B	A	A	A	B	A	A	A	A	A	A	B	B
19/ Soil or sediment organic content	A	A	A	A	A	A		A	A	A	A	A	A	A
23/ Submersed cover: Woody/ emergent	A	A	A	A	A	A	A	A	A	A	A	A	A	A
29/ Open water interspersion		B	A	A	A	A	A	A	A	A	A	A	A	A
31/ Vegetation class richness	A	A	A	A	A	A	A	A	A	A	A	A		
101/ Water storage rating	A	A	A	A	A	A	A	A	A	A	A			

NOTES:
1/ *Region*. Primary productivity of wetland/ riparian sites is probably higher in some regions than others, due to regional differences in growing season length and regional correlations with wetland/ riparian type.

2/ *HGM subclass*.

In Oregon, differences might occur among HGM subclasses with regard to primary production, but are potentially overshadowed by other influences. For example, decomposition and export processes that influence Primary Production are likely to differ more among HGM subclasses than productivity does. Exporting forces are generally greatest in Estuarine and Riverine subclasses. Productivity of vascular plants at the outer margins of lacustrine and estuarine fringe wetlands is often limited by wave erosion, but export rates are high for whatever carbon is produced.

3/ *Valley bottom or channel type.* Similarly, differences in primary productivity among valley bottom or channel types may not be substantial; decomposition and export processes that influence Primary Production are likely to differ more. In the Coast Range, instream woody debris accumulations are more prevalent in the lower gradient, headwater channel types (Stack and Beschta 1989).

7/ *Growing season length*. Among 8 Oregon wetlands located from the Ochocos to the coast, the net annual aboveground productivity of plants was greatest in the coastal wetlands, probably due to the relatively moderate climate, extended growing season, sustained inputs of nutrients, and little summer moisture stress (Boss 1983).

18/ *Soil nutrient levels*. Fertilization increases plant production and ultimately soil organic content, unless the organic matter is exported (cycled) by decomposition, erosion, or burning. In the Willamette Valley, pasture sites accumulated more soil organic carbon than grass seed management sites (Laurent 1979).

19/ *Soil or sediment organic content.* Relatively large amounts of sediment organic content can imply that that a large portion of a site is being flooded (Shaffer et al. 1999), but it can also indicate that carbon is not being cycled effectively. The annual productivity of plants on sites with carbon-poor sandy soils can be less than on clay/ loam soils, because sandy soils are less enriched and less able to retain moisture throughout the growing season (Boss 1983). Sediment organic content is not necessarily related to landscape positions (i.e., stream order), but rather can be influenced most by local land cover; some agricultural land uses are associated with lower instream sediment organic matter, with consequently reduced rates of instream Primary Production (Delong and Brusven 1993).

23/ *Submersed cover: Woody/ emergent.* The functions and cycling of woody material in riverine sites has been the subject of perhaps more research than any other aquatic ecosystem component in the Pacific Northwest. Woody material gradually releases carbon and other nutrients when submersed, as it is slowly fragmented and consumed ("processed") by decay microorganisms and invertebrates. Carbon consumed by these organisms is processed again when the initial consumers die, thus cycling the carbon repeatedly and sustaining a wide variety and number of organisms. Moreover, the decaying woody material provides an excellent substrate for algae that contribute strongly to aquatic productivity. The density of submersed wood and emergent vegetation as well as its extent must be taken into account. Denser stands of vegetation (>50% ground cover) generally produce more organic matter, but dispersal of the decaying plants can be restricted. Trees are most likely to supply woody material to a site if the trees are in a diverse-aged stand located on slopes within about 66 feet of mean high water (McDade et al. 1990, Van Sickle and Gregory 1990, Robison and Beschta 1990). Most instream woody material comes from trees larger than 12 inches in diameter (mostly stands older than 40 years if located in western Oregon)(Washington Forest Practices Board 1994).

29/ Open water interspersion. Carbon is more likely to be cycled rather than accumulated at sites where open water and vegetation is spatially interspersed. Vascular plant production can also be higher at such sites.

31/ *Vegetation class richness.* Some studies have reported particular plant communities or wetland/ riparian types to be more productive than others. For example, Doug-fir stands at a relatively fertile site in the Coast/ Range region were more productive than adjacent alder-conifer stands of the same age, although the opposite was true at a less fertile site (Binkley et al. 1992). Some studies also report particular vegetation types as being quicker to decompose and cycle (e.g., deciduous species, especially alder, Sedell et al. 1974, 1975, Cole et al. 1978). Carbon inputs from trees and shrubs tend to be spread more evenly across a season compared to carbon inputs from herbs (Gregory et al. 1991). Mixed stands of woody riparian vegetation in Oregon also tend to have greater biomass than monotypic stands (Veldhusien 1990). Thus, a variety of plant forms (including algae as well as macrophytes) helps insure that a steady and abundant input of carbon is made available for cycling in wetland/ riparian sites, while ensuring that aquatic systems do not become so overwhelmed by big pulses of organic matter that they become chronically anoxic.

101/ *Water storage rating.* Increased storage, infiltration, and evaporation of surface water in wetlands implies that carbon is not being cycled widely beyond the site, and decomposition may be retarded due to stagnant conditions associated with decelerated flow. However, at least in arid regions, increased water storage may support higher wetland productivity. For example, in wet meadows of the Blue Mountains region, total herbaceous standing crop, both above and below ground, was greater at wetter (higher July water table) sites (Otting 1998).

Potential Values of Primary Production

Wetlands are widely reputed to have the highest capacity of world ecosystems for producing carbon. However, not all wetlands are so productive. Most wetland/ riparian sites in good condition are able to process, oxidize, and/or disperse much of the organic matter they produce, thereby minimizing severe and uninterrupted oxygen deficits. Such deficits will otherwise occur in many wetlands as the organic matter accumulates, and can further limit productivity and use by aquatic animals. An exception is bogs, where major organic accumulations and prolonged oxygen deficits are typical even in undisturbed sites, but where an adapted community of native plants and animals exists.

Primary Production is essential to sustain animal communities and water quality processes such as denitrification and detoxification. The high productivity of some wetland environments also supports the commercial production of hay and the consumption of wetland plants by domestic grazers. For organisms supported by organic matter, the seasonal timing of available digestible carbon can be at least as important as its amount. The carbon need not come from vascular plants; algae can be equally or more important, especially in larger channels (Naiman and Sedell 1980).

Ultimately, much of the organic matter produced at wetland/ riparian sites is transported into estuaries and the ocean (Dahm et al. 1991), where it continues to support important food webs. For example, an estimated 37% of the primary productivity of the Columbia estuary has been attributed to wetland vascular plants (McIntire and Amspoker 1986). Headwater sites tend to be more retentive of organic matter than lower-elevation sites (Naiman and Sedell 1979, Minshall et al. 1983).

Because Primary Production provides trophic support in ecosystems regardless of where it occurs, no particular variables are proposed to address value (opportunity or significance) of this function. Although some researchers have suggested that some forms of carbon (e.g., alder leaves, algae) are more valuable to particular species or food chains than others because they decompose rapidly, ultimately all forms of carbon are likely to be used. Thus, this guidebook makes no distinctions of relative value based on presumed form in which carbon occurs.

4.4 Fish Habitat Support

This chapter deals with the capacity of wetland/ riparian sites to serve directly as habitat for 140+ species of native and introduced fin fish (Appendix C) by providing feeding, breeding, nursery, overwintering, and/or refuge areas. Habitat features important to invertebrate communities also are incorporated to some extent, although some factors that are critical to fish use of a wetland (e.g., connectedness to other surface waters) are less important to invertebrates. The Oregon Natural Heritage Program recognizes 65 snails, 23 insects, 4 freshwater mussels, 1 amphipod, and 1 flatworm species as rare or threatened and associated with wetland or riparian habitats in Oregon (Christy and Titus 1997).

The fish habitat support function is similar to and/or includes the following functions defined by other assessment methods used in the region:

- From OFWAM (Roth et al. 1996), the function "Fish Habitat"
- From Hruby et al. (1999, 2000), the functions:
    - Anadromous Fish
    - Resident Fish
    - Invertebrate Richness
- From Gersib (1997), the functions:
    - Anadromous and Resident Fish Diversity & Abundance
    - Aquatic Diversity & Abundance
- From Smith et al. (1995), the function:
    - Maintenance of Plant and Animal Communities

Because the number of fish species in Oregon is large and each species has very specific habitat needs, a single chapter or model cannot possibly address all species' needs. What is presented here, then, should be viewed as a minimum description of variables that are important to most fish species in each of two categories: anadromous fish (e.g., salmon) and resident native fish (e.g., sculpins, some trout).

Function Documentation, Processes, and Variables

Anadromous fish include species that spawn in freshwater but spend much of their lives at sea. While in freshwater, all anadromous species make extensive use of wetland/ riparian sites. For example, when they are connected to larger water bodies by channels or floodplains, many tidal and nontidal wetlands throughout the Pacific Northwest provide important rearing and overwintering habitat for young coho and steelhead (e.g., Schreffler et al. 1992, Peterson 1982a, 1982b, Peterson and Reid 1984, Cederholm et al. 1988, Healey 1992). Use of specific aquatic sites by anadromous fish is influenced primarily by their accessibility, water quality, water quantity, food, and extent of physical cover that provides shelter from predators and extreme environmental conditions. Variables useful for describing the needs of anadromous species are shown in Table 15 below.

Resident fish are defined in this guidebook as species that spend their entire life either in freshwater or shallow estuarine habitats. They include introduced species and both warmwater and coldwater species. Some, such as the Oregon chub, are officially listed as endangered and depend almost entirely on wetland/ riparian sites, e.g., Riverine Impounded sites. Many others that are not officially listed may be experiencing long term population declines in Oregon (Hayes et al. 1996). Stream margins, backwater areas, and other "lateral habitats" typically classified as "wetland" or "riparian" (especially Riverine Impounding HGM subclass) are extremely important in fostering the survival of the fry of resident fish such as cutthroat trout. They comprise only 15-20% of the total wetted habitat during summer low flow of headwater and mid-elevation channels, but contain almost all the fry habitat and support densities of invertebrates that are more than 5 times greater than in mid-channel. (Moore 1987). Variables useful for describing the needs of anadromous species are shown in Table 15.

Table 15. Variables possibly associated with capacity for support of Anadromous Fish

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to an ecoregion. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
dark shade = no variables necessary because this function usually minimal in all sites in this subclass
Subclasses: FT= flow-through, I= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region	░	░	░	░	░	░	░	░	░	░	░	░	░	░
2/ HGM subclass	░	░	░	░	░	░	░	░	░	░	░	░	░	░
3/ Valley bottom or channel type	A	A	░	░	░	░	░	░	░	░	░	░	░	░
13/ Duration of flooded		A	▓	▓	A	▓	▓	A	A	▓				

connection														
15/ Maximum summer depth	A	B			A			A	A		B	B		
23/ Submersed cover: Woody/ emergent	A	A			A			A	A		A	A	A	A
27/ Shaded water	A	A			A			A	A		B	B	B	B
42/ Water quality status	A	A			A			A	A		B	B	B	B
43/ Watershed fish rating	A	A			B			B	B		B	B	B	B
102/ Thermoregulation rating	A	A			A			B	B		B	B	B	B

NOTES:

1/ *Region*. There are important regional differences in salmon use of Oregon's waters. For example, anadromous salmon are much more likely to use streams in the Coast Range than streams in the Owyhee Uplands. Maps are available showing the regional distribution (range of anadromy) of anadromous species in Oregon. Regional differences in land cover and geology also influence habitat suitability for anadromous species. Aquatic species distributions in Oregon sometimes correlate with ecoregions, but also correlate with catchments (river basins) or geographic clusters, depending on the species (Van Sickle & Hughes 2000).

2/ *HGM subclass*. HGM subclasses that are not ultimately connected by surface water to the ocean, during at least one season of the year, do not comprise anadromous fish habitat. This includes the two Depressional Closed subclasses. Depressional Alkaline and Depressional Bog subclasses also lack sufficient fish access in most cases.

3/ *Valley bottom or channel type*. Clear differences exist among valley bottom and channel types with regard to importance to anadromous species (Denman 2000):

Channel Type	Primary Functions
Estuarine Channel -- Narrow	Coho rearing
Estuarine Channel -- Large	Coho rearing
Floodplain Channel -- Wide, Lowland	Coho, steelhead: spawning, rearing, migration
Floodplain Channel -- Low Gradient, Large to Medium Sized Streams	Coho, steelhead: spawning, rearing
Floodplain Channel -- Low Gradient, Small Streams	Coho, steelhead: spawning, rearing
Alluvial Fan Channel	Coho, steelhead: rearing, spawing in lower gradient segments
Constrained Channel -- Mod. Gradient	Steelhead: spawning, rearing
Constrained Channel -- Low. Gradient	Steelhead: spawning, rearing
Narrow Valley Channel -- Moderately Steep	Steelhead: spawning, rearing
Narrow Valley Channel -- Steep	Limited rearing in lower segments
Headwater Channel -- Mod. Gradient	Steelhead: spawning, rearing
Headwater Channel -- Very Steep	No anadromous fish
Bedrock Canyon Channel	Limited rearing in lower gradient segments

13/ *Duration of flooded connection*. Connection to a waterway containing anadromous species is an overriding factor in all assessments of habitat potential for anadromous fish. Although wetland/

riparian sites that are flooded intermittently will sometimes be used, sites that are flooded for longer will meet needs of anadromous fish for shelter and spawning as well as simply feeding.

15/ *Maximum summer depth*. Maximum pool depth is correlated not only with pool persistence probability during low flow, but also with cool temperatures required by anadromous fish. In the Coast Range, summer pool volume and number of summertime pools also was correlated with contributing watershed area and presence of beaver dams (Stack and Beschta 1989).

23, 27/ *Submersed cover: woody/ emergent*; *Shaded water.* Natural cover is most important when the contributing watershed and/or the input channels have little shading vegetation, as in much of eastern Oregon. Woody debris and partly submersed wetland plants serve several roles:

- shelter fish (especially young fish) from strong currents and predators
- initiate turbulence that oxygenates water in steep stream segments
- provide a substrate for proliferation of aquatic invertebrates fed upon by fish
- retain suspended litter temporarily and facilitates cycling of associated carbon
- remove and detain suspended sediment that otherwise could smother fish spawning areas.

Severe accumulations of woody debris may occasionally block fish movements.

42/ *Water quality status*. Even the best physical habitat may go unused if water quality is poor. Sites located in watersheds that are 303(d) listed due to non-bacterial water quality issues may support few anadromous fish.

43/ *Watershed fish rating*. Several reports have attempted to prioritize or rate watersheds or stream segments across the entire state or within large regions, for their potential to support anadromous species. Many factors (social as well as technical) have sometimes been used to assign priorities. When just the technical factors are considered, a correlation is likely to exist between high-rated watersheds and individual sites within these watersheds that are most able to support anadromous fish.

102/ *Thermoregulation rating*. Sites that maintain or reduce water temperature as a result either of shading or groundwater discharge, are more likely to be used by anadromous fish because of their requirements for cooler water.

Table 16. Variables possibly associated with capacity for support of habitat of Resident Fish

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to each region. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
dark shade = no variables necessary because this function usually minimal in all sites in this subclass
Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
11/ Water level fluctuation	A	A	A	A	A	▨	B	A	A	▨	A	A	A	A
13/ Duration of flooded connection		B	A	A	A	▨	A	A	A	▨				
15/ Maximum summer depth	A	B	A	A	A	▨	A	A	A	▨	B	B		
21/ Shore slope	A	A	A	A	A	▨	B	A	A	▨	A	A	A	A
23/ Submersed cover: Woody/ emergent	A	A	A	A	A	▨	B	A	A	▨	A	A	A	A
27/ Shaded water	A	A	B	B	A	▨	B	A	A	▨				
31/ Vegetation class richness	A	A	A	A	A	▨	A	A	A	▨	A	A		
36a/ Size of largest connected permanent water body within 1 km		B			A	▨	A	A	A	▨				
42/ Water quality status	A	A	A	A	A	▨	B	A	A	▨	B	B	B	B
43/ Watershed fish rating	A	A	B	B	B	▨	B	B	B	▨	B	B	B	B
102/ Thermoregulation rating	A	A	B	B	A	▨	B	B	B	▨	B	B	B	B

NOTES:
1/ *Region.* There are important regional differences in the distribution of Oregon's fish species. For example, a clear statistical association between Oregon ecoregions and fish community composition

was demonstrated by Hughes et al. (1990). Streams at lower elevations tend to support greater biomass of invertebrate foods critical to fish (Carlson et al. 1990).

2/ *HGM subclass.* HGM subclasses differ somewhat in their general suitability for resident fish. For example, Depressional Alkaline and Depressional Bog subclasses often have chemical environments hostile to some species.

3/ *Valley bottom or channel type*. Some differences exist among the types with regard to importance to resident salmonid fish species (Denman 2000):

Channel Type	Primary Functions
Estuarine Channel -- Narrow	minor use
Estuarine Channel -- Large	minor use
Floodplain Channel -- Wide, Lowland	Spawning, rearing, overwintering
Floodplain Channel -- Low Gradient, Large to Medium Sized Streams	Spawning, rearing, overwintering
Floodplain Channel -- Low Gradient, Small Streams	Spawning, rearing
Alluvial Fan Channel	Spawning, rearing
Constrained Channel -- Mod. Gradient	Spawning, rearing, overwintering
Constrained Channel -- Low. Gradient	Spawning, rearing, overwintering
Narrow Valley Channel -- Moderately	Steep Spawning, rearing
Narrow Valley Channel -- Steep	Limited spawning and rearing
Headwater Channel -- Mod. Gradient	Spawning, rearing
Headwater Channel -- Very Steep	Very limited rearing
Bedrock Canyon Channel	Limited spawning and rearing

11/ *Water level fluctuation.* Severely aberrant water level fluctuations can reduce reproductive success of many species that spawn in shallow areas.

13/ *Duration of flooded connection.* Sites connected to permanent surface water (lakes, estuaries, large rivers) by a channel or floodplain are usually used more frequently by fish from the connected waters, and the connected permanent waters can serve as important overwintering areas or as refuges from drought or high water temperatures.

15/ *Maximum summer depth.* Sites with a greater maximum depth provide more space and more stable environmental conditions for many resident species. For example, trout biomass in high desert streams was correlated with channel depth and discharge (Li et al. 1994).

21/ *Shore slope.* Gradually sloping shorelines provide proportionately more area for spawning and growth of sheltering aquatic vegetation.

23/ *Submersed cover: Woody/ emergent.* In high desert streams of north-central Oregon, resident fish communities were more diverse and productive where channels were most hydraulically retentive and complex (Pearsons et al. 1992). Woody debris and emergent vegetation can provide such complexity, and also provide critical shade (Li et al. 1994). The importance of woody debris in supporting invertebrate communities that serve as food for fish has been extensively documented in the Pacific Northwest (e.g., Anderson et al. 1978).

27/ *Shaded water*. Although sometimes inconsistent with #23, a relatively open canopy helps insure that solar inputs are adequate to support invertebrate communities at abundance levels sufficient to promote rapid growth of young fish. For example, trout production was 3 times greater in an unshaded section than a shaded section of some Cascade region streams (Murphy et al. 1981). However, such positive effects are likely to occur only in dynamically stable channels. Lack of sunlight limits resident fish production mainly at sites where input channels are heavily forested, particularly with evergreens, or where low shrubs (e.g., blackberry) overgrow narrow channels. Shading (more than about 75% canopy closure, Carlson et al. 1990) reduced the growth of algae and consequently the biomass of invertebrates fed upon by trout in Coast/ Range, Cascade (Hawkins et al. 1982), and Blue Mountain region streams (Carlson et al. 1990), and perhaps to a lesser degree does so in high desert streams (Li et al. 1994, Tait et al. 1994). This is of concern because Invertebrate abundance can limit trout to an even greater degree than can habitat (e.g., Wilzbach et al. 1986). Changes in shade occur naturally, both seasonally (e.g., leaf drop of deciduous plants) and interannually (changes in width of riparian canopy as a result of changes in balance between sediment and discharge, MacDonald et al. 1991).

31/ *Vegetation class richness*. Multiple vegetation classes are more likely to meet multiple life history needs of resident fish, or indirectly indicate varied water regimes which do. For example, in RFT sites, fallen coniferous trees create and sustain natural pools for long time periods (Bisson et al. 1987, Andrus et al. 1988), whereas deciduous trees and shrubs are often nitrogen-rich, rapidly decomposed (Bilby 1988), and support a large abundance of invertebrates important as food for fish.

36a/ *Size of largest connected permanent water body within 1 km*. See #13

42/ *Watershed water quality status.* Poor water quality can limit fish survival and reproduction.

43/ *Watershed fish rating*. Several reports have attempted to prioritize or rate watersheds or stream segments across the entire state or within large regions, for their potential to support resident fish species. Many factors (social as well as technical) have sometimes been used to assign priorities. When just the technical factors are considered, a correlation is likely to exist between high-rated watersheds and individual sites within these watersheds that are most able to support resident fish.

102/ *Thermoregulation rating.* Several resident fish species (e.g., trout) are limited in Oregon by maximum water temperature. Sites that are relatively effective at reducing or maintaining water temperature should provide better habitat for these species.

Potential Values of Fish Habitat Functions

Fish are of obvious recreational and commercial importance. They also support aquatic birds, mammals, and nutrient cycles. About one-half of the commercially harvested fish and shellfish species along the Pacific Coast depend on wetland/ riparian sites during some stage of their life (ODSL 1989).

The *value* of an individual site's capacity to support fish cannot be adequately estimated simply from knowing the site's habitat capacity. Value depends as well on the uniqueness of the site's productivity in a watershed and regional context, and on the degree to which users depend on the resource from a particular site. These are not easily and reliably estimated, so no variables for assessing fish values of a particular site are recommended in this guidebook.

4.5 Support of Wildlife Habitat

This chapter deals with the capacity of wetland/ riparian sites to provide habitat directly for a wide variety of *amphibians and water birds*, by providing feeding, breeding, and refuge areas. Because the number of wildlife species in Oregon is large and each species has very specific habitat needs, a single chapter or model cannot possibly address all species' needs. What is presented here, then, should be viewed as a minimum description of readily-estimated variables that are important to most wetland and riparian species in each of two groups: amphibians and waterbirds.

This function is similar to and/or includes the following from other assessment methods used in the region:

From OFWAM (Roth et al. 1996), the function "Wildlife Habitat"
From Hruby et al. (1999, 2000), the functions:
  Habitat for Amphibians
  Habitat for Wetland-associated Birds
From Smith et al. (1995), the function:
  Maintenance of Plant and Animal Communities

Amphibians include salamanders, frogs, and toads. Species known to use Oregon wetland/ riparian sites to varying degrees are listed in Appendix D. Requirements of some Oregon amphibians are summarized by Thoms and Corkran (Northwest Ecological Research Institute, Portland; *pers. comm.*):

> *Eastern Oregon*: **Long-toed Salamander, Tiger Salamander, Pacific Tree Frog, Spadefoot and Woodhouse's Toad**: these species use shallow, temporary, often extensive water bodies. **Leopard Frog**: deep permanent warm water bodies with emergent or woody vegetation. **Bullfrog, Spotted Frog**: thickly vegetated, warm perennial ponds.
> *Western Oregon*: **Northwestern Salamander, Red-legged Frog** use perennial, cool, deep (>2 m) sites with small woody debris or fine (5-10 mm diameter) living branches. **Cascades Frog, Western Toad**: temporary, shallow ponds or shallow lake edges with silty substrate and short, sparse, herbaceous vegetation.

Waterbird habitat concerns the capacity of a site to support regular use during at least one season by a variety of bird species that are the most dependent on (obligate to) wetlands, riparian sites, and/or fresh water. Species known to use Oregon wetland/ riparian sites to varying degrees are listed in Appendix F.

Function Documentation, Processes, and Variables

Use of specific aquatic areas by wildlife is influenced primarily by water quality, water quantity, food, and extent of physical cover that provides shelter from predators and extreme environmental conditions. Many native species spend only a short time in wetland/ riparian sites, spending most of their lives in uplands. Nonetheless, the short time spent may be critical to breeding. For example, most frog eggs require several weeks of inundation to develop.

Table 17. Variables possibly associated with capacity for supporting Amphibian Habitat

The variables below should be considered as “starting points” for the development of HGM-based assessment methods appropriate to each region. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
dark shade = no variables necessary because this function usually minimal in all sites in this subclass
Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
7/ Growing season length	A	A	A	A	A	B	A	A	A	A	A	A	▓	▓
11/ Water level fluctuation	A	A	A	A	A	B	B	B	B	A	A	A	▓	▓
12/ Proportion of basin lacking permanent surface water	A	A	A	A	A	B	A	A	A	A	A	A	▓	▓
13/ Duration of flooded connection		A			A	A	A	A	A	A			▓	▓
16/ Dominant depth class	A	A	A		A	A	A	A	A	A	B	B	▓	▓
21/ Shore slope	A	A	A	A	A	B	B	B	B	A	A	A	▓	▓
22/ Deadwood & large trees	A	A						A	A	B	A	A	▓	▓
23/ Submersed cover: Woody/ emergent	A	A	A	A	A	A	A	A	A	A	A	A	▓	▓
24/ Submersed cover: grasslike emergents	A	A	A	A	A	A	A	A	A	A	A	A	▓	▓
29/ Open water interspersion		A	A	A	A	A	A	A	A	A	A	A	▓	▓
36a/ Proximity to/ size of largest permanent body		A	A	A	A	A	A	A	A	A			▓	▓

of water														
38/ Proximity to/ extent of natural vegetation	A	A	A	A	A	A	A	A	A	A	A	A		
39/ Proximity to/ extent of nonpermanently flooded gravel	A	A	A	A							A	A		
42/ Watershed water quality status	A	A	A	A	A	B	A	A	A		B	B		
101/ Water storage	A	A	A	A	A	A	A	A	A	A	A	A		

NOTES:

1/ *Region.* Different regions of Oregon have somewhat different amphibian faunas, and as a result the ranges of particular variables needed to predict the habitat functions will differ among regions.

2/ *HGM subclass.* Different subclasses also have somewhat different amphibian faunas. For example, several amphibian species show strong affinity for springs, seeps, and other areas of groundwater discharge. Such areas typically belong to the Slope HGM class. Bogs and highly alkaline Depressional sites typically provide very limited habitat for most amphibians.

3/ *Valley bottom or channel type*. Some amphibian species have an affinity for steep headwater streams, while others prefer broad floodplains. Thus, the ranges of particular variables needed to predict amphibian habitat functions will differ among valley bottom or channel types.

7/ *Growing season length.* Within some regions, the abundance of many amphibian species may be positively related to mean temperature and growing season length.

11/ *Water level fluctuation.* Severe fluctuations in water levels are detrimental to amphibians that lay eggs in water on vegetation.

12/ *Permanent surface water*. Although permanent surface water is more likely to harbor animals that prey on native amphibians (e.g., some fish, bullfrogs), it also potentially attracts more amphibian species, particularly if habitat is structurally complex.

13/ *Duration of flooded connection.* Although adult amphibians can easily disperse over land, the presence of a channel that connects a wetland to a larger water body facilitates colonization of the wetland by larvae (e.g., tadpoles) and even adults. However, channels increase access by predatory fish and bullfrogs, sometimes resulting in reduced survival of native amphibians.

16/ *Dominant depth class*. Sites that are mostly shallowly flooded in late summer provide the best habitat for most amphibian species.

21/ *Shore slope.* Sites with gently sloping shores provide a larger area of suitable habitat for most amphibian species.

22/ *Deadwood & large trees.* The importance of "old growth" forests in sustaining biodiversity in the Pacific Northwest has been widely documented. In wetland/ riparian sites, large trees (whether classified as old growth or not) annually generate a large amount of fallen dead wood, which provides exceptional foraging and cover sites for many amphibians during all stages of decay, both in and out of the water.

23/ *Submersed cover: Woody/ emergent.*
24/ *Submersed cover: Grasslike emergents.*
Sites with extensive stands of partly submersed emergent vegetation (especially thin-stemmed species) and woody cover provide excellent breeding habitat for some amphibians (Richter and Azous 1995, 1997).

29/ *Open water interspersion*. Sites in which unvegetated open water areas are well-interspersed with stands of emergent vegetation often provide the best habitat for amphibians because they provide good access to vegetated spawning and rearing areas. This variable is important mainly at sites that are larger than about 1 acre and wider than 100 feet.

36a/ *Connection to permanent water*. See #13.

38/ *Surrounding natural vegetation*. One of the most important factors predicting amphibian use of a particular site in the Pacific Northwest is the type and density of vegetation in uplands adjoining the site (e.g., Richter and Azous 1995, 1997). The extent, proximity, and age of natural cover types (native grassland and especially dense woods with much fallen woody material) is particularly important. The presence of distinguishable corridors connecting the site to nearby natural areas is probably less important than the total area of natural vegetation in the respective areas, and the quality of the separating land cover (Rosenberg et al. 1997). Removal of forest cover as far as 156 m away from breeding ponds can affect amphibian dispersal movements (Raymond and Hardy 1991), which for many species span a distance of at least 300 m. In the Oregon Coast Range, riparian buffers of 40 m width had twice the amphibian richness as buffers of 20m (Vesely 1997). In the West Slope Cascades, 7 of 9 amphibians were more abundant at sites within or adjoining mature (>80 yr old) forest (Gilbert and Allwine 1991). Canopy density is crucial to many forest salamanders (Vesely 1997). However, a dense canopy can limit the productivity of some aquatic salamanders (Murphy and Hall 1981, Murphy et al. 1981, Hawkins et al. 1983). In Willamette Valley oak woodlands, amphibian abundance was found to be correlated with riparian acreage within 1 km, and even the abundance of reptiles was correlated with acreage of open water in the vicinity of the oak sites (Vesely et al. 1999).

42/ *Watershed water quality status*. Poor water quality can limit amphibian survival and reproduction. For example, excessive sedimentation of low- and moderate-gradient headwater channels in Oregon can harm some salamander populations (Murphy et al. 1981, Hawkins et al. 1983).

44/ *Water storage*. Sites that are most able to store water are likely to provide at least minimal habitat for many amphibian species.

Table 18. Variables possibly associated with capacity for supporting Waterbird Habitat

The variables below should be considered as "starting points" for the development of HGM-based assessment methods appropriate to each region. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
4/ Maximum pool size		B	A	A	A	A	A	A	A	A	B	B		
7/ Growing season length	A	A	A	A	A	A	A	A	A	A	A	A	A	A
11/ Water level fluctuation	A	A	A	A	A	B	B	B	B	A	A	A		
16/ Dominant depth class	A	A	A	A	A	A	A	A	A	A	A	A	A	A
21/ Shore slope	A	A	A	A	A	A		B	B	A	A	A	A	A
22/ Mud flat dimensions	A	A	A	A	A	A		B	B	A	A	A	A	A
28/ Shoreline/ upland visibility	A	A	A	A	A	A	A	A	A	A	A	A	A	A
29/ Open water interspersion		A	A	A	A	A	A	A	A	A	B	B		B
30/ Dominant vegetation class	A	A	A	A	A	A	A	A	A	A	A	A	A	A
32/ Large trees	A	A						A	A	B				
33a/ Waterfowl foods	A	A	A	A	A	A	A	A	A	A	A	A	A	A
36/ Proximity to/ size of open standing water	B	B	B	A	A	A	A	A	A	A			B	B
40/ Proximity to/ extent of grassland/ cropland	B	B	A	A	A	B	B	B	B	A	B	B	A	A
41/ Proximity to managed waterbird areas	A	A	A	A	A	A	A	A	A	A	A	A	A	A

NOTES:
1/ *Region.* Different regions of Oregon have somewhat different waterbird faunas, and as a result the ranges of particular variables needed to predict the habitat functions will differ among regions.

2/ *HGM subclass.* Different subclasses also have somewhat different waterbird faunas. For example, several bird species (e.g., American Avocet, American Pelican) show strong affinity for Depressional Alkaline sites. Relatively few waterbirds make extensive use of Depressional Bog or Headwater Slope subclasses. Also, specific functions of wetland/ riparian sites vary by subclass. For example, waterbirds use Estuarine Fringe sites mainly as wintering and migration habitat, and Depressional Closed sites mainly as nesting habitat.

3/ *Valley bottom or channel type*. Some waterbird species (e.g., American Dipper) have an affinity for steep headwater streams, while others (e.g., Green Heron) prefer broad floodplains. Thus, the ranges of particular variables needed to predict bird habitat functions will differ among valley bottom or channel types.

4/ *Maximum pool size*. Many waterbird species require large areas of open water to escape mammalian predators, or for feeding or molting functions. Many are highly sensitive to disturbance from people passing by on foot, and large expanses of open water can provide an adequate buffer to reduce the disturbance.

7/ *Growing season length.* Within some regions, the abundance of many bird species may be positively correlated with mean temperature and growing season length. Longer growing seasons provide more time for newborn birds to mature, and are usually associated with more abundant food resources and shorter duration of ice cover.

11/ *Water level fluctuation.* Although moderate seasonal fluctuations in water levels are beneficial to many waterbird species, severe fluctuations are detrimental to waterbirds that nest along the water's edge.

16/ *Dominant depth class*. Sites that are mostly 2-24 inches deep provide habitat to the largest variety of waterbird species.

21/ *Shore slope.* Sites with gently sloping shores provide better habitat for waterbird species that nest along shores.

22/ *Mud flat dimensions*. A large number of the waterbird species (e.g., most sandpipers) require seasonally-exposed mud flats for feeding and/or resting. This variable is important mainly at sites that are not dominated by woody vegetation, and where the mudflats are larger than about 1 acre and wider than 100 feet.

28/ *Shoreline/ upland visibility.* Many waterbird species (particularly wading birds) are reluctant to visit sites that are mostly enclosed by tall vegetation or tall banks, because these waterbirds require visibility over long distances to detect approaching predators (e.g., Medin & Clary 1990).

29/ *Open water interspersion*. Sites in which unvegetated open water areas are well-interspersed with stands of emergent vegetation often provide the best habitat for waterbirds because they provide good access to food-rich vegetated areas and provide a natural separation of territories. This variable is important mainly at sites that are larger than about 1 acre and wider than 100 feet.

30/ *Dominant vegetation class*. Most of Oregon's obligate waterbird species (as highlighted in Appendix G) favor aquatic bed and emergent vegetation (e.g., Sanders 1995).

32/ *Large standing trees*. Mature trees are particularly important as nest and roosting sites for the following riparian bird species: Marbled Murrelet, Bald Eagle, Osprey, Great Blue Heron, Green Heron, Wood Duck, Barrow's Goldeneye, and Hooded Merganser (McComb and Hagar 1992).

33a/ *Waterfowl foods*. A few plant species (e.g., wild rice, *Zizania,* and wapato, *Sagittaria latifolia)* provide food so attractive that it draws large numbers of ducks and other obligate waterbirds (Crawford 1938, Yocom 1951), whereas some other plant species (e.g., reed canarygrass, *Phalaris*) seem to draw few waterbirds unless more favorable foods are completely lacking.

36/ *Proximity to/ size of open standing water*. Waterbirds are highly mobile and are influenced as much by proximity and size of other wetland/ riparian sites as by the characteristics of a particular site (e.g., Richter and Azous 1997). The relative importance of this variable is probably great in arid regions of Oregon than in moist regions (the "oasis effect"). Also, non-estuarine sites located near the coast are often species-rich because many migrant birds follow coastal routes and stop to forage in freshwater wetlands. Nearby estuaries with their open expanse of water provide birds with a degree of freedom from persistent disturbance by people on foot. Birds that typically spend much of their time on saltwater periodically visit freshwater sites to feed or gain shelter when seas are high or tides are unusually high.

40/ *Proximity to/ extent of grassland/ cropland.* Many waterbirds, particularly in winter, forage widely in nearby croplands and in summer may nest in adjoining grasslands. Presence of such areas near a wetland/ riparian site increases the probability the site's habitat will be used by waterbirds.

41/ *Proximity to managed waterbird areas*. Throughout Oregon, dozens of areas are being actively managed (through water level manipulation, control of non-native plants, and other means) for the specific purpose of encouraging use by one or more waterbird species. Presence of such areas near a wetland/ riparian site increases the probability the site's habitat will be used by waterbirds.

Potential Values of Wildlife Habitat Functions

Amphibians and birds are enjoyed by many citizens, and also are key parts of food chains that support aquatic birds and mammals. For example, the Pacific Giant Salamander replaces salmonid fishes as the primary vertebrate predator in wooded headwater channels, where they may comprise up to 99% of the total predator biomass at some sites (Murphy and Hall 1981). However, the value of wildlife at an individual site cannot be adequately estimated simply from knowing the site's capacity to support wildlife habitat. Value depends as well on actual use of the site by wildlife, and the uniqueness of the site's fauna in a watershed and regional context. These and other factors are described in Section 4 of Volume IA.

4.6 Support of Characteristic Native Vegetation

This chapter deals with the capacity of wetland/ riparian sites to provide habitat for a diverse array of native plants. At least 63 of the 1406 vascular plant species that are associated with wetlands in Oregon are considered rare, threatened, or endangered by the Oregon Natural Heritage Program (Christy and Titus 1997).

As used in this guidebook, "Support of Characteristic Native Vegetation" does not address the contribution of an individual site to local or regional biodiversity -- only the capacity of a site to support species richness within that site. This is a serious limitation because sites that are internally diverse, while often contributing significantly to local and regional diversity, do not inevitably do so. Sometimes sites that individually have low species richness contribute immensely to biodiversity at a regional level because the species they do support are ones seldom found elsewhere. For example, many early and mid-successional sites are highly diverse, yet contain mostly generalist species that occur widely and thus contribute little to local or regional diversity. Also, it is understood that the concept of "biodiversity" includes diversity of processes (not just species) measured at multiple scales, even though these are not easily estimated.

This function is similar to and/or includes the following from other assessment methods used in the region:

- From Hruby et al. (1999, 2000) it includes the function:
  Native Plant Richness
- From Smith et al. 1995, it includes the function:
  Maintenance of Plant and Animal Communities

Documentation, Processes, and Variables

In eastern Oregon, unaltered wetland and riparian sites almost always support more plant species than do their adjoining uplands. The situation in western Oregon is more variable. In one area of western Oregon, plant diversity was found to be higher in forested riparian (mostly RFT) sites than in adjoining upland forests (Gregory et al. 1991). In another survey (mainly in western Oregon), plant diversity in 8 wetlands was generally less than in adjoining uplands (Boss 1983). However, at a landscape scale wetland/ riparian sites in the Pacific Northwest are important for supporting biodiversity regardless of their relative species richness because they contain relatively undisturbed (by humans) habitat and many species not found in uplands (Raedeke 1989, Gregory et al. 1991, Naiman et al. 1993).

Table 19. Variables possibly associated with capacity for support of Characteristic Native Vegetation

The variables below should be considered as “starting points” for the development of HGM-based assessment methods appropriate to each region. They do not by themselves constitute an assessment method.

Legend:
A = important variable for distinguishing level of this function among sites in this subclass, compared to its influence in distinguishing level of this function within other subclasses
B = less important
blank = usually not relevant
light shade = these 3 variables may be useful when conducting landscape-scale assessments of this function.
Subclasses: FT= flow-through, Im= impounding, CP= closed permanently flooded, CNP= closed nonpermanently flooded, OF= outflow, Alk= alkaline, V= valley, HW= headwater, R= river-sourced, B= embayment

Class:	Riverine		Depressional					Slope		Flats	Lacustrine		Estuarine	
Subclass:	FT	Im	CP	CNP	OF	Alk	Bog	V	H		V	H	R	B
1/ Region														
2/ HGM subclass														
3/ Valley bottom or channel type	A	A												
7/ Growing season length	A	A	A	A	A	A	A	A	A	A	A	B	B	B
11/ Water level fluctuation	A	A	A	A	A	A	A	A	A	A	A			
30/ Dominant vegetation class	A	A	A	A	A	A	A	A	A	A	A	A		
31/ Vegetation form richness	A	A	A	A	A	A		B	B	A	A	A	A	A
34/ Seral stage	A	A	A	A	A	A	B	A	A	B	B			
38/ Proximity to/ extent of natural vegetation	A	A	A	A	A	A	A	A	A	A	A	B	B	B
42/ Watershed water quality rating	A	A	A	A	A	B	A	A	A		A	A	A	

NOTES:

1/ *Region.* The pool of species available to colonize wetland/ riparian sites varies considerably by region within Oregon. Considering just those wetland/ riparian dependent plant and animal species that the Oregon Natural Heritage Program considers to be rare, threatened, or endangered at the state or national level, the largest number are found in wetland/ riparian sites of the East Cascades region (80), followed by wetland/ riparian sites of the West Cascades, Basin & Range, Coast/ Range, Klamath Mountains, Blue Mountains, Willamette Valley, Columbia Basin, Lava Plains, and Owyhee Uplands regions (Christy and Titus 1997). These tabulations must be viewed cautiously because of differences in the sizes of the regions and the degree of effort spent searching for rare species.

2/ *HGM subclass.* Important differences exist among the subclasses with regard to their capacity to support biodiversity. At an individual site level in Oregon, plant and animal richness per unit of wetland area is probably greatest during most seasons in Riverine and Lacustrine Fringe sites, and lowest in Depressional Alkaline and Depressional Bog sites. However, if one were to tally just the number of rare, specialist species, the converse might be true. Slope sites (e.g., natural springs) also harbor large assemblages of specialist species, including many rare plants that occur in sites of no other subclass. The number of wetland-associated plant *communities* occurring in each HGM class may be approximately as follows (interpreted from Christy and Titus 1998):

Depressional/Flat	224 (66%)
Riverine	170 (50%)
Slope	54 (16%)
Lacustrine	39 (12%)
Estuarine	25 (7%)

3/ *Valley bottom or channel type*. Richness of many groups is probably correlated with valley bottom or channel type. Broad floodplains with plant communities that are subjected to frequent natural disturbance often have relatively high species richness, whereas riparian sites bordering steep headwater channels probably have relatively low richness. This is due in part to the greater frequency and intensity of natural floods at lower elevations, which reset plant succession, and in part to the fact that topographically lower sites are in a better position to be periodically colonized by a different complement of plant and invertebrate species that are washed out of headwaters by floods.

7/ *Growing season length*. Abundance and possibly richness of many groups increases in Oregon with decreasing elevation (or proximity to the coast) and consequently longer growing seasons. However, good local documentation of this relationship is lacking for most groups.

11/ *Water level fluctuation.* Both the absence of measurable fluctuation and the occurrence of excessive fluctuation can limit plant species richness. For example, in a survey of 19 Seattle-area wetlands, Cooke and Azous (1997) found fewer plant species in emergent and scrub-shrub wetlands that had large mean annual fluctuations, whereas in forested wetlands no relationship was detected.

30/ *Dominant vegetation class*. A statewide analysis of the habitat affinities of Oregon's rare, wetland-dependent plant and animals concluded that *emergent vegetation* in wetland/ riparian sites hosts the largest number of such species, followed by shrub-scrub vegetation, forest vegetation, aquatic bed vegetation, and moss (bog) vegetation (Christy and Titus 1997). However, in a different region or hydrogeomorphic type these vegetation types might be ranked differently. From a survey of 19 Seattle-area wetlands, Cooke and Azous (1997) concluded that vegetation classes such as forested, shrub, and emergent are of little use in predicting the presence or absence of rare plant species.

31/ *Vegetation form richness*. Presence of a variety of Cowardin classes (e.g., aquatic bed, emergent, shrub-scrub, forested communities) suggests that within-site richness of individual species may be large as well. Presence of multiple forms also suggests a site has been periodically and unevenly disturbed, or that microtopography (and consequently water regime) is internally diverse. This complexity supports more plant species. In a survey of 8 wetlands from the Ochocos to the

Coast, vegetation patterns were found to be less complex in wetlands that had flat gradients dominated by sheet flow (Boss 1983).

34/ *Seral stage.* In forested regions, the presence of late seral stages with large trees also can be one sign that a site has had time to develop a high degree complexity in its structure, microtopography, and ecological processes. However, plant richness onsite may sometimes be greater during earlier seral stages.

42/ *Watershed water quality rating*. Sites located in watersheds with relatively good water quality would be expected to support greater richness of wetland/ riparian plants. Indeed, a survey of 19 Seattle-area wetlands found fewer plant species in the emergent and shrub zones of sites whose watersheds contained greater proportions of impervious surface (Cooke and Azous 1997).

Potential Values of Plant Habitat

Aside from insects, plants contribute more visual and taxonomic diversity to Oregon's landscape than any other biological group. In addition, they play an obvious role in supporting a diversity of animals, including a few which rely almost entirely during certain parts of their life on a narrow range of plant species. The value to biodiversity of the plants at an individual site cannot be adequately estimated simply from knowing only the site's species richness. Value depends as well on the scarcity of the site's flora in a watershed and regional context, and on the degree to which users (humans or other animals) depend on or otherwise value the particular plant species. These values are not easily and reliably estimated.

Section 5. Profiles of Biological Sensitivity of Wetland/Riparian Systems in Oregon

Although many studies have documented the statewide distribution and life histories of plant and animals in Oregon wetland/ riparian systems, relatively little research has focused on responses of Oregon's plants and animals to human influence on wetland and riparian processes. As described in Section 9 of Volume IB, such information is needed in order to define ecological condition (integrity) of Oregon's wetlands, and to develop performance standards that protect aquatic life. The USEPA has published reviews of the North American literature on this topic (Adamus and Brandt 1990, Danielson et al. *in draft*), and hosts internet databases wherein one can search for what is known about the requirements and sensitivities of individual species of wetland plants (Adamus and Gonyaw 2001) and invertebrates (Adamus and Gonyaw *in preparation*). Following is a summary of published information available concerning responses of plants and animals to human influences on Oregon's wetland and riparian systems. This summary includes some references from elsewhere in the Pacific Northwest, and is not comprehensive. It focuses mainly on response of entire biological communities, and less on responses of individual species. Although wetlands are the primary focus, some information from streams and lakes is included when relevant.

Algae

- Benthic diatom diversity in a nutrient-poor Slope wetland in the East Slope Cascades region was generally uncorrelated with nitrogen concentration during a month-long period, but algal production generally was limited by nitrogen (Dodds and Castenholz 1988).
- Oregon tidal marshes subjected to the longest periods of desiccation had the lowest species diversity of diatoms (Moore and McIntire 1977).
- A variety of distinctively sediment-associated (as opposed to plant-associated) diatom taxa are characterized for Oregon estuaries by Whiting and McIntire (1985). Coastal diatom assemblages show little geographic variability within Oregon but are very sensitive to salinity and sediment (Whiting and McIntire 1985), thus suggesting good potential for use as indicators of those stressors.
- In one Oregon estuary, salinity was the factor most responsible for influencing diatom community structure (Moore and McIntire 1977).
- Not only does algal biomass increase with decreased shading, but shifts in community composition occur as well. Where at least 3% of full sunlight reaches the substrate of a channel, filamentous green algae often become dominant, whereas diatoms prevail in more shaded reaches (Warren et al. 1960, Hansmann and Phinney 1972).
- Assemblages of benthic algae were found to be good indicators of enrichment and turbidity in the Yakima River Basin, Washington, both in the mountainous Cascade region and in agricultural lands of the Columbia Basin. Community composition was a much more sensitive indicator than biomass in regard to reflecting water quality conditions.
- Blue-green algae were especially prevalent in nitrate-poor streams of the Cascades, whereas other species predominated in agricultural areas (Leland 1995).
- Phytoplankton assemblages among 7 montane lakes on the Olympic Peninsula were influenced by lake depth and nitrate concentrations (Larson et al. 1995).
- Surveys of Columbia Slough algae report a cumulative total of 114 taxa (N.S. Geiger, SRI/ Shapiro, Portland; *pers. comm.*).
- The USDA Forest Service, BLM, USGS, Oregon DEQ, and other agencies sometimes collect and analyze algal communities of Oregon streams, and occasionally make collections from slackwater areas and wetlands (e.g., MacCoy 1994).

Vascular Plants

- Plant species richness in 8 wetlands in western Oregon tended to be greater in wetland zones that were flooded for shorter duration, probably due to oxygen stress associated with long-duration flooding (Boss 1983).
- In 6 Seattle-area wetlands, plant richness declined significantly when flooding lasted longer than 6 days, even though this happened less than 6 times per year (Azous et al. 1997). When sites were flooded more often, shorter floods caused a decline in plant richness. Flood frequency influenced plant richness only when flood durations exceeded 3 days.
- Riparian plant species richness recovered dramatically (17 to 45 species) after removal of livestock from a central Oregon riparian site (Winegar 1977). However, low-intensity (<30% use) short-term autumn grazing seemed compatible with maintaining woody riparian vegetation in some sites in the Blue Mountain region (Sanders 1995, Kauffman and Krueger 1984).
- In a survey of 723 PNW riverine sites, Hesser and Gangstad (1990) found nuisance growths of aquatic bed species most often in irrigated landscapes (53%), urban landscapes (48%), and

heavily grazed sagebrush (43%). Species that dominated disturbed sites were often found just as often, but at lower densities, among less disturbed sites (e.g., riverine aquatic bed species, Hesser and Gangstad 1990).

- When two common sedges (*Carex rostrata* and *C. stipata*) were covered with a layer of sediment for 42 days, their productivity was greatly diminished. Flooding the sediment aggravated this impact. Likewise, an 18-inch layer of sediment added to pots containing red alder caused an immediate drop in photosynthesis of the saplings (Ewing 1996).
- In coastal Oregon, freshwater species that can persist after salinity intrusions include bentgrass (*Agrostis alba*) and Pacific silverweed (Frenkel and Morlan 1991). Salinity tolerances of some Pacific Northwest coastal plants are reported by Hutchinson (1988).
- Two common sedges (*Carex rostrata* and *C. stipata*) not only tolerated alternating drought and flooded conditions, but showed greater leaf elongation when flooded after a period of drought; photosynthetic rates were not altered. Flooding was for 60 days at a depth of 10 cm. It took only 4-6 days to kill saplings of red alder (*Alnus rubra*) and Oregon ash (*Fraxinus latifolia*) when they were flooded at or slightly above the soil surface. When soil was saturated to within 5 cm of the surface (either constant or alternating), growth of the red alder but not Oregon ash was reduced (Ewing 1996). Occurrence of 12 wetland plant species in 19 Seattle-area wetlands was related to specific ranges of water level and water level fluctuation by Cooke and Azous (1997).

Invertebrates

- Constructed depressional basins in southeastern Idaho exposed to wastewater (domestic and industrial) had fewer taxa but higher numbers of individuals of most taxa as compared to natural basins. This was partly due to lack of fish in the wastewater basins. The more nutrient-enriched basins had more Rotifera, Daphnidae, and Notonectidae (Cieminski and Flake 1995).
- In the Klamath Mountains region, invertebrate taxonomic richness declined with increasing logging (Fore et al. 1996).
- In a survey of permanent and nonpermanent streams in western Oregon, Dieterich (1992) found more taxa in streams with longer flow duration.
- Similarly, in a survey of 19 Seattle-area wetlands, Richter et al. (1997) found more taxa in sites with the more seasonally persistent water levels. This correlation with water regime was stronger than the correlation of invertebrate richness to watershed land cover.
- From data collected during a 3-year survey of Seattle-area wetlands, Ludwa (1994) concluded that the following metrics (variables), when combined into a multimetric index, were useful for detecting differences in the geomorphometry and land use setting of wetlands:

    Taxa richness (-)
    Richness of Ephemeroptera + Plecoptera + Odonata + Trichoptera (EPOT) taxa (-)
    Richness of Tanytarsini taxa
    Richness of Chironomini taxa
    Richness of Tanypodini taxa
    Percent of individuals as EPOT (-)
    Percent of individuals as Tanytarsini
    Percent of individuals as Chironomini
    Percent of individuals as Tanypodini
    Scraper and/or piercer taxa presence (-)
    Shredder taxa presence (-)
    Collector taxa presence (+)
    Presence of *Thienemanniella*

Presence of *Endochironomus nigricans*
Presence of *Parachironomus*
Presence of *Polypedilum*
Presence of *Ablabesmyia*
Presence of *Aspectrotanypus algens*
Presence of *Paramerina smithae*
Presence of *Psectrotanypus dyari*
Presence of *Zavrelimyia thryptica*
Presence of *Tanytarsus*

- A subsequent analysis of the data found that reduced effort (keying out invertebrates only to Order) yielded essentially useless information (Richter et al. 1997). This has important implications for programs that seek to use bioassessments in routine, rapid, decision-making.
- In estuarine systems in the Pacific Northwest, considerably more research may be required before invertebrate assemblages can be used to assess biological condition of wetlands, as they have in Atlantic estuaries, e.g., Summers et al. (1997), Deegan et al. (1997), Carlisle (1998).
- Zooplankton assemblages among 7 montane lakes on the Olympic peninsula were influenced by lake elevation and conductivity (Larson et al. 1995).
- Zooplankton in ten Cascade Depressional basins were studied by Girdner and Larson (1995). They found temporary ponds to be dominated by rotifers with short generation times and a crustacean that could encyst during dry periods. The deeper permanent ponds had two large-bodied crustacean taxa that were absent from shallower permanent ponds. The composition of the zooplankton community in temporary ponds that were inundated for relatively long periods was more similar to composition in the permanent ponds than to composition in the briefly inundated temporary pond.
- In nonpermanently-flooded channels in western Oregon, aquatic invertebrates are almost entirely highly mobile species that colonize from nearby, more permanent waters (Tew 1971, Dieterich 1992).
- Increases in invertebrate species that graze algae were logically associated with reduced shade and increased algal growths in the Blue Mountain region, whereas collector, shredder, and predator groups were not influenced (Tait et al. 1994). In West Cascade and Coast Range streams, these groups (particularly some Chironomid taxa) increased with increasing sunlight.
- In western Oregon, the tiny beetle, *Hydraena vandykei*, occurs disproportionately and in high numbers in channels that are nonpermanently flooded, and the blackfly, *Greniera* sp., was found only in such habitat (Dieterich 1992). Species in the taxonomic families Tipulidae, Empididae, and Ceratopogonidae also predominate in nonpermanently flooded channels.

Fish

- In high desert streams of northcentral Oregon, richness was greater, community composition varied less, and fish populations were depleted less by flood events, when channels were hydrologically complex. Species that spawn in early spring were, as expected, more affected by early spring floods than by summer floods, and summer-spawing species were more affected by summer floods than early spring floods. (Pearsons et al. 1992).
- Inventories of fish at 38 sites in the Tualatin River watershed identified the following species as relatively intolerant: torrent sculpin (*Cottus rhotheus*), coho salmon, cutthroat trout, rainbow trout (Friesen and Ward 1996).
- In the Willamette River, the following taxa were found to be the least tolerant of degraded water quality: all salmonids, Paiute sculpin, and torrent sculpin (Hughes and Gammon 1987).

- In 7 streams on the west side of the Willamette Valley, squawfish, redside shiner, largescale sucker, longnose dace, and speckled dace were encountered in warmer areas. Longnose dace, sculpins, and trout were particularly sensitive to sedimentation and reduced flow (Kruse 1989).
- Sculpin and cutthroat abundance can be greater in open than shaded areas (Hawkins et al. 1983).

Amphibians

- A survey of 19 Seattle-area wetlands reported decreasing amphibian species richness with increasing water level fluctuations. When mean annual water level fluctuation was >20 cm, only 3 or 4 species were present (Richter and Azous 1997).
- Some species, such as Pacific Tree Frog (*Pseudacris regilla*) appear to be quite tolerant of grazing whereas others (e.g., Cascade frog, *Rana cascadae*) are not (Quigley and Arbelbide 1997).
- Bullfrogs (*Rana catesbbeiana*), a nonnative species, are generally more prevalent in sites with permanent or long flooding duration (Adams 1997).

Birds

- From a survey of 19 Seattle-area wetlands, Richter and Azous (1997) concluded that richness and abundance of "adapters," "avoiders," and "exploiters" (a species-level classification) were more sensitive to urbanization than was the variable, "total avian richness."
- Bird species most sensitive to grazing in eastern Oregon are mostly shrub nesters, and in particular include Yellow Warbler, Willow Flycatcher, Song Sparrow (Taylor 1986, Taylor & Littlefield 1986, Sanders 1995), and Common Yellowthroat (personal observation). Grazing tends to increase the abundance of canopy-nesting species relative to abundance of ground- and shrub-nesting species (Saab and Rich 1997).
- Some studies (Kauffman 1982, Clary & Medin 1993, Medin & Clary 1990, 1991) have failed to find a decline in overall avian richness and/or abundance associated with grazing. Effects depend on the grazing regime, the wetland plant community that is being grazed, and other factors (Sanders 1995).
- Each year, the USFWS conducts aerial and ground surveys of wintering waterfowl in western Oregon. Data may be available, but counts are for large areas, not individual sites.
- The ODFW conducted aerial surveys in recent years of nesting waterfowl, along 200 transects, each 3-30 miles long, located in all regions of the state.

Section 6. Future Directions

This volume has provided a framework for selection and classification of reference sites, and for development of rapid methods for assessing functions, in ten regions of Oregon. Volumes IA and IB of the guidebook demonstrated how this volume's framework can be (and were) applied for these purposes to a particular region. Products resulting from the initial framework application to the Willamette Valley are presumed to be inappropriate for use in other regions of Oregon. Thus, reference sites should be selected, and methods for assessing functions and values should eventually be developed and applied, in the other regions of Oregon. This need not be an enormous undertaking, owing to improved efficiency as a result of experience gained in the Willamette Valley, and the potential for combining some regions. Information from such efforts will lead to improved performance standards for restored wetlands, as well as clues for improving design of restored and constructed wetlands.

Simulaneously, (a) efforts should be initiated to quantify the amount and distribution of wetlands by HGM subclass within watersheds of each region, so data gathered at reference sites can be extrapolated to the entire resource, and (b) efforts should continue to define reliable biological indicators of wetland/riparian ecological condition (or impairment of "beneficial uses") in HGM subclasses in each region, in order to provide resource managers with increased capability for diagnosing causes of impairment of these systems. In particular, basic research on the physical and chemical functions of "drier-end" wetlands such as Flats, especially in urbanizing landscapes, deserves greater support.

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Appendix A. Review of Existing Wetland/ Riparian Classifications

This appendix lists and briefly describes classifications other than the HGM classification which have been applied to wetland or riparian systems by resource managers. This information was assembled as a foundation for identifying regionally appropriate HGM subclasses. It is not comprehensive. Emphasis is on the Pacific Northwest. See preceding part of the Classification and Profiles report for the Literature Cited section.

1. Classification Systems for Wetlands in General

Cowardin et al. (1979):
This is the classification framework that has been used in the mapping of Oregon's wetlands by the National Wetlands Inventory (NWI) of the U.S. Fish & Wildlife Service. Wetland and deepwater aquatic sites have been mapped at scales of 1 inch = 1 mile or 1 inch = 0.5 mile. The major categories are:

Palustrine	Freshwater sites dominated by woody or emergent plants, or other freshwater sites <20 acres and with water depth <2 m.
Lacustrine	Freshwater sites on the fringe of lakes or dammed channels, excepting sites dominated by woody or emergent plants.
Riverine	Freshwater sites within channels, excepting sites dominated by woody or emergent plants.
Estuarine	Brackish tidal wetlands and adjoining deepwater that is semi-enclosed by land.
Marine	Open, saline, tidal shorelines.

Vegetation-based Classifications
The Oregon Natural Heritage Program began work in 1990 on a classification framework using wetland vegetation. Through field data collection, expert review, and cross-walking to the National Vegetation Classification System (NVCS), it has evolved into its present list of “plant communities” (Christy and Titus 1998). It incorporates and builds upon vegetation classifications developed locally (for example) for the Willamette Valley (Titus et al. 1996); Deschutes, Ochoco, Fremont, and Winema National Forests (Kovalchik 1987); the Mount Hood National Forest (Diaz and Mellen 1996); and the Malheur, Umatilla, and Wallowa-Whitman National Forests (Crowe and Clausnitzer 1997). The plant communities have not been mapped, except in a few very local instances. In Appendix C, we have attempted to relate these plant communities to the HGM classes.

Also, for classifying Oregon wetlands at a coarse level for wildlife, Christy and Titus (1997) recognized the following "species groups":

A. Middle-upper elevation riparian & woodland sites; temporarily flooded to saturated.
B. Lower-middle elevation riparian & woodland sites; temporarily to seasonally flooded.
C. Perennial springs & uppermost stream reaches; saturated to semipermanently flooded.
D. Rivers, streams, meadows, mires, ponds, lakes; seasonally to semipermanently flooded.
E. Subalpine peatlands.
F. Low-elevation alkaline floodplains, playas, estuarine salt marshes.

G. Seasonally-flooded pools & seepage areas.

Reinelt et al. (1997):

Hydrologic studies of wetland sites in the Seattle area defined the following 4 classes of wetlands

Stable base water level with low event fluctuations
Stable base water level with high event fluctuations
Fluctuating base water level with low event fluctuations
Fluctuating base water level with high event fluctuations

"Fluctuations" were defined as water level changes of greater than 20 cm.

Marcot (1990):

Based on their support of habitat for wetland vertebrates, the author categorized landslide-formed ponds in the Coast Range of northern California as:

Ephemeral (dry annually)
Astatic (fluctuate seasonally >10% of their maximum depth)
Stable (fluctuate seasonally <=10% of their maximum depth)

Models were developed for predicting these categories, given site-specific and landscape-scale information.

Gwin et al. (1999):

In the only other Oregon effort to define HGM subclasses, this team while working on an EPA project in the Portland area, recognized three subclasses:

depression in riverine setting: Topographic depression located alongside a stream or river
in stream depression: Topographic depression located within a stream or river
depression in slope setting: Topographic depression placed on sloping land where there is a discharge of groundwater to the surface

Using human alterations to define HGM subclasses runs counter to national HGM guidance for defining subclasses:

> "A major reason for classification is to separate variation from natural sources that relate to functioning from variation due to disturbance, particularly disturbance caused by human activity." (Brinson et al.1996).

Nonetheless, this subclassification seems appropriate for the specific purpose for which it was intended. By using an Impact Characterization Form (such as the one in Appendix C of Volume IA), one can accomplish the same objectives, while considering a wider variety of potential impacts.

2. Riverine Classifications

Guidance from the Corps of Engineers suggests that Riverine subclasses be identified within regions based on factors such as "water source, position in watershed, stream order, watershed size, channel gradient, and floodplain width" (Brinson et al.1995).

NWI Riverine Subclasses (Cowardin et al. 1979):

Tidal: Water flow is controlled by tides and salinity is less than 0.5 parts per thousand. Gradient is low, streambed is mainly mud and sand. Floodplain is broad.
Lower Perennial: No tidal influence. Gradient is low and floodplain is broad.
Upper Perennial: Gradient is high and floodplains are absent or narrow.

Intermittent: Surface water flows in the channel during only part of the year, though it may be present other seasons as small isolated pools.

This classification has been applied to most riverine sites in Oregon. The NWI defines a "riverine" category as including all wetlands and deepwater habitats contained within a channel, with two exceptions: (1) wetlands dominated by above-surface vegetation such as trees, shrubs, and emergent plants, and (2) saltwater channels. Nearly all sites classified as "riverine" by the NWI would be included in the HGM riverine class. However, the HGM riverine class also includes many sites that would be classified by NWI as palustrine. This is because the NWI riverine category does not include vegetated sites (except those with submerged plants).

Kovalchik (1987):

The author split channel systems of central Oregon into geomorphic categories as follows, and described their associated plant communities:

- Gradient low (<1% gradient)
  - Elevation low-moderate (<5200 ft); Soil Derivation: rhyolite, tuff
    - Floodplain Active
    - Floodplain Inactive (includes terraces)
  - Elevation moderate-high (>5200 ft); Soil Derivation: basalt
    - Floodplain Active
    - Floodplain Inactive (includes terraces)
- Gradient moderate (2-4% gradient)
  - Floodplain Active
    - Channel shelves
    - Fluvial surfaces, well-developed
  - Floodplain Inactive
- Gradient steep (>4%); first-order streams in V-shaped valleys
  - Streambanks
  - Narrow floodplains and toe slopes

Jensen and Platts (1989); Jensen et al. (1989):

The authors defined at least five "valley bottom types" (VBT's) based fundamentally on geologic origins and recognized directly by shape, gradient, width, side slope gradient, and aspect.

- Glacial Basin (includes many bogs and fens)
- Glacial Valley (U-shaped, Glacial Train or Outwash)
- Erosional Canyon (V-shaped or Notched)
- Depositional Canyon (V-shaped or Notched)
- Alluvium (Confined or Unconfined floodplain)

Jensen's group (White Horse Associates, 1992) also categorized valley bottoms in the Umatilla National Forest as Basin, Low-gradient Canyon, Moderate-gradient Canyon, High-gradient Canyon, or Draw. Each valley bottom type is said to have a unique "ecological potential" and proceeds, following disturbance, through a somewhat predictable "succession of states." Jensen et al. (1989) further described the valley bottom types by their associated valley widths and by the landforms (fluvial surfaces) they contain. For each landform category, he collected plant community data from a series of reference sites. The landform categories most applicable to these riverine sites were: stream channel, channel levee, floodplain, and alluvial fan.

Rosgen (1994):

This is one of the most often used geomorphic classifications for channels, and recognizes the following categories:

Type A. Steep, highly entrenched channels containing step pool systems with high sediment transport potential.

Type B. Moderate gradient channels that are moderately entrenched in gentle to moderately steep terrain, have low sinuosity, and are riffle-dominated.

Type C. Low gradient channels, moderately high sinuousity, pool-riffle bedform with well-developed floodplains.

Type D. Braided channels with moderate channel slope.

Type E. Very low gradient, highly sinuous channel.

Type F. Highly entrenched channel.

Oregon Watershed Assessment Manual (Denman 1999):

A chapter in this manual describes specific, easily-recognized channel types and subtypes. The following types are most likely to contain or border wetlands, and have the most in common with the HGM riverine class:

Alluvial Fan channel
Low Gradient Large Floodplain channel
Low Gradient Medium Floodplain channel
Low Gradient Small Floodplain channel
Low Gradient Moderately Confined channel
Moderate Gradient Moderately Confined channel
Low Gradient Confined channel

Beechie et al. (1994):

In the Skagit River watershed of Washington, channel features were characterized by their geomorphology as follows:

Side channels: small channels branching off the main stem; typically abandoned river channels or overflow channels on the floodplain or on low terraces near the main stem.

Distributary channels: channels that branch off the main stem in the delta and flow into the estuary as separate channels.

Sloughs: Side or distributary channels with >90% of their area consisting of pools, even during flooding

Maxwell et al. (1995):

The authors of this national report propose the following subclasses for riverine systems:

Intermittent Stream, Steep Riverine, Moderate Riverine, Gentle Riverine, Flat Riverine

Pennsylvania HGM Project:

Brooks et al. (1996) split the Riverine HGM class into subclasses as follows:

- *Floodplain In-stream*: sites within banks or channel
- *Headwater*: in floodplain, sites on order-1 or 2 channels
  - *Impoundment*: flow controlled by beaver or humans
  - *Floodplain:* frequent flooding
- *Mainstem*: in floodplain, sites on order 3 or higher channels
  - *Impoundment*: flow controlled by beaver or humans
  - *Floodplain*: frequent flooding

Subsequently, detailed hydrologic data collected by Cole et al. (1997) supported the hypothesis that some of these HGM subclasses were functionally distinct, despite the presence of potentially confounding factors related to human alteration of surrounding land cover and water tables.

North Carolina Piedmont HGM Project:

Brinson et al. (1996) recognized the following riverine subclasses based on presence or absence of overbank flooding, and impounding conditions:

Overbank Flow-dominated
Riparian Source-dominated
Beaver Dam-dominated

Other Riverine Classifications:
Perhaps the commonest method of categorizing riverine sites is by their *channel (stream) order*, *drainage area size*, or *landscape position*. For example, under the Strahler (1957) classification, initial undivided channels are considered first order channels. When they join, the resulting channel is categorized as second order. When a second order channel is joined by a first order channel it remains second order, but when joined by another second order channel it becomes third order, and so on. First order channels usually occur relatively high in a watershed whereas fourth and higher-order channels occur nearer to sea level. Channel order or drainage area has been used in Oregon to predict stream width, discharge, channel shape and dynamics, and fish use (see Boechler and McAllister 1992 for a rationale for using stream order as a primary classifier of Oregon streams). Although drainage area is a more accurate and direct indicator of riverine function, channel order can be determined much easier from available topographic maps.

3. Depressional/ Flats Classifications

Guidance from the Corps of Engineers suggests that Depressional subclasses be identified within regions based on factors such as "water source and degree of connection with other surface waters"

Depressional/ Flats Classification Frameworks Used in Oregon

Geomorphic factors have only rarely been used to classify Oregon's Depressional/ Flats sites. Under most geomorphic classifications, probably all sites belonging to the HGM Depressional/ Flats class would be classified as "valley-bottom" sites. However, not all sites classified as valley-bottom will be Depressional/ Flats sites as defined by the HGM classification because the valley-bottom category can sometimes include sites subjected to frequent flooding, i.e., riverine sites. Under the NWI classification, all sites classified by HGM as Depressional or Flats would be classified by NWI as "palustrine" or rarely, "lacustrine." Conversely, sites mapped as palustrine or lacustrine will *sometimes* be Depressional or Flat sites, but not always.

In the Umatilla National Forest, depressional sites were categorized as Vegetated (8 subclasses), Dike, or Pond (White Horse Associates 1992). In central Oregon, Kovalchik (1987) categorized depressional sites as:

Permanent to semipermanently flooded ponds
Wet meadows, swales, and drainages
Moist meadows

The Oregon Watershed Assessment Manual (Watershed Professionals Network 1999) does not explicitly recognize any wetland types analogous to the Depressional/ Flats HGM class.

A statewide classification of lakes (Johnson et al.1985) which may be applicable to some of the larger depressional sites recognizes the following geomorphic categories:

Tectonic-formed Basins
Volcanic-formed Basins
Landslide-formed Basins
Glacially-formed Basins
Shoreline (Coastal) Basins
River-formed Basins
Artificial Basins

The same authors categorize Oregon lakes across a gradient of increasing productivity (trophic status):

Ultraoligotrophic, Oligotrophic, Mesotrophic, Eutrophic, Hypereutrophic

Depressional/ Flats Classification Frameworks Used Elsewhere

Among the projects that have been initiated nationally to define HGM subclasses within regions, about 11 are dealing with the Depressional and/or Flats HGM classes:

Western Washington - Lowland Depressional (2 subclasses)
Central Valley of California - Vernal pools
Northern Rockies - Intermontane Depressional
Upper Midwest U.S. - Prairie Pothole Depressional (2 subclasses)
Peninsular Florida - Depressional and Flats
Maryland (eastern shore of Chesapeake Bay) - Depressional
Everglades Florida - Flats (3 subclasses: rock, marl, organic)
Southeastern U.S. - Pine Flats
Lower Mississippi Valley - Protected Depressional
Pennsylvania - Riparian Depressional
Interior Alaska - Organic Flats

In western Washington lowlands, the HGM project (Hruby et al.1999) is not considering the Flat HGM class in any detail, but split the Depressional HGM class into two subclasses, Closed and Outflow. The eastern Washington HGM project is classifying Depressional sites as Long Duration, Short Duration, or Alkali. In the northern Prairie Pothole region, some of the depressional wetlands have been split into two subclasses based on mainly on hydroperiod: Temporary and Seasonal. In Pennsylvania, Brooks et al. (1996) split the Depressional HGM class into subclasses as follows:

- Associated with a stream or river:
  - *Mainstem Depression*: seldom or not flooded by river
    - *Riparian Depression*: inlets & outlets present, mineral soil, groundwater-fed
    - *Organic Depression*: inlets & outlets present, organic soil
  - *Surface Water Depression*: fed mostly by overland flow or interflow, inlets & outlets present.
- Not associated with a stream or river:
  - *Isolated Depression*: no inlets or outlets

Detailed hydrologic data collected by Cole et al. (1997) supported the hypothesis that some of these HGM subclasses are functionally distinct, despite the presence of potentially confounding factors related to human alteration of land cover and water tables.

Although not specifically part of national HGM efforts, a report by Maxwell et al. (1995) proposes several subclasses for depressional sites, three of which may be relevant to Oregon: Playa, Morainal, and Dune-field.

Preliminary results from a statewide biological and geomorphic survey of 80 Montana wetlands may be useful (Apfelbeck 1997). The collected data mostly supported the following categories for Depressional/ Flats sites:

- Permanently Flooded Basins
  - Small Watershed
    - Dilute (pH <6.5)
    - Recharge (pH 7-9)
    - Alkaline (pH >9)
  - Large Watershed
    - Fresh (conductivity <20,000 uS/ cm)
    - Saline (conductivity >20,000 uS/ cm)
- Ephemerally Flooded Basins

For northern Nevada, Jensen et al. (1989) defined several categories of valley bottoms, based fundamentally on their geologic origins and recognized directly by their shape, gradient, width, side slope gradient, and aspect. Most depressional sites fell within the "basin" valley-bottom type. Jensen further described the categories by their associated valley widths and by the landforms (fluvial surfaces) they contain. For each landform category, Jensen's group collected plant community data from a series of reference sites. The landform categories most applicable to the depressional sites were probably alluvial fan, basin, moraine, glacial outwash plain, and terminal moraine.

4. Slope Wetland Classifications

Slope Wetland Classification Frameworks Used in Oregon

Apparently no geomorphic classification used in Oregon has specifically recognized subclasses of springs or other nonriverine Slope sites. All sites classified by HGM as belonging to the Slope class would be classified by NWI as palustrine or rarely, lacustrine or riverine. Conversely, sites mapped as palustrine, lacustrine, or riverine will *sometimes* be Slope sites, but not typically.

Slope HGM Subclasses Used Elsewhere

Guidance from the Corps of Engineers suggests that Slope subclasses be identified within regions based on factors such as "degree of slope, landscape position, and source of water." Among the HGM projects that have been initiated nationally, only three (New England, Mid-Atlantic, and Southeast Alaska) are doing assessments at a series of Slope sites.

At a national level, Baker and Foulk (1975) recognized 8 types of springs:

Seep: Water discharges from numerous small openings in permeable earth material, usually at very low discharge rates

Tubular: Water discharges from rounded channels such as lava tubes

Fracture: Groundwater moves predominantly through fractures and emerges where the fractures intercept the ground surface

Contact: Water flows from a permeable water-bearing unit that overlies a less permeable unit that intersects the ground surface

Depression: Water flows from a groundwater depression that intersects the water table

Artesian: Water under pressure is released from a confined aquifer at the aquifer outcrop or through an opening in the confining unit

Geyser: Water under pressure ejected periodically as a result of expansive force of superheated steam within constricted subsurface channels

5. Lacustrine Fringe Classifications

Lacustrine Classification Frameworks Used in Oregon

Nearly all sites classified by HGM as belonging to the Lacustrine Fringe class would be classified by NWI as "lacustrine" or rarely, "palustrine." Conversely, sites mapped as lacustrine by NWI will almost always be Lacustrine Fringe sites according to the HGM criteria. Lakes themselves are most often classified by their water temperature (warm or cold), geomorphology, water chemistry, and/or productivity. Lake geomorphic classes applicable to Oregon were discussed earlier under Depressional/ Flats.

Lacustrine Fringe HGM subclasses Used Elsewhere

No guidance is available from the Corps of Engineers pertaining to factors useful for defining subclasses of the Lacustrine Fringe HGM class. Apparently only one HGM project (in Oklahoma) is dealing with this class.

Estuarine Classifications

Estuarine Classification Frameworks Used in Oregon

An estuarine classification proposed earlier by ODSL (Hamilton 1984) and developed partly by ODFW (Bottom et al.1979) defines the following estuarine categories ("subsystems"): Riverine, Slough, Bay, Marine. Within these, hydroperiod (intertidal vs. subtidal) is used as the primary delimiter, followed by vegetation class (marsh, aquatic beds, or unvegetated). A chapter in the Oregon Watershed Assessment Manual (Denman 1999) categorizes estuarine channels as Narrow or Large. Nearly all sites classified by HGM as belonging to the Estuarine Fringe class would be classified by NWI as "estuarine." Conversely, sites mapped as lacustrine or marine by NWI will always be Estuarine Fringe sites according to the HGM criteria.

Estuarine Fringe HGM subclasses Used Elsewhere

No guidance is available from the Corps of Engineers pertaining to factors useful for defining subclasses of the Estuarine Fringe HGM class. Apparently only one HGM project (in the Northwestern Gulf of Mexico) is dealing with this class.

Appendix B. Synopsis of Existing Methods for Assessing Functions and Values of Pacific Northwest Wetland and Riparian Systems

This appendix lists and briefly describes assessment methods which have been applied to wetland or riparian systems by resource managers in the Pacific Northwest. This information was assembled as a foundation for identifying regionally appropriate HGM subclasses. It is not comprehensive, and only the methods that are currently being used most often are included. For more complete reviews of wetland assessment methods, including methods applied in other regions of North America, see Adamus (1992) and Bartoldus (1998).

Types of Assessment Methods

Methods for inventorying or assessing riparian and wetland sites can be classified as:

Indirect, estimation-based
Indirect, measurement-based
Direct, measurement-based

Many assessment methods are multi-tiered, allowing for both estimation and measurement, using both indirect and direct approaches. Using the above categorization, the following sections describe some of the methods used currently in the Pacific Northwest for assessing functions and/or values of wetland/ riparian sites.

1. Indirect, Estimation-based Methods

Users of this type of method rely primarily on visual estimation and interpretation of existing databases, rather than making new measurements using field equipment. Users estimate the presence/ absence or amount of a particular variable such as canopy closure. These methods are called "indirect" because they do not require users to estimate or measure functions or biological condition directly. Rather, the users employ "variables" or “indicators” that collectively are correlated to functions or condition, to infer the occurrence or relative magnitude of the functions or condition at a particular site. Because of the generally lower precision expected from estimation as opposed to measurement, the models that are part of these methods often require only categorical assessments of most of the variables, e.g., users can choose from among canopy closure categories of 0-30%, 31-60%, or 61-100%. These methods are used mainly as planning tools because they are relatively comprehensive (they include wetland/ riparian functions other than just "habitat") and are relatively rapid. The output is one or more numerical scores or qualitative categories that represent the site's functions and/or condition.

Methods in this category that are most often used in Oregon aquatic systems are **OFWAM** (Oregon Freshwater Wetland Assessment Method, OFWAM, Roth et al. 1996) and the **PFC method** (Proper Functioning Condition, Pritchard et al. 1994, 1995, 1998). Although both methods focus on characterizing individual wetland/ riparian sites, they also consider how a site's functions are influenced by the contributing watershed or landscape. They cannot be used to characterize functions of an entire watershed or ecoregion because they do not separately assign a rating to the functions or condition of the non-aquatic component.

OFWAM (Roth et al. 1996).

In contrast to the PFC method and the Oregon Watershed Manual, OFWAM's primary purpose is "to determine the level of protection to afford specific wetlands" and is "not for evaluating site-specific impacts." For a particular site, the OFWAM output characterizes each of four functions as:

Function is intact
Function is impacted or degraded
Function is lost or not present

and gives specific models (narrative rating criteria) for determining these categories. OFWAM's rating criteria are not based on any data sets from Oregon. Although the vocabulary of the OFWAM ratings implies that suboptimal functioning must be due to human-related degradation, this is not always the case. Functions at a particular wetland/ riparian site sometimes operate at less than their full potential due to natural constraints. Experience with applying OFWAM during the past 5 years suggests that only an extremely small number of sites are assigned the lowest category ("function lost or not present") for more than one function. This lack of sensitivity reduces the usefulness of OFWAM's results. Also, OFWAM does not explicitly distinguish between functions and the values of those functions to society, but rather blends these concepts together. OFWAM has been used most commonly by consultants involved in local wetland inventories.

PFC Method (Pritchard et al. 1994, 1995, 1998)

The PFC method is a descriptive approach that allows users to assign a site to one of four categories:

Proper Functioning Condition
Functional - At Risk
Nonfunctional
Unknown

The PFC method includes no explicit model for processing the estimates of variables. Users answer "yes," "no," or "not applicable" to describe the condition of 20 easily-observed variables in three categories (hydrologic, vegetation, and soils-erosion) on a checklist, and then must decide in which of the above categories their responses would collectively place the site. Decisions should be made by a 3-person multidisciplinary team during a site visit. "Sites" are stream reaches at least 0.25-mile long or are discrete wetlands. Wetland (lentic) sites are assigned the Proper Functioning Condition designation when users have judged there to be "adequate vegetation, landform, and debris" to:

- dissipate energies associated with wind action, wave action, and overland flow from adjacent sites, thereby reducing erosion and improving water quality;
- filter sediment and aid floodplain development;
- improve flood-water retention and groundwater recharge;
- develop root masses that stabilize islands and shoreline features against cutting action;
- restrict water percolation;
- develop diverse ponding characteristics to provide the habitat and water depth, duration, and temperature necessary for fish production, waterbird breeding, and other uses;
- support greater biodiversity.

A "Functional - At Risk" designation means a site "would likely lose any habitat that exists in a 25- to 30-year flood event." PFC guidance cautions that just because a site is considered Proper Functioning Condition, it does not mean that conditions are optimal for all functions and species. Users are instructed to view PFC as just the minimum condition needed before efforts can be made to attain more rigorous water quality and biological objectives. Users have the option of using other methods to define higher goals and objectives, e.g., Desired Future Condition (DFC). That is particularly appropriate because the PFC method does not directly or explicitly assess vegetation or fish/ wildlife habitat.

PFC was designed primarily for prioritizing restoration activities at a site level, and for suggesting design features for such projects. As of the end of 1996, the PFC method had been used by BLM, Forest Service, and others to categorize 7229 miles of streams and 15,120 acres of wetlands in Oregon and Washington, likely making it the most-used assessment method in the region. A statistical sample of sites is now being revisited to determine recent trends in condition (Adamus & Thomas 1998).

NRCS Minimal Effects Procedure

This procedure was drafted by the Oregon office of the National Resource Conservation Service (NRCS) for the very specific purpose of judging if a proposed alteration to a wetland as a result of agricultural activities should result in a "minimal effect exemption to wetland functions and values under guidelines of the Federal Food Security Act." NRCS staff apply specific criteria to determine if a minimal effect exemption should be granted. Unlike other methods, the procedure is prescriptive. With just 8 basic steps, it also is the most simple and rapid. Among several conditions it defines that should lead to a "not minimal" determination, it includes a provision that attempts to address cumulative effects by requiring a "not minimal" determination if the area proposed for alteration comprises more than 0.1 percent of a small watershed (defined as a 5-digit HUC watershed in western Oregon, a 6-digit HUC watershed in eastern Oregon). If the models indicate that "more than 50% of the functions present...are eliminated or significantly reduced by the proposed activity," a determination of "not minimal" should be made. The consequence of a "not minimal" determination is that a NRCS state wetland specialist must help the applicant develop and implement "appropriate mitigation or additional conditions to minimize impacts of lost functions." One component of this procedure requires the user to complete a functional assessment procedure ***which may be based on use of "regional HGM models as available."***

Washington Methods for Assessing Wetland Functions (Hruby et al. 1999, Hruby et al. 2000)

These methods -- one guidebook for freshwater riverine and depressional wetlands of the Puget Lowlands of western Washington and the other for depressional wetlands in the Columbia Basin of eastern Washington -- are currently the only regional methods in the Pacific Northwest that use the classification and some of the principles of the HGM Approach. They differ from Oregon's HGM guidebooks with regard to (for example) several of their indicators of functions, the operations used to combine the indicators (or variables) into scores, and a few of the functions. They have, of course, been calibrated to a set of wetlands in Washington rather than Oregon.

Washington DOT Characterization Method (Null et al. 2000)
This is a descriptive method, not intended to assign a score to an assessed site. It implicitly blends functions and values, and is fairly rapid to use. Its primary intended use is for linear projects, such as assessments of wetlands along highway rights-of-way, in the state of Washington. Our "Judgmental Method" (Appendix B of Volume IA) is conceptually similar.

SAM (Wetland and Buffer Functions Semi-Quantitative Assessment Methodology)
(Cooke Scientific Services 2000)
Like the Washington DOT method, this method is fairly rapid to use and implicitly blends functions and values. Users assign 1, 2, or 3 points to each indicator of function based on conditions at a site, and then sum those points into a score for each function. Unlike HGM methods, these points were not derived by calibrating explicitly to a regional set of wetlands. Our "Judgmental Method" (Appendix B of Volume IA) is conceptually similar, but allows users to specify scores and weights for various conditions.

Urban Riparian Inventory and Assessment Guide (van Staveren et al. 1998)
This method, sponsored by the Oregon DSL and the USEPA, is intended specifically for riparian areas (not necessarily wetlands) in urban areas of Oregon. It is similar to SAM in the manner in which it scores functions: users assign 1, 2, or 3 points to each indicator of function based on conditions at a site, and then sum those points into a score for each function. Unlike HGM methods, these points were not derived by calibrating explicitly to a regional set of riparian sites.

2. Indirect, Measurement-based Methods

These kind of methods commonly include procedures known as "wildlife/ fish habitat relationship models." They are called "indirect" because they do not assess wildlife or fish populations directly, but rather infer species presence/ absence or populations based on variables thought to comprise "habitat" for particular species. Users measure the predictive variables directly by employing transects, quadrats, and/or measurements from aerial imagery. For example, users might measure a variable such as canopy closure at several points along a riparian transect using a spherical densiometer. Or, they might employ a computerized Geographical Information System (GIS) to measure the connectedness of wooded swamps at a landscape scale. The information on connectedness or canopy closure is then plugged into models that infer (for example) bird richness or species presence. Those models can be fairly simple and based on correlation such as those used (for example) by the Oregon Biodiversity (Gap Analysis) Project. Or, they can attempt to account for complex conditional relationships among variables ("expert systems"), or can be deterministic (based on fundamental principles and proven interactions among variables) such as some spatially-explicit demographic and climate models. They can make predictions on a regional or landscape scale (e.g., Freemark et al. 1996, Adamus 2000, Hulse et al. 2000) or on a site-specific scale, such as the Habitat Evaluation Procedures (HEP)(USFWS 1981) and wildlife habitat assessment approaches developed specifically for Oregon wetland and riparian sites (e.g., Marshall 1993).

This category also includes methods used to measure (and sometimes classify) the geomorphic condition or adaptive stability of stream channels (Table 20). Such methods generally do not explicitly make the next logical step and infer specific aquatic functions from the measurements.

This category also includes methods that assess multiple wetland or riparian functions at a landscape level, typically by using GIS tools and qualitative models or criteria to measure and relate mapped variables to specific functions. Examples from the state of Washington include Gersib's (1997) *Restoring Wetlands at a River Basin Scale* and EPA's "Synoptic Approach" (*Application of the Synoptic Approach to Wetland Designation: A Case Study in Washington* -- Abbruzzese et al. 1990).

Table 20. Examples of indirect, measurement-based methods for wetland/ riparian assessment

Methods published by USDA Forest Service:	
• Methods for Evaluating Stream, Riparian, and Biotic Conditions	Platts et al. 1983
• Methods for Evaluating Riparian Habitats with Applications to Management	Platts et al. 1987
• The RAPID Technique: A New Method for Evaluating Downstream Effects of Forest Practices on Riparian Zones	Grant 1988
• Estimating Total Fish Abundance And Total Habitat Area In Small Streams Based On Visual Estimation Methods	Hankin and Reeves 1988
• Integrated Riparian Evaluation Guide	Burton et al. 1988, 1992
• Monitoring the Vegetation Resources in Riparian Areas	Winward 2000
Methods published by USDI Bureau of Land Management:	
• Procedures for Ecological Site Inventory (ESI) -- With Special Reference to Riparian-Wetland Sites (TR 1737-7)	Leonard et al. 1992
• Greenline Riparian-Wetland Monitoring (TR 1737-8)	Cagney 1983
Method published by Oregon Department of Fish and Wildlife:	
• Methods for Stream Habitat Surveys	Moore et al. 1997

3. Direct, Measurement-based Methods

These type of methods involve direct monitoring of organisms (bioassessments, inventories) or of ecosystem processes. For example, they include standard procedures for surveying biological communities of invertebrates (e.g., Rapid Bioassessment Protocol I, Plafkin et al. 1989, Richter and Wisseman 1997), fish (e.g., Klemm et al. 1993), plants (Magee et al. 1993), amphibians (Olson et al. 1997), and birds (Ralph et al. 1993, Huff et al. 2000), as well as for measuring soil (Magee et al. 1993, Horner et al. 1997, USDA-NRCS 1998), hydrologic variables (Reinelt et al. 1997, Shaffer et al. 2000), and water quality (MacDonald et al. 1991). Many were not designed for use in wetland and riparian settings, but information directed specifically to issues surrounding sampling of wetlands is fast becoming available (see USEPA web site: http://www.epa.gov/owow/wetlands/wqual/bio_fact/). Because these methods measure biological communities or functions directly, they do not need to incorporate predictive models. However, an "index of biotic integrity" (Karr et al. 1981) sometimes can be developed and calibrated, then used to organize data in a manner that represents a site's overall biological condition (see Section 8 in Volume IB for further discussion). Alternatively, data can be analyzed statistically -- sometimes in combination with geomorphic data -- to define relatively homogeneous wetland and riparian "classes" or "associations," as is frequently done with vegetation data. These classes can be used in some cases to infer a wetland or riparian site's sensitivity to particular types of future alteration.

Function Capacity vs. Function Value

The "value" of a function is its relative importance to society (an individual or group). Value need not be expressed in monetary units. Any given function can have multiple values, depending on who (or what resource) benefits or is impaired by the function. This is depends largely on the geographic location of the wetland relative to location of "user" groups. Also, it is no more realistic to expect that we can assess all possible values of a site as it is to expect that we can assess all functions. Frequently, some values are not immediately apparent, and others may grow or diminish in the future due to changing watershed conditions and changing societal norms, regardless of any change in the structure of the wetland itself.

In the context of wetland/ riparian assessment, one perspective holds that although value is a vital part of assessment, no systematic procedure should be used to assess value of a particular site or its functions, but rather that assessments should strictly involve intuitive, context-specific judgments by resource managers and the general public. This perspective is central to the HGM approach as defined by the Corps of Engineers (Smith et al. 1995). A different perspective is that limited standardization should be imposed on assessments regarding the manner in which they consider the potential and actual values of a site and its functions. The WDOE approach, for example, considers a site's relative opportunity to perform a particular function, and "opportunity" is one component of value. Another component of value has been termed "significance." This addresses the issue -- if a site performs a particular function -- of whether that functioning is likely to be assigned more value by society than if it were performed at the same level at another site (Adamus 1983).

When a value component is included in an overall assessment method, either explicitly or implicitly, it begs the question of "*Whose* values?" Whatever consideration of values occurs must reflect more than concerns of the scientists or people who developed the method. This is not an impossible requirement. The drafters of assessment methods can justify the inclusion of "value" components in methods they develop by basing these components on principles that underlay existing statutes and by providing for extensive public review. Unless this is done, the assessment results may fail to adequately address the larger social context of wetland/ riparian functions.

By considering variables generally acknowledged to relate to the "opportunity" and "significance" of functions at a particular site, a function assessment method can provide some explicit standardization in the consideration of value. Unlike the indicators used for assessment of functions, the "value" variables may not be quantified, and cannot be calibrated realistically using data from reference sites.

Summary of Wetland/ Riparian Assessment Needs

Traditionally, the managers of wetland/ riparian resources were comfortable simply assessing functions of individual sites. However, managers increasingly are calling for broader standardized approaches to wetland/ riparian assessment (Kusler & Niering 1998). Specifically mentioned has been the need for:

- procedures that better assess the status of wetland/ riparian resources at a broad-scale (landscape) level, so as to better understand the *regional* contribution of an individual site and its interactions with other sites;

- procedures that explicitly and aggressively incorporate *biological monitoring*, so as to better evaluate the health or integrity of a particular wetland/ riparian site;
- procedures that assess the geomorphic *viability* of a wetland/ riparian site as a functioning whole (in addition to assessing its component functions individually) so as to better predict if the site is capable of physically resisting and recovering from moderate natural disturbances, e.g., is self-sustaining (Bedford 1996).

Applying these and other concerns to Oregon, the following needs become apparent:

1. Few comparisons have been made among the many methods developed, to determine if they yield approximately the same ranking of sites. Although methods sometimes differ with regard to the units used to represent functions, thus making direct comparisons difficult, they may be compared with regard to correlations among *rankings assigned to a series of sites* (Mann-Whitney U-test, a nonparametric paired-ranks test).

2. Except for the methods in this Willamette Valley guidebook and the WDOE methods (Hruby et al. 1999, 2000), no rapid method for assessing PNW wetland/ riparian sites has explicitly used data collected from reference sites. Such data should always be collected and analyzed to help set realistic ranges for model variables or indicators in assessment methods developed in other parts of the Pacific Northwest in the future.

3. Until this guidebook was prepared, efforts in this region to distinguish between assessments of function and assessments of values of those functions have been limited. This distinction needs to be maintained in order to preserve public confidence and trust in results from assessment methods.

4. Rapid methods are still needed to address the viability of a site. This concerns the local settings (especially urban settings) in which wetlands can be sustained hydrologically with minimal management, as well as the types of wetland that best "fit" a particular landscape setting, i.e., are likely to endure over time despite extreme natural events and normal human intrusion. Models of "site potential" exist for predicting *riparian* vegetation type and wildlife use in a few parts of the Pacific Northwest (Hessburg et al. 2000), but "site potential" models for predicting *wetland* size and functions do not exist. Considerable research effort will be needed to develop and validate these tools.

5. Rapid methods are still needed to estimate the relative magnitudes of the various hydrologic inputs to a site at various seasons, and also, the relative magnitude of a seemingly “isolated” site’s subsurface hydrologic contribution to navigable waters.

6. A need exists to compile, interrelate, intelligently interpret, and distribute much *digital data* – especially data pertaining to soil characteristics, land cover, and hydrologic inputs -- that is already available in Oregon, so that developers and users of assessment methods may be able to provide *a priori*, calibrated, "default" values for many assessment variables. No method in the Pacific Northwest has fully tapped the potential of existing digital data for characterizing the functions, condition, and values of individual sites and their watersheds. This is true despite the fact that some degree of watershed characterization is required by most rapid assessment methods, and the data gathering associated with it is often the most time consuming part of an assessment.

7. Most assessment data should be made publicly available so wasteful duplication of assessments can be avoided and assessment data can find broader application. Currently, no agency or institution has maintained a public database containing results of assessments of wetland/ riparian function or condition. Data also need to be made available to encourage more comparisons among methods and to foster the improvement of wetland/ riparian methods.

Appendix C. Possible Relationships of Oregon Plant Communities to HGM Classes

This table was interpreted from Christy and Titus (1998) and is included by permission.

Abbreviations:
Veg Form: A = aquatic bed, E = emergent, F = forested, M = moss lichen, S = scrub-shrub
Hydroperiod: IE = irregularly exposed tidal, IF = irregularly flooded, P = permanently flooded, R = regularly flooded tidal, S = saturated, SP = semipermanently flooded, SS = seasonally flooded, T = temporarily flooded
Regions: BR= Basin & Range, BM=Blue Mountains, CB=Columbia Basin, CR=Coast Range, EC=East Slope Cascades, KM=Klamath Mountains, HP=High Lava Plains, OU=Owyhee Uplands, WC=West Slope Cascades, WV=Western Interior Valleys

1. Class = Riverine:

Characterizing	Veg Form	Hydro-periods	Regions	Habitats
(Alnus rubra)-Populus balsamifera ssp. trichocarpa/Rubus spectabilis	F	T	WV	Floodplains.
(Alnus rubra)-Populus balsamifera ssp. trichocarpa/Symphoricarpos albus	F	T	WV	Floodplains.
(Alnus rubra)/Salix sitchensis/Equisetum arvense	F	SS	WC	
Abies grandis/Athyrium filix-femina	F	SS	BM	Montane streambanks and floodplains, 3200-5200 ft.
Abies grandis/Symphoricarpos albus	F	T	BM	Low to mid-montane floodplains, terraces and seeps, 3200-4500 ft.
Abies lasiocarpa/Athyrium filix-femina	F	SS	BM	Midmontane to subalpine floodplains and terraces.
Abies lasiocarpa/Calamagrostis canadensis	F	SS	BM	Midmontane to subalpine floodplains and terraces.
Abies lasiocarpa/Carex aquatilis	F	SS	BM	Midmontane to subalpine floodplains and terraces.
Abies lasiocarpa/Carex disperma	F	SS	BM	Subalpine streambanks and floodplains.
Abies lasiocarpa/Senecio triangularis	F	SS	BM	Midmontane to subalpine streambanks and floodplains.
Acer macrophyllum-Populus balsamifera ssp. trichocarpa/Equisetum hyemale	F	SS	WV	Stream terraces in Willamette Valley.
Acer macrophyllum-Populus balsamifera ssp. trichocarpa/Symphoricarpos albus	F	T	WV	Stream terraces in Willamette Valley.
Acer macrophyllum/Rubus spectabilis	F	T	WV	Stream terraces in Willamette Valley.
Adiantum pedatum	E	SS	BM, WC.	Low elevation to mid-montane streambanks.
Alnus incana-Betula occidentalis (Salix)	S	T	BM, BR	Floodplains and margins of peatlands, low to middle elevations.
Alnus incana-Cornus sericea	S	T	BM, BR, EC, HP	Mid-montane floodplains, seeps, streambanks, alluvial bars.
Alnus incana-Ribes hudsonianum	S	T	BM	Low to mid-montane floodplains, streambanks.
Alnus incana-Spiraea douglasii	S	SS	BM, EC	Lower to mid-montane floodplains.
Alnus incana-Symphoricarpos albus	S	T	BM, EC	Low to mid-montane floodplains and streambanks.
Alnus incana/Carex	S	T	BM, BR, EC, WC	Floodplains, peatlands, springs and avalanche tracks at middle elevations.
Alnus incana/Equisetum arvense	S	SS	BM	Low to mid-montane streambanks, alluvial bars and floodplains.
Alnus rubra/(Tolmeia menziesii-Stachys ciliata)	F	T	WV	Floodplains in Willamette Valley.
Alnus rubra/Athyrium filix-femina	F	S	BM	Lower montane streamsides and seeps, low-gradient valleys.
Alnus rubra/Athyrium filix-femina-Lysichiton americanum	F	S	WV	Floodplains and edges of wetlands in Willamette Valley.
Alnus rubra/Cornus sericea	F	T	BM.	Low elevation floodplain.
Alnus rubra/Lysichiton americanum	F	S	CR, WV	Low to mid-elevation floodplains and depressions.
Alnus rubra/Petasites frigidus	F	SS	BM	Lower montane floodplains.
Alnus rubra/Physocarpus capitatus	F	T	BM	Lower to mid-montane floodplains of major rivers and streams.
Alnus rubra/Rubus spectabilis	F	T	WV	Floodplains.

Characterizing	Veg Form	Hydro-periods	Regions	Habitats
Alnus rubra/Rubus spectabilis/Carex obnupta-Lysichiton americanum	F	SS	CR, WV	Low to mid-elevation floodplains and depressions.
Alnus rubra/Symphoricarpos albus	F	T	BM	Low-elevation floodplain terraces.
Alnus viridis ssp. sinuata/Athyrium filix-femina	S	T	BM, WC	Mid-montane seepage areas, peatlands, margins of wet meadows, floodplains, springs, streambanks. Soils usually mucky, with few rocks.
Alnus viridis ssp. sinuata/Cinna latifolia	S	T	BM	Mid-montane floodplains, streambanks, gravel bars.
Artemisia cana/Muhlenbergia richardsonis	S	IF	BR	Alkaline seeps, floodplains and playas.
Artemisia cana/Poa cusickii	S	IF	BM, BR, EC, HP, OU	Low elevation alkaline seeps, floodplains and playas.
Atriplex confertifolia/Distichlis spicata	S	IF	BR	Low elevation alkaline seeps, floodplains and playas.
Bidens cernua	E	SS	WV	Low elevation marshes on floodplains.
Bidens frondosa	E	SS	WV	Margins of streams and ponds, exposed by early to midsummer.
Brodiaea sp.	E	SS	KM, WV	Low-elevation vernal pools and intermittent streams and seepage areas.
Calamagrostis canadensis	E	SS	BM	Lower to mid-montane basins and floodplains.
Callitriche heterophylla	A	SS	CR, KM, WC, WV	Low-elevation pools, ponds and sloughs.
Caltha palustris-Lysichiton americanum	E	S	CR	Freshwater tidal marshes, lower Columbia River.
Carex amplifolia	E	SS	BM, CR	Mid-montane fens, floodplains and springs.
Carex angustata	E	SS	EC	Middle elevation streamsides and floodplains.
Carex aquatilis var. aquatilis	E	SS	BM, BR, EC	Lower montane to subalpine fens, floodplains, springs, lakeshores.
Carex cusickii	E	SS	BM	Lower to mid-montane fens, springs, floodplains.
Carex illota-Eleocharis pauciflora	E	S	BM	Middle elevation peatlands, meadows and floodplains.
Carex lenticularis	E	SS	BM	Lower to upper montane basins, flooodplains and springs.
Carex luzulina	E	SS	BM	Upper montane to subalpine headwater basins and floodplains.
Carex lyngbyei	E	R	CR	Freshwater tidal marshes along lower Columbia River.
Carex nebrascensis	E	SS	BM, BR, EC	Mid-montane fens, floodplains, springs.
Carex nigricans	E	SS	BM, BR, EC, WC	Upper montan to subalpine basins, floodplains, lakeshores, snowmelt depressions.
Carex pellita	E	SS	BM, BR, EC	Middle elevation streambanks, floodplains, peatlands, basins, and springs.
Carex scopulorum	E	SS	BM, BR, WC	Upper montane to subalpine headwater basins, floodplains, lakeshores and streambanks.
Carex utriculata	E	SS	BM, BR, EC, WC	Middle to upper montane fens, springs, edges of lakes and ponds, and floodplains.
Ceratophyllum demersum	A	P	CR, KM, WV	Shallow lakes, ponds and slow-moving streams.
Chiloscyphus polyanthos	A	P	CR, WC	Perennial cold-water springs and upper stream reaches.
Cornus sericea	S	T	BR, WV	Low elevation to mid-montane floodplains, streambanks, sloughs.
Cornus sericea-Salix sitchensis	S	SP	CR, WV	Floodplain along lower Columbia River.
Cupressus lawsoniana/Rhododendron occidentale/Carex	F	T	KM	Fens and floodplain on ultramafic soils and bedrock.
Danthonia californica-Deschampsia cespitosa	E	SS	KM, WV	Low-elevation bottomland and floodplains.
Deschampsia cespitosa-Carex douglasii	E	SS	BM	Low-elevation prairie on alkaline floodplains.
Distichlis spicata	E	IF	BR, HP	Low-elevation alkaline seeps, floodplains and playas.
Eleocharis ovata	E	SS	WV	Mudflats of shallow pools, ponds, lakes and sloughs, exposed at low water.
Eleocharis palustris	E	SS	All	Basins, floodplains, gravel bars, shores of pools, ponds and lakes.
Elodea canadensis	A	P	CR, EC, WV	Lakes, ponds, sloughs and slow-moving streams and rivers.
Equisetum arvense	E	SS	BM	Low elevation to upper montane alluvial bars and floodplains.

Characterizing	Veg Form	Hydro-periods	Regions	Habitats
Equisetum fluviatile	E	S	CR, EC, WC	Low elevation to low montane marshes, lakeshores, riverbanks.
Eragrostis hypnoides-Gnaphalium palustre	E	SS	WV	Mudflats of shallow pools, ponds, lakes and sloughs, exposed at low water.
Euthamia occidentalis	E	SS	WV	Sand bars and beaches, lower Columbia River.
Fontinalis antipyretica	A	P,IE	CR, EC, WC, WV.	Springs, lakeshores, pools, streams and rivers.
Fontinalis neomexicana	A	P	CR	Springs and streams.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Acer circinatum	F	T	WV	Low-elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Cornus sericea	F	T	CR, WV	Low-elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Corylus cornuta-Physocarpus capitatus	F	T	WV	Low-elevation floodplains. Transitional to uplands.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Rubus spectabilis	F	T	WV	Low-elevation floodplains, northern Willamette Valley.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Symphoricarpos albus	F	T	KM, WV	Low elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia-Quercus garryana/Symphoricarpos albus	F	T	WV	Low-elevation floodplains. Transitional to uplands.
Fraxinus latifolia/Carex deweyana-Symphoricarpos albus	F	T	KM, WV	Low elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia/Carex obnupta	F	SS	WV	Low-elevation floodplains.
Fraxinus latifolia/Spiraea douglasii	F	SS	WV	Low-elevation floodplains and depressions.
Fraxinus latifolia/Urtica dioica ssp. gracilis	F	SS	WV	Low-elevation floodplains.
Glyceria borealis	E	SP	BM, BR, EC	Marshy shores of montane streams and lakes.
Glyceria elata	E	SP	BM	Low to mid-montane floodplains, lakeshores, streambanks, spring, gravel bars.
Glyceria grandis	E	SP	BR	Marshy shores of montane streams and lakes.
Glyceria striata	E	SP	BM	Marshy shores of montane streams and lakes.
Isoetes nuttallii	SB	SS	WV	Low elevation intermittent streams and vernal pools.
Juncus balticus	E	SS	All	Low elevation to mid-montane floodplains, basins, lakeshores, springs.
Juncus balticus-Carex obnupta	E	SS	CR, WV	Floodplains and marshy shores of lakes and streams.
Juncus effusus	E	SS	All	Low-elevation floodplains, basins, seepage areas, margins of lakes and ponds.
Leymus cinereus	E	IF	BR, CB	Alkaline floodplains.
Lilaeopsis occidentalis	E	SS	CR, WV	Mud flats along Columbia River, exposed after spring runoff.
Marchantia polymorpha-Philonotis fontana	M	S	BM, BR, EC, KM, OU.	Middle to upper-elevation streamsides, springs, and perennial seeps on shallow soils over bedrock.
Myriophyllum hippuroides	A	SS,SP	WV	Ponds, lakes and sloughs, sometimes drying by late summer.
Myriophyllum sibiricum	A	P	EC	Submerged in slow-flowing streams and ponds.
Oenanthe sarmentosa	E	SS	CR, WV	Brackish and freshwater marshes, floodplains.
Paspalum distichum	E	SS	CR, WV	Freshwater marshes with tidal or seasonal flooding.
Phragmites australis	E	SP	CB, HP, OU	Low to middle elevation streams, lakes, ponds and depressions.
Picea engelmannii/Athyrium filix-femina	F	SS	BM	Mid-montane floodplains, streambanks, terraces.
Picea engelmannii/Carex angustata	F	SS	EC	Montane floodplains and peatlands.
Picea engelmannii/Carex disperma	F	SS	BM	Midmontane to subalpine streambanks and floodplains.
Picea engelmannii/Cinna latifolia	F	SS	BM	Upper montane to subalpine floodplains.
Picea engelmannii/Cornus sericea	F	SS	BM	Midmontane to subalpine floodplains.
Picea engelmannii/Equisetum arvense	F	S	BM, EC	Midmontane to subalpine basins and floodplains.
Picea engelmannii/Senecio triangularis	F	SS	BM	Midmontane to subalpine bars, floodplains and springs.
Picea sitchensis/Cornus sericea	F	IF	CR	Riverbanks, floodplains, upper salt marsh. With freshwater or brackish tidal flooding.
Picea sitchensis/Rubus spectabilis/Carex obnupta-Lysichiton americanum	F	S	CR	Coastal swamps, usually on floodplains, some with freshwater tidal flooding.

Characterizing	Veg Form	Hydro-periods	Regions	Habitats
Pinus contorta ssp. murrayana/Carex aquatilis	F	SS	BM, EC	Midmontane to subalpine floodplains, lakeshores, meadows, springs.
Pinus contorta ssp. murrayana/Deschampsia cespitosa	F	SS	BM, EC	Midmontane basins and floodplains.
Pinus contorta ssp. murrayana/Vaccinium uliginosum	F	SS	EC, WC	Montane basins and floodplains, peatlands, meadows.
Pinus contorta ssp. murryana-Populus tremuloides/Spiraea douglasii	F	SS	EC	Montane basins and floodplains.
Pinus monticola/Deschampsia cespitosa	F	T	BM	Mid montane floodplains.
Poa cusickii	E	SS	BM, BR, EC	Montane floodplains, basins, and meadows.
Poa secunda	E	SS	BM, BR, EC	Montane floodplains, basins, and meadows.
Poa secunda-Puccinellia lemmonii	E	SS	BR	Montane floodplains, basins, and meadows.
Polygonum bistortoides-Ranunculus macounii	E	S	BM, BR	Middle to upper elevation floodplains, seepage areas, and peatlands.
Populus balsamifera ssp. trichocarpa/Acer glabrum	F	T	BM	Low to mid-montane terraces and floodplains.
Populus balsamifera ssp. trichocarpa/Alnus incana	F	T	BM, BR, EC.	Floodplains and basins at low to middle elevations.
Populus balsamifera ssp. trichocarpa/Betula occidentalis-Salix	F	T	BM, BR	Low to middle elevation floodplains. Includes variants with lodgepole pine and ponderosa pine.
Populus balsamifera ssp. trichocarpa/Carex agustata	F	T	EC	Lower to middle elevation floodplains.
Populus balsamifera ssp. trichocarpa/Cornus sericea	F	T	BM, BR, CB, HP	Lower to mid-montane floodplains and terraces.
Populus balsamifera ssp. trichocarpa/Cornus sericea/Impatiens capensis	F	S	CR, WV	Floodplains along lower Columbia River.
Populus balsamifera ssp. trichocarpa/Salix exigua	F	T	BM, BR, CB, HP	Low to mid-elevation floodplains.
Populus balsamifera ssp. trichocarpa/Salix lucida ssp. caudata	F	SS	BM	Low to mid-montane floodplains and abandoned channels.
Populus balsamifera ssp. trichocarpa/Symphoricarpos albus	F	T	BM, CB, HP	Low to mid-elevation floodplains, terraces along major rivers and streams.
Populus tremuloides/Alnus incana-Cornus sericea	F	T	BM	Lower to mid-montane floodplains.
Populus tremuloides/Alnus incana-Symphoricarpos albus	F	T	BM	Midmontane floodplains.
Populus tremuloides/Carex pellita	F	SS	BM	Mid to upper montane basins, floodplains, headwaters for perennial streams.
Populus tremuloides/Salix scouleriana	F	T	BR	Low-elevation floodplains.
Pseudotsuga menziesii/Symphoricarpos albus	F	T	BM	Low to mid-montane floodplains and terraces.
Pseudotsuga menziesii/Trautvetteria caroliniensis	F	T	BM	Mid-montane floodplains and terraces.
Ribes lacustre/Cinna latifolia-Glyceria elata	S	T	BM	Middle to upper montane floodplains, streambanks, gravel bars.
Ruppia maritima (estuarine association)	A	IE	CR	Subtidal and intertidal mudflats and channels.
Sagittaria latifolia	E	SS	WV	Lakes, ponds, pools, and freshwater intertidal zone along lower Columbia River and in Willamette Valley.
Salicornia virginica-(Jaumea carnosa)	E	R		Coastal estuaries, on silt and mud flats.
Salicornia virginica-Triglochin maritimum	E	R		Coastal estuaries, on silt and mud flats.
Salix (hookeriana-sitchensis)-Spiraea douglasii/Carex obnupta	S	S	CR	Margins of coastal lakes, floodplains.
Salix amygdaloides-Salix exigua	S	T	CB, HP	Low to mid-elevation floodplains.
Salix boothii-Salix eastwoodiae	S	T	EC	Subalpine floodplains.
Salix boothii-Salix geyeriana/Carex angustata	S	S	EC	Lower to mid-montane floodplains, basins and peatlands.
Salix boothii-Salix geyeriana/Carex aquatilis	S	SS	BM	Middle to upper montane floodplains, springs.
Salix boothii-Salix geyeriana/Carex	S	SS	BR	Mid to upper montane floodplains.

Characterizing	Veg Form	Hydro-periods	Regions	Habitats
pellita				
Salix boothii-Salix geyeriana/Carex utriculata	S	S	BM, EC	Mid-elevation floodplains, peatlands, springs.
Salix commutata-Salix eastwoodiae/Carex scopulorum	S	S	BM, EC	Upper montane to subalpine floodplains, peatlands, seepage slopes.
Salix eriocephala-Ribes aureum	S	T	BM, BR, OU	Low to middle elevation floodplains.
Salix exigua	S	T	BM, BR, CB, EC, HP, OU	Low to mid-montane cobble banks and bars, floodplains.
Salix exigua-Salix eriocephala	S	T	BM	Low elevation floodplains.
Salix exigua-Salix lucida ssp. caudata	S	T	BM, BR, CB, EC, HP, OU	Low-elevation floodplains.
Salix geyeriana	S	SS	BM, BR, EC	Low to mid-elevation floodplains, peatlands.
Salix geyeriana-Salix lemmonii/Carex aquatilis var. dives	S	T	EC	Mid-elevation floodplains or peatland.
Salix hookeriana	S	SS	WV	Floodplains along lower Columbia River, and in Willamette Valley.
Salix hookeriana-Salix sitchensis	S	SS	WV	Floodplains along lower Columbia River, and in Willamette Valley.
Salix lemmonii-Vaccinium uliginosum	S	SS	BM, BR	Mid-elevation floodplains and peatlands.
Salix lucida ssp. caudata-Rosa woodsii	S	T	BR, CB	Low-elevation floodplains.
Salix lucida ssp. lasiandra/Salix fluviatilis	S	T	WV	Sandbars and floodplains, lower Willamette and lower Columbia Rivers.
Salix lucida ssp. lasiandra/Urtica dioica ssp. gracilis	F	SS	WV	Floodplains along lower Columbia River and Willamette River.
Salix sitchensis	S	SS	WV	Thickets along rivers, creeks and sloughs.
Saxifraga odontoloma	E	S	BM	Mid to high-elevation floodplains, springs
Scirpus acutus	E	SP,R	All	Margins of lakes, ponds, and in riverine shallows and seepage areas.
Scirpus americanus (estuarine-riverine)	E	R	CR	Low salt marsh, intertidal mud and sand flats, fresh water tidelands.
Scirpus microcarpus	E	SS	BM, CR, EC, OU, WV, KM, WC	Low elevation to mid-montane streambanks, floodplains, fens, seepage areas, springs.
Scirpus tabernaemontani	E	SP	All	Marshes, margins of ponds and lakes, riverine shallows
Sparganium emersum	E	SP	BR, EC, WV	Low elevation to subalpine marshes, lakeshores and ponds, and freshwater tidal reaches of rivers.
Spiraea douglasii	S	SS	CR, EC, WC, WV	Low-elevation to low montane floodplains, basins, peatlands.
Thuja plicata-Tsuga heterophylla/Lysichiton americanum	F	S	CR, WC, WV	Floodplains and basins, low to mid-elevations.
Thuja plicata-Tsuga heterophylla/Oplopanax horridum	F	S	WC	Mid-montane floodplains and basins.
Tsuga heterophylla/Acer circinatum/Lysichiton americanum	F	SS	CR, WC	Floodplains and seepage areas.
Typha angustifolia-Typha latifolia	E	R	CR	Freshwater tidal marshes along lower Columbia River.
Veronica americana	E	S	BM	Floodplains.
Zostera marina	A	IE	CR	Subtidal and intertidal sand and mud flats and channels.

2. Class = Depressional and/or Flats

Characterizing Species	Veg Form	Hydro-periods	Eco-regions	Habitats
(Alnus rubra)/Salix sitchensis/Equisetum arvense	F	SS	WC	
Abies amabilis/Oplopanax horridus	F	SS		
Abies lasiocarpa/Streptopus amplexifolius	F	T		

Abies lasiocarpa/Trautvetteria caroliniensis	F	T		
Abies lasiocarpa/Vaccinium uliginosum/Carex scopulorum	F	S	BM	Subalpine basins.
Acer circinatum/Alnus incana	F	T		
Acer circinatum/Rubus spectabilis/Athyrium filix-femina	F	SS		
Acer circinatum/Stachys ciliata	F	T		
Allenrolfea occidentalis	S	IF	BR	Alkaline seeps and intermittently-flooded playas, at low elevations. Forming sparse, monotypic stands.
Alnus incana-Betula occidentalis (Salix)	S	T	BM, BR	Floodplains and margins of peatlands, low to middle elevations.
Alnus incana-Vaccinium ovalifolium	S	T		
Alnus incana/Carex	S	T	BM, BR, EC, WC	Floodplains, peatlands, springs and avalanche tracks at middle elevations.
Alnus rhombifolia/Betula occidentalis	F	T		
Alnus rubra-Thuja plicata/Rubus spectabilis/Oxalis oregana	E	SS		
Alnus rubra/Acer circinatum/Claytonia sibirica	F	T		
Alnus rubra/Athyrium filix-femina	F	S	BM	Lower montane streamsides and seeps, low-gradient valleys.
Alnus rubra/Elymus glaucus	F	T		
Alnus rubra/Lysichiton americanum	F	S	CR, WV	Low to mid-elevation floodplains and depressions.
Alnus rubra/Oplopanax horridus	F	S		
Alnus rubra/Oxalis oregana	F	T		
Alnus rubra/Rubus parviflorus	F	T		
Alnus rubra/Rubus spectabilis/Carex obnupta-Lysichiton americanum	F	SS	CR, WV	Low to mid-elevation floodplains and depressions.
Alnus rubra/Trautvetteria caroliniensis	F	T		
Alnus viridis ssp. sinuata/Acer circinatum	S	SS		
Alnus viridis ssp. sinuata/Athyrium filix-femina	S	T	BM, WC	Mid-montane seepage areas, peatlands, margins of wet meadows, floodplains, springs, streambanks. Soils usually mucky, with few rocks.
Alopecurus saccatus-Plagiobothrys bracteatus	E	SS	KM	Low elevation vernal pools over hardpan.
Argentina egedii-Carex obnupta	E	SS	CR	Freshwater to slightly brackish marshes on deflation plains and in upper estuaries.
Artemisia cana/Muhlenbergia richardsonis	S	IF	BR	Alkaline seeps, floodplains and playas.
Artemisia cana/Poa cusickii	S	IF	BM, BR, EC, HP, OU	Low elevation alkaline seeps, floodplains and playas.
Athyrium filix-femina	E	S	CR	Coastal freshwater fens and marshes.
Atriplex confertifolia/Distichlis spicata	S	IF	BR	Low elevation alkaline seeps, floodplains and playas.
Azolla mexicana	A	SS	CR, WV	Lakes, ponds and sloughs with little or no current. Becoming stranded on mud when water dries up.
Betula glandulosa/Carex utriculata	S	S	EC, WC	Middle to upper elevation peatlands.
Bidens frondosa	E	SS	WV	Margins of streams and ponds, exposed by early to midsummer.
Brasenia schreberi	A	P	CR, KM	Shallow lakes and ponds, and littoral zone in deeper lakes.
Brodiaea sp.	E	SS	KM, WV	Low-elevation vernal pools and intermittent streams and seepage areas.
Brodiaea-Deschampsia danthonioides	E	SS	KM	Vernal pools over hardpan.
Calamagrostis canadensis	E	SS	BM	Lower to mid-montane basins and floodplains.
Calamagrostis nutkaensis	E	SS	CR	Coastal peatlands, freshwater.
Callitriche heterophylla	A	SS, SP	CR, KM, WC, WV	Low-elevation pools, ponds and sloughs.
Camassia quamash	E	SS	KM, WV	Bottomland prairie.

Carex amplifolia	E	SS	BM, CR	Mid-montane fens, floodplains and springs.
Carex aperta	E	SS	WV	Bottomland prairie.
Carex aquatilis var. aquatilis	E	SS	BM, BR, EC	Lower montane to subalpine fens, floodplains, springs, lakeshores.
Carex aquatilis var. dives	E	S	CR, EC, WC	Marshy shores of middle elevation lakes and ponds, and seasonally-flooded depressions in montane peatlands.
Carex aquatilis var. dives-Carex obnupta	E	S	CR	Coastal freshwater fens and marshes.
Carex buxbaumii	E	SS	EC	Middle elevation peatlands.
Carex californica	E	S	KM	Seepage fens on ultramafic soils.
Carex canescens-Carex muricata	E	S	WC	Middle to upper elevation peatlands.
Carex cusickii	E	SS	BM	Lower to mid-montane fens, springs, floodplains.
Carex cusickii-Comarum palustre	E	S	CR	Low-elevation fens around edges of lakes and ponds.
Carex densa-Deschampsia cespitosa	E	SS	KM, WV	Bottomland prairie.
Carex densa-Eleocharis palustris	E	SS	WV	Depressions in low-elevation wet prairie.
Carex densa-Juncus patens	E	SS	KM	Seasonally-flooded bottomland prairie, Umpqua Valley.
Carex illota-Eleocharis pauciflora	E	S	BM	Middle elevation peatlands, meadows and floodplains.
Carex interrupta	E	S	EC	High-elevation peatlands.
Carex lasiocarpa	E	SS		
Carex lenticularis	E	SS	BM	Lower to upper montane basins, flooodplains and springs.
Carex leporinella	E	S	BM	Middle elevation peatlands.
Carex luzulina	E	SS	BM	Upper montane to subalpine headwater basins and floodplains.
Carex nebrascensis	E	SS	BM, BR, EC	Mid-montane fens, floodplains, springs.
Carex nigricans	E	SS	BM, BR, EC, WC	Upper montane to subalpine basins, floodplains, lakeshores, snowmelt depressions.
Carex obnupta	E	SS	CR, WV	Fens and marshes.
Carex pellita	E	SS	BM, BR, EC	Middle elevation streambanks, floodplains, peatlands, basins, and springs.
Carex praegracilis	E	SS	BM	Middle to upper montane headwater basins
Carex scopulorum	E	SS	BM, BR, WC	Upper montane to subalpine headwater basins, floodplains, lakeshores and streambanks.
Carex scopulorum-Eleocharis quinqueflora	E	S	BM, EC.	Upper montane to subalpine peatlands.
Carex simulata	E	SS	BM, BR, EC	Middle to upper montane meadows and peatlands.
Carex unilateralis-Hordeum brachyantherum	E	SS	KM, WV	Low-elevation bottomland prairie.
Carex utriculata	E	SS	BM, BR, EC, WC	Middle to upper montane fens, springs, edges of lakes and ponds, and floodplains.
Carex vesicaria	E	SS	BM, BR, EC	Lower to mid-montane lakeshores and depressions in peatlands.
Carex vesicaria-Carex obnupta	E	SS	CR	Depressions and margins of shallow lakes and ponds in coastal dune sheets.
Ceratophyllum demersum	A	P	CR, KM, WV	Shallow lakes, ponds and slow-moving streams.
Chamaecyparis nootkatensis/Oplopanax horridus	F	T		
Corydalis (aqua-gelidae-scouleri)	E	SS		
Cupressus lawsoniana/Rhododendron occidentale/Carex	F	T	KM	Fens and floodplain on ultramafic soils and bedrock.
Cupressus nootkatensis/Oplopanax horridum	F	SS	WC	Montane depressions with snowbed seepage.
Danthonia californica-Deschampsia cespitosa	E	SS	KM	Seasonally wet serpentine meadows, on flat topography.
Danthonia californica-Deschampsia cespitosa	E	S	KM	Seepage areas and fens on ultramafic soils.
Danthonia unispicata-Deschampsia danthonioides	E	SS	BM	Vernal pools on shallow soils over bedrock.

Deschampsia cespitosa	E	SS	BM, BR, EC, WC	Middle to upper montane meadows, peatlands and lakeshores.
Deschampsia danthonioides	E	SS	KM	Vernal pools over hardpan or bedrock.
Deschampsia danthonioides-Plagiobothrys leptocladus	E	SS	CB	Vernal pools over bedrock.
Distichlis spicata	E	IF	BR, HP	Low-elevation alkaline seeps, floodplains and playas.
Distichlis spicata-Scirpus nevadensis	E	IF	BR, HP	Alkaline marshes, springs and pools.
Downingia elegans	E	SS	EC	Middle elevation vernal pools and depressions.
Downingia yina-Plagiobothrys bracteatus	E	SS	KM	Vernal pools over bedrock.
Dulichium arundinaceum	E	SS	CR, EC, WC, WV	Peatlands and marshy shores of pools, ponds and lakes.
Eleocharis acicularis	E	S	EC	Shores of pools, ponds and lakes.
Eleocharis ovata	E	SS	WV	Mudflats of shallow pools, ponds, lakes and sloughs, exposed at low water.
Eleocharis palustris	E	SS	All	Basins, floodplains, gravel bars, shores of pools, ponds and lakes.
Eleocharis palustris-Carex unilateralis	E	SS	WV	Vernally-flooded depressions in prairie and around shallow ponds.
Eleocharis palustris-Juncus nevadensis	E	SS	CR	Deflation plains along coast.
Eleocharis palustris-Ludwigia palustris	E	SS	WV	Vernally-flooded depressions and shallow ponds.
Eleocharis quinqueflora	E	S	BM, BR, EC, WC	Middle to upper montane peatlands, with higher elevation sites mostly east of Cascade Range.
Eleocharis quinqueflora-Eriophorum criniger	E	S	KM	Seepage fens on ultramafic soils.
Eleocharis rostellata	E	S	BR	Springs and marshes.
Elodea canadensis	A	P	CR, EC, WV	Lakes, ponds, sloughs and slow-moving streams and rivers.
Equisetum fluviatile	E	S	CR, EC, WC	Low elevation to low montane marshes, lakeshores, riverbanks.
Eragrostis hypnoides-Gnaphalium palustre	E	SS	WV	Mudflats of shallow pools, ponds, lakes and sloughs, exposed at low water.
Eryngium petiolatum-Grindelia nana	E	SS	WV	Vernally-flooded depressions and small pools.
Festuca rubra-Juncus lesueurii	E	SS	CR	Deflation plains along coast.
Fontinalis antipyretica	A	P	CR, EC, WC, WV.	Springs, lakeshores, pools, streams and rivers.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Acer circinatum	F	T	WV	Low-elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Cornus sericea	F	T	CR, WV	Low-elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia-Populus balsamifera ssp. trichocarpa/Symphoricarpos albus	F	T	KM, WV	Low elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia/Carex deweyana-Symphoricarpos albus	F	T	KM, WV	Low elevation floodplains and depressions. Transitional to uplands.
Fraxinus latifolia/Juncus patens	F	SS	KM	Seasonally-flooded bottomland prairie, Umpqua Valley.
Fraxinus latifolia/Spiraea douglasii	F	SS	WV	Low-elevation floodplains and depressions.
Glyceria borealis	E	SP	BM, BR, EC	Marshy shores of montane streams and lakes.
Glyceria elata	E	SP	BM	Low to mid-montane floodplains, lakeshores, streambanks, spring, gravel bars.
Glyceria grandis	E	SP	BR	Marshy shores of montane streams and lakes.
Glyceria striata	E	SP	BM	Marshy shores of montane streams and lakes.
Gratiola ebracteata-Plagiobothrys bracteatus	E	SS	KM	Vernal pools over hardpan.
Hippuris vulgaris	E	SP	CR, EC, WV	Pools, lakes and ponds, peatlands.
Hydrocotyl ranunculoides	E	SP	CR	Pools and ponds, peatlands.
Isoetes nuttallii	SB	SS	WV	Low elevation intermittent streams and vernal pools.
Isoetes nuttallii-Plagiobothrys bracteatus	E	SS	KM	Vernal pools over hardpan.
Juncus balticus	E	SS	All	Low elevation to mid-montane floodplains, basins, lakeshores, springs.

Juncus balticus-Carex obnupta	E	SS	CR, WV	Floodplains and marshy shores of lakes and streams.
Juncus bufonius	E	SS	All	Vernal pools, edges of lakes, sloughs and ponds, where exposed by receding water levels.
Juncus effusus	E	SS	All	Low-elevation floodplains, basins, seepage areas, margins of lakes and ponds.
Juncus ensifolius	E	SS	KM	Seasonally-flooded bottomland prairie, Umpqua Valley.
Juncus falcatus-(Juncus lesueurii-Juncus nevadensis)	E	SS	CR	Deflation plains along coast.
Juncus lesueurii	E	SS	CR	Deflation plains along coast.
Juncus nevadensis	E	SS	EC	Montane seasonally wet meadows.
Kalmia polifolia ssp. microphylla	S	S	BM, EC, WC	Middle to upper montane peatlands, on hummocks or around margins.
Lasthenia californica	E	SS	KM	Margins of vernal pools, with least inundation, on relatively deep soils over hardpan.
Ledum glandulosum-Myrica gale/Sphagnum	S	S	CR	Coastal peatlands.
Ledum glandulosum/Darlingonia californica/Sphagnum	S	S	CR	Coastal peatlands, between Curry and Tillamook counties.
Ledum glandulosum/Sphagnum	S	S	CR	Coastal peatlands, south of Columbia River.
Lemna minor	A	SP	Throughout	Lakes, ponds and sloughs, with little or no current. Becoming stranded on mud when water dries up.
Leymus triticoides-Poa secunda ssp. juncifolia	E	IF	BR	Playas.
Ludwigia palustris-Polygonum hydropiperoides	E	SS	KM, WV	Mud and sand flats on seasonally-receding shorelines of lakes, ponds and rivers.
Luetkea pectinata-Saxifraga tolmiei	E	SS	EC, WC	Alpine to subalpine depressions with snowbed seepage.
Lysichiton americanum-Senecio triangularis	E	S		
Malus fusca	S	SS	WV	Seasonally-flooded depressions at low elevations, northern Willamette Valley.
Malus fusca-Salix hookeriana/Carex obnupta	S	SS	CR	Margins of coastal lakes and ponds.
Menyanthes trifoliata	E	SP	BM, CR, WC, WV	Low elevation to mid-montane lakes, pools and ponds.
Mertensia paniculata-Urtica dioica ssp. gracilis	E	S	BM	Seepage in cirques and at the bases of avalanche slopes.
Mimulus guttatus	E	SS		
Myosurus minimus-Plagiobothrys bracteatus	E	SS	KM	Vernal pools.
Myrica californica-Salix hookeriana	S	SS	CR	Deflation plains, dune lakes and ponds.
Myriophyllum hippuroides	A	SS, SP	WV	Ponds, lakes and sloughs, sometimes drying by late summer.
Myriophyllum sibiricum	A	P	EC	Submerged in slow-flowing streams and ponds.
Navarretia intertexta-Polygonum kelloggii	E	SS	BM	Vernal pools in tabular basalt.
Navarretia leucocephala-Plagiobothrys bracteatus	E	SS	KM	Vernal pools over hardpan.
Nuphar lutea ssp. polysepala	E	SP	BM, CR, EC, WC, WV	Low elevation to upper montane ponds, lakeshores, sloughs.
Oplopanax horridum	S	S		
Oxalis (oregana-trilliifolia)-(Corydalis scouleri)	S	T		
Paspalum distichum	E	SS	CR, WV	Freshwater marshes with tidal or seasonal flooding.
Petasites frigidus	E	SS		
Phragmites australis	E	SP	CB, HP, OU	Low to middle elevation streams, lakes, ponds and depressions.
Picea engelmannii/Equisetum arvense	F	S	BM, EC	Midmontane to subalpine basins and floodplains.
Picea engelmannii/Vaccinium uliginosum	F	SS	EC	Montane peatlands, riparian.

Picea sitchensis/Rubus spectabilis/Carex obnupta-Lysichiton americanum	F	S	CR	Coastal swamps, usually on floodplains, some with freshwater tidal flooding.
Pinus contorta ssp. contorta/Carex obnupta	F	SS	CR	Depressions on marine terraces and old deflation plains.
Pinus contorta ssp. contorta/Ledum glandulosum/Sphagnum	F	S	CR	Coastal swamps.
Pinus contorta ssp. murrayana/Carex aquatilis	F	SS	BM, EC	Midmontane to subalpine floodplains, lakeshores, meadows, springs.
Pinus contorta ssp. murrayana/Deschampsia cespitosa	F	SS	BM, EC	Midmontane basins and floodplains.
Pinus contorta ssp. murrayana/Symphorcarpos albus	E	SS		
Pinus contorta ssp. murrayana/Vaccinium uliginosum	F	SS	EC, WC	Montane basins and floodplains, peatlands, meadows.
Pinus contorta ssp. murryana-Populus tremuloides/Spiraea douglasii	F	SS	EC	Montane basins and floodplains.
Plagiobothrys bracteatus-Veronica peregrina	E	SS	KM	Vernal pools over hardpan.
Plagiobothrys leptocladus-Veronica peregrina	E	SS	CB	Vernal pools on shallow soils over bedrock. Sometimes alkaline.
Poa cusickii	E	SS	BM, BR, EC	Montane floodplains, basins, and meadows.
Poa secunda	E	SS	BM, BR, EC	Montane floodplains, basins, and meadows.
Poa secunda-Puccinellia lemmonii	E	SS	BR	Montane floodplains, basins, and meadows.
Polygonum amphibium	E	SP	WV	Shallow lakes, ponds, and marshes.
Polygonum bistortoides-Ranunculus macounii	E	S	BM, BR	Middle to upper elevation floodplains, seepage areas, and peatlands.
Polygonum hydropiperoides	E	SS	CR	Deflation plains along coast.
Polytrichum commune	M	SS	EC, WC	Middle to upper elevation potholes and seasonally-flooded lodgepole pine forest.
Populus balsamifera ssp. trichocarpa/Alnus incana	F	T	BM, BR, EC.	Floodplains and basins at low to middle elevations.
Populus tremuloides/Calamagrostis canadensis	F	S	BM	Mid to upper montane basins.
Populus tremuloides/Carex pellita	F	SS	BM	Mid to upper montane basins, floodplains, headwaters for perennial streams.
Potamogeton natans	A	SP	CR, EC, KM, WC, WV	Lakes, ponds, pools.
Psilocarphus brevissimus	E	SS	KM	Vernal pools over hardpan.
Ranunculus aquatilis	A	SS	All	Seasonally-flooded depressions, low to middle elevations.
Ranunculus lobbii	A	SS	KM, WV	Seasonally-flooded vernal pools and ash swamps.
Rhododendron occidentale/Camassia quamash	S	SS	KM	Serpentine fens at low elevation.
Ribes bracteosum-Rubus spectabilis	S	T		
Rosa nutkana/Deschampsia cespitosa	S	SS	WV	Low-elevation brush prairie.
Rosa nutkana/Oenanthe sarmentosa	S	SS	WV	Low-elevation brush prairie.
Ruppia maritima (interior alkaline association)	A	SS, SP	BR, HP	Alkaline ponds and pools.
Sagittaria latifolia	E	SS	WV	Lakes, ponds, pools, and freshwater intertidal zone along lower Columbia River and in Willamette Valley.
Salix (hookeriana-sitchensis)-Spiraea douglasii/Carex obnupta	S	S	CR	Margins of coastal lakes, floodplains.
Salix boothii-Salix drummondiana	S	S	BR	Subalpine peatlands, Steens Mountain.
Salix boothii-Salix geyeriana/Carex angustata	S	S	EC	Lower to mid-montane floodplains, basins and peatlands.
Salix boothii-Salix geyeriana/Carex utriculata	S	S	BM, EC	Mid-elevation floodplains, peatlands, springs.
Salix commutata-Salix eastwoodiae/Carex scopulorum	S	S	BM, EC	Upper montane to subalpine floodplains, peatlands, seepage slopes.
Salix drummondiana	S	S	BM, BR	Subalpine peatlands.

Salix geyeriana	S	SS	BM, BR, EC	Low to mid-elevation floodplains, peatlands.
Salix geyeriana-Salix hookeriana	S	S	WV	Peatlands.
Salix geyeriana-Salix lemmonii/Carex aquatilis var. dives	S	T	EC	Mid-elevation floodplains or peatland.
Salix hookeriana/Argentina egedii ssp. egedii-Carex obnupta	S	SS	CR	Seasonally-flooded deflation plains.
Salix lemmonii-Vaccinium uliginosum	S	SS	BM, BR	Mid-elevation floodplains and peatlands.
Sarcobatus vermiculatus/Distichlis spicata	S	IF	BR, HP	Playas, margins of alkaline lakes and ponds.
Sarcobatus vermiculatus/Suaeda moquinii	S	IF	BR	Playas, margins of alkaline lakes and ponds.
Scirpus acutus	E	SP	All	Margins of lakes, ponds, and in riverine shallows and seepage areas.
Scirpus americanus (interior alkaline)	E	SS	BR, CB	Alkaline springs, marshes and ponds.
Scirpus maritimus (interior alkaline)	E	IF	BR	Margins of playas and lakes.
Scirpus microcarpus	E	SS	BM, CR, EC, OU, WV, KM, WC	Low elevation to mid-montane streambanks, floodplains, fens, seepage areas, springs.
Scirpus subterminalis	A	P	CR	Submerged along margins of lakes and ponds.
Scirpus tabernaemontani	E	SP	All	Marshes, margins of ponds and lakes, riverine shallows
Senecio triangularis	E	SS	BM, BR, EC, WC	Mid-montane meadows and peatlands.
Sparganium emersum	E	SP	BR, EC, WV	Low elevation to subalpine marshes, lakeshores and ponds, and freshwater tidal reaches of rivers.
Sparganium eurycarpum	E	S	CR, WV	Margins of marshes, lakes and ponds.
Spiraea douglasii	S	SS	CR, EC, WC, WV	Low-elevation to low montane floodplains, basins, peatlands.
Spiraea douglasii/Sphagnum	S	S	WV	Margins of lakes and ponds, peatlands.
Stachys ciliata	E	SS		
Thuja plicata-Tsuga heterophylla/Ledum glandulosum/Sphagnum	F	S	CR	Coastal peatlands.
Thuja plicata-Tsuga heterophylla/Lysichiton americanum	F	S	CR, WC, WV	Floodplains and basins, low to mid-elevations.
Thuja plicata-Tsuga heterophylla/Oplopanax horridum	F	S	WC	Mid-montane floodplains and basins.
Thuja plicata/Acer circinatum/Athyrium filix-femina	E	SS		
Tsuga heterophylla/Oplopanax horridus	F	S		
Typha latifolia	E	SP	All	Low elevation to mid-montane marshes, lakeshores, ponds. Also lacustrine littoral.
Typha latifolia-Veronica scutellata	E	SS	WV	Vernally-flooded areas and shallow pools and ponds.
Utricularia macrorhiza	A	P	CR, WV, WC	Marshes, lakes and ponds.
Vaccinium alaskaense-Vaccinium ovalifolium	S	T		
Vaccinium caespitosum	S	SS	CR, WV	Bottomland prairie and edges of peatlands.
Vaccinium uliginosum/Carex aquatilis var. dives	S	SS	EC, WC	Montane meadows and peatlands.
Vaccinium uliginosum/Carex obnupta	S	SS	CR	Deflation plains along coast.
Vaccinium uliginosum/Deschampsia cespitosa	S	SS	CR, EC, WC	Montane meadows and peatlands.
Vaccinium uliginosum/Eleocharis pauciflora	S	SS	EC, WC	Montane peatlands.
Wolffia borealis-Wolffia columbiana	A	P	KM, WV	Lakes, pools, ponds and sloughs, with little or no water movement. Becoming stranded when water dries up.

3. Class = Slope wetlands

Characterizing Species	Veg Form	Hydro-periods	Eco-regions	Habitats
Abies grandis/Symphoricarpos albus	F	T	BM	Low to mid-montane floodplains, terraces and seeps, 3200-4500 ft.
Abies lasiocarpa/Carex disperma	F	SS	BM	Subalpine streambanks and floodplains.
Allenrolfea occidentalis	S	I	BR	Alkaline seeps and intermittently-flooded playas, at low elevations. Forming sparse, monotypic stands.
Alnus incana-Cornus sericea	S	T	BM, BR, EC, HP	Mid-montane floodplains, seeps, streambanks, alluvial bars.
Alnus incana/Carex	S	T	BM, BR, EC, WC	Floodplains, peatlands, springs and avalanche tracks at middle elevations.
Alnus rubra/Athyrium filix-femina	F	S	BM	Lower montane streamsides and seeps, low-gradient valleys.
Alnus viridis ssp. sinuata/Athyrium filix-femina	S	T	BM, WC	Mid-montane seepage areas, peatlands, margins of wet meadows, floodplains, springs, streambanks. Soils usually mucky, with few rocks.
Alnus viridis ssp. sinuata/Oplopanax horridum	S	S	BM, WC	Seepage areas and avalanche tracks at middle to upper elevations. Soils usually rocky. Includes variants containing vine maple.
Artemisia cana/Muhlenbergia richardsonis	S	I	BR	Alkaline seeps, floodplains and playas.
Artemisia cana/Poa cusickii	S	I	BM, BR, EC, HP, OU	Low elevation alkaline seeps, floodplains and playas.
Atriplex confertifolia/Distichlis spicata	S	I	BR	Low elevation alkaline seeps, floodplains and playas.
Caltha leptosepala ssp. howellii-Dodecatheon jeffreyi	E	S	BM, EC, WC	Seepage slopes and springs at the margins of middle to upper-elevation wetlands.
Camassia cusickii	E	SS	BM	Middle elevation perennial or intermittent seeps on shallow soils over bedrock.
Carex amplifolia	E	SS	BM, CR	Mid-montane fens, floodplains and springs.
Carex aquatilis var. aquatilis	E	SS	BM, BR, EC	Lower montane to subalpine fens, floodplains, springs, lakeshores.
Carex californica	E	S	KM	Seepage fens on ultramafic soils.
Carex cusickii	E	SS	BM	Lower to mid-montane fens, springs, floodplains.
Carex cusickii-Comarum palustre	E	S	CR	Low-elevation fens around edges of lakes and ponds.
Carex lenticularis	E	SS	BM	Lower to upper montane basins, flooodplains and springs.
Carex luzulina	E	SS	BM	Upper montane to subalpine headwater basins and floodplains.
Carex nebrascensis	E	SS	BM, BR, EC	Mid-montane fens, floodplains, springs.
Carex obnupta	E	SS	CR, WV	Fens and marshes.
Carex praegracilis	E	SS	BM	Middle to upper montane headwater basins
Carex scopulorum	E	SS	BM, BR, WC	Upper montane to subalpine headwater basins, floodplains, lakeshores and streambanks.
Carex utriculata	E	SS	BM, BR, EC, WC	Middle to upper montane fens, springs, edges of lakes and ponds, and floodplains.
Chiloscyphus polyanthos	A	P	CR, WC	Perennial cold-water springs and upper stream reaches.
Cupressus lawsoniana/Rhododendron occidentale/Carex	F	T	KM	Fens and floodplain on ultramafic soils and bedrock.
Danthonia californica-Deschampsia cespitosa	E	S	KM	Seepage areas and fens on ultramafic soils.
Danthonia californica-Juncus tenuis	E	SS	BM	Perennial or intermittent seeps on shallow soils over bedrock.
Darlingtonia californica	E	S	KM	Hillslope seeps on peat and mineral soil over ultramafic bedrock.
Distichlis spicata	E	I	BR, HP	Low-elevation alkaline seeps, floodplains and playas.
Distichlis spicata-Scirpus nevadensis	E	I	BR, HP	Alkaline marshes, springs and pools.
Eleocharis quinqueflora-Eriophorum criniger	E	S	KM	Seepage fens on ultramafic soils.

Eleocharis rostellata	E	S	BR	Springs and marshes.
Fontinalis antipyretica	A	P	CR, EC, WC, WV.	Springs, lakeshores, pools, streams and rivers.
Fontinalis neomexicana	A	P	CR	Springs and streams.
Juncus balticus-Scirpus nevadensis	E	SS	BR	Low-elevation springs, sometimes alkaline.
Juncus effusus	E	SS	All	Low-elevation floodplains, basins, seepage areas, margins of lakes and ponds.
Marchantia polymorpha-Philonotis fontana	M	S	BM, BR, EC, KM, OU.	Middle to upper-elevation streamsides, springs, and perennial seeps on shallow soils over bedrock.
Mertensia paniculata-Urtica dioica ssp. gracilis	E	S	BM	Seepage in cirques and at the bases of avalanche slopes.
Mimulus-Saxifraga	E	SS	BM, EC, WC	Seepage on shallow soils over bedrock.
Picea engelmannii/Senecio triangularis	F	SS	BM	Midmontane to subalpine bars, floodplains and springs.
Polygonum bistortoides-Ranunculus macounii	E	S	BM, BR	Middle to upper elevation floodplains, seepage areas, and peatlands.
Populus tremuloides/Carex pellita	F	SS	BM	Mid to upper montane basins, floodplains, headwaters for perennial streams.
Rhododendron occidentale/Camassia quamash	S	SS	KM	Serpentine fens at low elevation.
Salix boothii-Salix eastwoodiae	S	T	EC	Subalpine floodplains.
Salix boothii-Salix geyeriana/Carex aquatilis	S	SS	BM	Middle to upper montane floodplains, springs.
Salix boothii-Salix geyeriana/Carex utriculata	S	S	BM, EC	Mid-elevation floodplains, peatlands, springs.
Salix commutata-Salix eastwoodiae/Carex scopulorum	S	S	BM, EC	Upper montane to subalpine floodplains, peatlands, seepage slopes.
Saxifraga odontoloma	E	S	BM	Mid to high-elevation floodplains, springs
Scirpus acutus	E	SP	All	Margins of lakes, ponds, and in riverine shallows and seepage areas.
Scirpus americanus (interior alkaline)	E	SS	BR, CB	Alkaline springs, marshes and ponds.
Scirpus microcarpus	E	SS	BM, CR, EC, OU, WV, KM, WC	Low elevation to mid-montane streambanks, floodplains, fens, seepage areas, springs.
Tsuga heterophylla/Acer circinatum/Lysichiton americanum	F	SS	CR, WC	Floodplains and seepage areas.

4. Class= Lacustrine Fringe

ONHP Subclass, Characterizing Species	Veg Form	Hydro periods	Eco-regions	Habitats
Azolla mexicana	A	SS	CR, WV	Lakes, ponds and sloughs with little or no current. Becoming stranded on mud when water dries up.
Bidens frondosa	E	SS	WV	Margins of streams and ponds, exposed by early to midsummer.
Brasenia schreberi	A	P	CR, KM	Shallow lakes and ponds, and littoral zone in deeper lakes.
Callitriche heterophylla	A	SS	CR, KM, WC, WV	Low-elevation pools, ponds and sloughs.
Carex aquatilis var. dives	E	S	CR, EC, WC	Marshy shores of middle elevation lakes and ponds, and seasonally-flooded depressions in montane peatlands.
Carex cusickii-Comarum palustre	E	S	CR	Low-elevation fens around edges of lakes and ponds.
Carex utriculata	E	SS	BM, BR, EC, WC	Middle to upper montane fens, springs, edges of lakes and ponds, and floodplains.
Ceratophyllum demersum	A	P	CR, KM, WV	Shallow lakes, ponds and slow-moving streams.
Eleocharis acicularis	E	S	EC	Shores of pools, ponds and lakes.
Eleocharis palustris	E	SS	All	Basins, floodplains, gravel bars, shores of pools, ponds and lakes.
Elodea canadensis	A	P	CR, EC, WV	Lakes, ponds, sloughs and slow-moving streams and rivers.

Equisetum fluviatile	E	S	CR, EC, WC	Low elevation to low montane marshes, lakeshores, riverbanks.
Fontinalis antipyretica	A	P	CR, EC, WC, WV.	Springs, lakeshores, pools, streams and rivers.
Glyceria borealis	E	SP	BM, BR, EC	Marshy shores of montane streams and lakes.
Glyceria elata	E	SP	BM	Low to mid-montane floodplains, lakeshores, streambanks, spring, gravel bars.
Glyceria grandis	E	SP	BR	Marshy shores of montane streams and lakes.
Glyceria striata	E	SP	BM	Marshy shores of montane streams and lakes.
Lemna minor	A	SP	Throughout	Lakes, ponds and sloughs, with little or no current. Becoming stranded on mud when water dries up.
Malus fusca-Salix hookeriana/Carex obnupta	S	SS	CR	Margins of coastal lakes and ponds.
Menyanthes trifoliata	E	SP	BM, CR, WC, WV	Low elevation to mid-montane lakes, pools and ponds.
Myriophyllum hippuroides	A	SS, SP	WV	Ponds, lakes and sloughs, sometimes drying by late summer.
Myriophyllum sibiricum	A	P	EC	Submerged in slow-flowing streams and ponds.
Nuphar lutea ssp. polysepala	E	SP	BM, CR, EC, WC, WV	Low elevation to upper montane ponds, lakeshores, sloughs.
Phragmites australis	E	SP	CB, HP, OU	Low to middle elevation streams, lakes, ponds and depressions.
Pinus contorta ssp. murrayana/Carex aquatilis	F	SS	BM, EC	Midmontane to subalpine floodplains, lakeshores, meadows, springs.
Polygonum amphibium	E	SP	WV	Shallow lakes, ponds, and marshes.
Potamogeton natans	A	SP	CR, EC, KM, WC, WV	Lakes, ponds, pools.
Sagittaria latifolia	E	SS	WV	Lakes, ponds, pools, and freshwater intertidal zone along lower Columbia River and in Willamette Valley.
Salix (hookeriana-sitchensis)-Spiraea douglasii/Carex obnupta	S	S	CR	Margins of coastal lakes, floodplains.
Scirpus acutus	E	SP	All	Margins of lakes, ponds, and in riverine shallows and seepage areas.
Scirpus maritimus (interior alkaline)	E	I	BR	Margins of playas and lakes.
Scirpus subterminalis	A	P	CR	Submerged along margins of lakes and ponds.
Scirpus tabernaemontani	E	SP	All	Marshes, margins of ponds and lakes, riverine shallows
Sparganium emersum	E	SP	BR, EC, WV	Low elevation to subalpine marshes, lakeshores and ponds, and freshwater tidal reaches of rivers.
Sparganium eurycarpum	E	S	CR, WV	Margins of marshes, lakes and ponds.
Spiraea douglasii/Sphagnum	S	S	WV	Margins of lakes and ponds, peatlands.
Typha latifolia	E	SP	All	Low elevation to mid-montane marshes, lakeshores, ponds. Also lacustrine littoral.
Utricularia macrorhiza	A	P	CR, WV, WC	Marshes, lakes and ponds.
Wolffia borealis-Wolffia columbiana	A	P	KM, WV	Lakes, pools, ponds and sloughs, with little or no water movement. Becoming stranded when water dries up.

Appendix D. Oregon Fish That Use Wetland/ Riparian Habitats

Species	**Habit** A= anadromous RF= resident freshwater RE= resident or seasonal in estuarine wetlands I= introduced	**General Status***	**State Status***
River Lamprey	A	G4	S4
Pit-Klamath Brook Lamprey	R	G3G4	S3
Pacific Brook Lamprey	A	G5	S4
Pacific Lamprey	A	G5	S3
Goose Lake Lamprey	R	G5T1	S1
Klamath Lamprey	R	G2G3Q	S?
Sharpnose Sculpin	R	G5	S4
Coastrange Sculpin	R	G5	S4
Prickly Sculpin	RE	G5	S4
Mottled Sculpin	R	G5	S4?
Malheur Mottled Sculpin	R	G5T3Q	S3
Paiute Sculpin	R	G5	S4
Shorthead Sculpin	R	G5	S4
Riffle Sculpin	R	G5	S4
Marbled Sculpin	R	G4	S4
Margined Sculpin	R	G3	S3
Reticulate Sculpin	R	G4	S4
Pit Sculpin	R	G4	S1
Klamath Lake Sculpin	R	G3	S3
Torrent Sculpin	R	G5	S4
Slender Sculpin	R	G3	S3
Pacific Staghorn Sculpin	R	G5	S4
Green Sturgeon	A	G4	S4
White Sturgeon	A	G4	S4
American Shad	I,RE	G5	SE
Threadfin Shad	I,RE	G5	SE
Pacific Herring	RE	G?	S4
Pink Salmon	A	G5	S4
Chum Salmon	A	G5	S3?
Chum Salmon (Columbia River Run)	A	G5T?Q	S2
Coho Salmon	A	G4	S3
Coho Salmon (Lower Columbia River/ Sw Washington Coast Runs)	A	G4T3Q	S3
Coho Salmon (S.Oregon/ N.Calif. Coast)	A	G4T3Q	S3
Coho Salmon (Oregon Coastal Runs)	A	G4T3Q	S3
Sockeye Salmon		G5	S4
Chinook Salmon	A	G5	S4?
Chinook Salmon (Lower Columbia River Fall Runs)	A	G5T3Q	S3
Chinook Salmon (Snake River, Fall Run)	A	G5T1Q	S1
Chinook Salmon (Southern Oregon Coast, Fall Runs)	A	G5T3Q	S3
Chinook Salmon (Snake River, Spring/ Summer Run)	A	G5T1Q	S1
Chinook Salmon (Upper Willamette River Runs)	A	G5T?Q	S2
Cutthroat Trout	A, R	G4	S4
Lahontan Cutthroat Trout	R	G4T2	S1
Westslope Cutthroat Trout	R	G4T3	S3
Coastal Cutthroat Trout	R	G4T4	S4

Species	**Habit** A= anadromous RF= resident freshwater RE= resident or seasonal in estuarine wetlands I= introduced	**General Status***	**State Status***
Coastal Cutthroat Trout (L. Columbia River Anadromous Form)	A	G4T?Q	S4
Umpqua River Cutthroat Trout	A	G4T3Q	S3
Rainbow Trout	A, R	G5	S5
Inland Columbia Basin Redband Trout	R	G5T4?	S3
Goose Lake Redband Trout	R	G5T2Q	S2
Catlow Valley Redband Trout	R	G5T1Q	S1
Warner Valley Redband Trout	R	G5T2Q	S2
Golden Trout	I,R	G5T3	SE
Klamath Mountains Province Steelhead	A	G5T2T3Q	S2S3
Jenny Creek Redband Trout	R	G5T2Q	S2
Snake River Basin Steelhead	A	G5T3Q	S3?
Lower Columbia River Steelhead	A	G5T3Q	S3?
Oregon Coast Steelhead	A	G5T3Q	S3?
Middle Columbia River Steelhead	A	G5T3Q	S3?
Oregon Great Basin Redband Trout	R	G5T4?	S3
Klamath Basin Redband Trout	R	G5T4?	S3
Upper Willamette River Steelhead	A	G5T?Q	S3?
Mountain Whitefish	R	G5	S4
Atlantic Salmon	I,R	G5	SE
Brown Trout	I,R	G5	SE
Bull Trout	R,A	G3	S3
Brook Trout	I,R	G5	SE
Dolly Varden	R, A	G5	S4
Lake Trout	I, R	G5	SE
Surf Smelt	RE	G5	S4
Longfin Smelt	I, R	G5	S4
Eulachon	RE	G5	S4
Chiselmouth	R	G5	S4
Goldfish	I,R	G5	SE
Grass Carp	I,R	G5	SE
Common Carp	I,R	G5	SE
Alvord Chub	R	G2	S2
Tui Chub	R	G4	S4
Hutton Spring Tui Chub	R	G4T1	S1
Catlow Tui Chub	R	G4T1	S1
Sheldon Tui Chub	R	G4T1	S1
Oregon Lakes Tui Chub	R	G4T2	S2
Summer Basin Tui Chub	R	G4T1	S1
Goose Lake Tui Chub	R	G4T2	S2
Warner Basin Tui Chub	R	G4T2Q	S2
Borax Lake Chub	R	G1	S1
Blue Chub	R	G2G3	S3
California Roach	RE	G5	S3
Pit Roach	RE	G5T3	S3
Peamouth	R	G5	S4
Golden Shiner	I, R	G5	SE
Fathead Minnow	I,R	G5	SE
Northern Squawfish	R	G5	S4
Umpqua Squawfish	R	G4	S4
Longnose Dace	R	G5	S4
Millicoma Dace	R	G5T3	S3
Umpqua Dace	R	G3	S3
Leopard Dace	R	G4	S4
Speckled Dace	R	G5	S4
Foskett Spring Speckled Dace	R	G5T1	S1

Species	**Habit** A= anadromous RF= resident freshwater RE= resident or seasonal in estuarine wetlands I= introduced	**General Status***	**State Status***
Redside Shiner	RE	G5	S4
Lahontan Redside	R	G4	S3
Tench	I,R	G5	SE
Oregon Chub	R	G2	S2
Umpqua Oregon Chub	R	G3	S3
Bridgelip Sucker	R	G5	S4
Largescale Sucker	R	G5	S4
Modoc Sucker	R	G1	SR
Sacramento Sucker	R	G5	S?
Goose Lake Sucker	R	G5T2Q	S2
Mountain Sucker	R	G5	S4
Klamath Smallscale Sucker	R	G5	S4
Jenny Creek Sucker	R	G4T2Q	S2
Klamath Largescale Sucker	R	G3	S3
Tahoe Sucker	R	G5	S1
Warner Sucker	R	G1	S1
Shortnose Sucker	R	G1	S1
Lost River Sucker	R	G1	S1
Oriental Weatherfish	I,R	G5	SE
Blue Catfish	I,R	G5	SE
Channel Catfish	I, R	G5	SE
Tadpole Madtom	I,R	G5	SE
Flathead Catfish	I,R	G5	SE
White Catfish	I,R	G5	SE
Black Bullhead	I,R	G5	SE
Yellow Bullhead	I,R	G5	SE
Brown Bullhead	I,R	G5	SE
Sand Roller	RE	G4	S4
Burbot	R	G5	S?
Pacific Tomcod	R	G5	S4
Banded Killifish	I, RE	G5	SE
Rainwater Killifish	I, RE	G5	SE
Western Mosquitofish	I,R	G5	SE
Threespine Stickleback	RE	G5	S4
Striped Bass	I,RE	G5	SE
Sacramento Perch	I,R	G3	SE
Green Sunfish	I,R	G5	SE
Pumpkinseed	I, R	G5	SE
Warmouth	I,R	G5	SE
Bluegill	I, R	G5	SE
Redear Sunfish	I, R	G5	SE
Smallmouth Bass	I,R	G5	SE
Largemouth Bass	I,R	G5	SE
White Crappie	I,R	G5	SE
Black Crappie	I, R	G5	SE
Yellow Perch	I,R	G5	SE
Walleye	I,R	G5	SE
Shiner Perch	RE	G5	S4
Saddleback Gunnel	RE	G?	S4
Starry Flounder	RE	G5	S4

* S1 or G1: Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors; S2 or G2: Imperiled due to rarity and/or other demonstrable factors; S3 or G3: Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction; S4 or G4: Apparently secure, though frequently quite rare in parts of its range, especially at its periphery; S5 or G5: Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery. Q: uncertain taxonomic status. From Oregon Natural Heritage Program.

Appendix E. Oregon Amphibians that Use Wetland/ Riparian Habitats

Legend
Dependence = Relative degree of dependence on wetland/ riparian habitat (based on Aubrey and Hall 1991, Gilbert and Allwine 1991, McComb and Hagar 1992, McComb et al. 1993, Washington Dept. Fish & Wildlife 1995, Gomez and Anthony 1996):
1 = occurs almost exclusively in wetland/ riparian habitat
2 = occurs in other habitats as well, but has been documented as occurring disproportionately in wetland/ riparian habitats even when other undisturbed habitats were present, in at least one region of Oregon
3 = probably occurs regularly in wetland/ riparian habitats but disproportionate or essential use has not been documented for such habitats in any region of Oregon

Keep in mind that many species that characteristically are thought of being less aquatic (species assigned a "2" or "3" in the “Dependence” column) nonetheless are more abundant in wetland/ riparian sites than in uplands (McComb et al. 1993).

	Dependence	General Rank*	State Rank*
Northwestern Salamander	1	G5	S5
Long-Toed Salamander	1	G5	S5
Tiger Salamander	1	G5T4	S?
Clouded Salamander	3	G4	S4
Black Salamander	3	G4	S2
California Slender Salamander	3	G5	S2
Oregon Slender Salamander	3	G3	S3
Ensatina	3	G5	S5
Dunn's Salamander	2	G4	S4
Del Norte Salamander	3	G3	S2
Larch Mountain Salamander	3	G2	S2
Siskiyou Mountains Salamander	3	G2Q	S2
Roughskin Newt	1	G5	S5
Cope's Giant Salamander	1	G3	S2
Pacific Giant Salamander	1	G5	S4
Southern Seep Salamander	1	G3	S3
Cascade Seep Salamander	1	G3	S3
Columbia Seep Salamander	1	G3	S3
Tailed Frog	1	G4	S3
Western Toad	1	G4	S4
Woodhouse's Toad	1	G5	S2
Pacific Treefrog	1	G5	S5
Great Basin Spadefoot	1	G5	S5
Red-Legged Frog	1	G4T4	S3S4
Foothill Yellow-Legged Frog	1	G3	S3?
Cascades Frog	1	G4	S3
Bullfrog	1	G5	SE
Northern Leopard Frog	1	G5	S2?
Oregon Spotted Frog	1	G2G3	S2
Columbia Spotted Frog	1	G4	S2?

* **S1 or G1:** Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors**;** **S2 or G2:** Imperiled due to rarity and/or other demonstrable factors**;** **S3 or G3:** Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction**;** **S4 or G4:** Apparently secure, though frequently quite rare in parts of its range, especially at its periphery**;** **S5 or G5:** Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery**.** Q: uncertain taxonomic status. From Oregon Natural Heritage Program.

Appendix F. Oregon Reptiles that Use Wetland/ Riparian Habitats

Legend:

Dependence = Relative degree of dependence on wetland/ riparian habitat (based on Aubrey and Hall 1991, Gilbert and Allwine 1991, McComb and Hagar 1992, McComb et al. 1993, Washington Dept. Fish & Wildlife 1995, Gomez and Anthony 1996):

1 = occurs almost exclusively in wetland/ riparian habitat

2 = occurs in other habitats as well, but has been documented as occurring disproportionately in wetland/ riparian habitats even when other undisturbed habitats were present, in at least one region of Oregon

3 = probably occurs regularly in wetland/ riparian habitats but disproportionate or essential use has not been documented for such habitats in any region of Oregon

Keep in mind that many species that characteristically are thought of being less aquatic (species assigned a "2" or "3" in the "Dependence" column) nonetheless are more abundant in wetland/ riparian sites than in uplands (McComb et al. 1993).

	Dependence	General Rank*	State Rank *
Painted Turtle	1	G5	S2
Western Pond Turtle	1	G3	S3
Northern Alligator Lizard	3	G5	S5
Southern Alligator Lizard	3	G5	S5
Desert Horned Lizard	3	G5	S3
Western Fence Lizard	3	G5	S5
Western Skink	3	G5	S5
Western Whiptail	3	G5	S4
Plateau Striped Whiptail	3	G5	SE
Rubber Boa	2	G5	S4
Racer	2	G5	S4?
Sharptail Snake	3	G5	S3
Ringneck Snake	2	G5	S4?
Night Snake	3	G5	S3
Common Kingsnake	2	G5	S2
California Mountain Kingsnake	2	G4	S3
Striped Whipsnake	3	G5	S4
Gopher Snake	2	G5	S5
Ground Snake	2	G5	S2
Western Terrestrial Garter Snake	2	G5	S5
Northwestern Garter Snake	2	G5	S5
Common Garter Snake	2	G5	S5
Pacific Coast Aquatic Garter Snake	2	G5	S4?
Western Rattlesnake	2	G5	S4

*** S1 or G1:** Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors**;** **S2 or G2:** Imperiled due to rarity and/or other demonstrable factors**;** **S3 or G3:** Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction**;** **S4 or G4:** Apparently secure, though frequently quite rare in parts of its range, especially at its periphery**;** **S5 or G5:** Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery**.** **E:** Exotic species (not native to Oregon). From Oregon Natural Heritage Program.

Appendix G. Oregon Birds that Use Wetland/ Riparian Habitats

Legend

Dependence = Relative degree of dependence on wetland/ riparian habitat (from personal experience and the following: Bull and Skovlin 1982, McGarigal and McComb 1992, McComb and Hagar 1992, Washington Dept. Fish & Wildlife 1995, Saab and Rich 1997, Loegering & Anthony 1999):

1 = occurs almost exclusively in wetland/ riparian habitat

2 = occurs in other habitats as well, but has been documented as occurring disproportionately in wetland/ riparian habitats even when other undisturbed habitats were present, in at least one region of Oregon

3 = probably occurs regularly in wetland/ riparian habitats but disproportionate or essential use has not been documented for such habitats in any region of Oregon

Status (from Oregon Natural Heritage Program): S1 or G1: Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors; S2 or G2: Imperiled due to rarity and/or other demonstrable factors; S3 or G3: Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction; S4 or G4: Apparently secure, though frequently quite rare in parts of its range, especially at its periphery; S5 or G5: Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery. B: rank applies only to breeding; E: Exotic, H: primarily of historical occurrence; N: rank applies only to non-breeding; U: range poorly known; Z: inconsistent or absent as breeder

	Dependence	General Rank*	State Rank*
Common Loon	2	G5	SH
Pied-Billed Grebe	1	G5	S5
Horned Grebe	1	G5	S2B,S5N
Red-Necked Grebe	1	G5	S1B,S4N
Eared Grebe	1	G5	S4
Western Grebe	1	G5	S4?
Clark's Grebe	1	G5	S4
American White Pelican	1	G3	S1
Brown Pelican	3	G4	S2N
Double-Crested Cormorant	2	G5	S5
American Bittern	1	G4	S4
Least Bittern	1	G5	S1
Great Blue Heron	1	G5	S4
Great Egret	1	G5	S3
Snowy Egret	1	G5	S2B
Cattle Egret	1	G5	SU
Green Heron	1	G5	S4
Black-Crowned Night-Heron	1	G5	S4
White-Faced Ibis	1	G5	S3B
Tundra Swan	1	G5	S4
Trumpeter Swan	1	G4	S2
Greater White-Fronted Goose	1	G5	SZN
Snow Goose	1	G5	S4
Ross' Goose	1	G4	SZN
Brant	1	G5	S4
Canada Goose	1	G5	S5
Wood Duck	1	G5	S4
Green-Winged Teal	1	G5	S5
Mallard	1	G5	S5
Northern Pintail	1	G5	S5
Blue-Winged Teal	1	G5	S4
Cinnamon Teal	1	G5	S5
Northern Shoveler	1	G5	S5
Gadwall	1	G5	S5
American Wigeon	1	G5	S5
Canvasback	1	G5	S4
Redhead	1	G5	S4

	Dependence	General Rank*	State Rank*
Ring-Necked Duck	1	G5	S3
Greater Scaup	1	G5	S4
Lesser Scaup	1	G5	S3B,S4N
Harlequin Duck	1	G4	S2B,S3N
Common Goldeneye	1	G5	S4
Barrow's Goldeneye	1	G5	S3B,S3N
Bufflehead	1	G5	S2B,S5N
Long-tailed Duck	1	G5	S5
Hooded Merganser	1	G5	S4
Common Merganser	1	G5	S4
Red-Breasted Merganser	1	G5	SZN
Ruddy Duck	1	G5	S4
Turkey Vulture	3	G5	S5
Osprey	1	G5	S4
White-Tailed Kite	3	G5	S1B,S3N
Bald Eagle	3	G4	S3B,S4N
Northern Harrier	2	G5	S5
Sharp-Shinned Hawk	3	G5	S4
Cooper's Hawk	3	G5	S4
Northern Goshawk	3	G5	S3
Red-Shouldered Hawk	3	G5	S3N
Swainson's Hawk	3	G5	S3B
Red-Tailed Hawk	3	G5	S5
Ferruginous Hawk	2	G4	S3B
Rough-Legged Hawk	3	G5	S4N
Golden Eagle	3	G5	S4
American Kestrel	3	G5	S5
Merlin	3	G5	SHB,SZN
Peregrine Falcon	3	G4	S1
Prairie Falcon	3	G5	S4
Gray Partridge	3	G5	SE
Chukar	3	G5	SE
Ring-Necked Pheasant	3	G5	SE
Spruce Grouse	3	G5	S3
Blue Grouse	3	G5	S4
Ruffed Grouse	3	G5	S4?
Sage Grouse	3	G5	S3

	Dependence	General Rank*	State Rank*
Sharp-Tailed Grouse	3	G4T3	S1
Wild Turkey	3	G5	SE
Northern Bobwhite	3	G5	SE
California Quail	3	G5	S4SE
Mountain Quail	3	G5	S4?
Yellow Rail	1	G4	S1B
Virginia Rail	1	G5	S4
Sora	1	G5	S4
American Coot	1	G5	S5
Sandhill Crane	1	G5	S3
Black-Bellied Plover	1	G5	SZN
Lesser Golden-Plover	1	G5	S?
Snowy Plover	1	G4	S2
Semipalmated Plover	1	G5	SZN
Killdeer	2	G5	S5
Black-Necked Stilt	1	G5	S4
American Avocet	1	G5	S4
Greater Yellowlegs	1	G5	S1B,S2N
Lesser Yellowlegs	1	G5	SZN
Solitary Sandpiper	1	G5	S1B
Willet	1	G5	S4
Spotted Sandpiper	1	G5	S4
Upland Sandpiper	2	G5	S1B
Whimbrel	1	G5	SZN
Long-Billed Curlew	2	G5	S3S4
Marbled Godwit	1	G5	SZN
Semipalmated Sandpiper	1	G5	SZN
Western Sandpiper	1	G5	SZN
Least Sandpiper	1	G5	SZN
Baird's Sandpiper	1	G5	SZN
Pectoral Sandpiper	1	G5	SZN
Sharp-Tailed Sandpiper	1	G5	SZN
Dunlin	1	G5	S5N
Short-Billed Dowitcher	1	G5	SZN
Long-Billed Dowitcher	1	G5	SZN
Common Snipe	1	G5	S4
Wilson's Phalarope	1	G5	S4
Red-Necked Phalarope	2	G5	SZN
Franklin's Gull	1	G4G5	S1B
Bonaparte's Gull	2	G5	SZN
Heermann's Gull	2	G4	SZN
Mew Gull	2	G5	SZN
Ring-Billed Gull	2	G5	S5
California Gull	2	G5	S5
Herring Gull	2	G5	SZN
Thayer's Gull	2	G5	SZN
Western Gull	2	G5	S4
Glaucous-Winged Gull	2	G5	S5
Glaucous Gull	2	G5	SZN
Caspian Tern	1	G5	S4?
Forster's Tern	1	G5	S4B
Black Tern	1	G4	S3B
Rock Dove	3	G5	SE
Band-Tailed Pigeon	3	G5	S4
Mourning Dove	3	G5	S5
Yellow-Billed Cuckoo	3	G5	S1B
Barn Owl	3	G5	S4?
Flammulated Owl	3	G4	S4B
Western Screech-Owl	3	G5	S4?
Great Horned Owl	3	G5	S5
Snowy Owl	3	G5	SZN

	Dependence	General Rank*	State Rank*
N. Pygmy-Owl	3	G5	S4?
Burrowing Owl	3	G4	S2?B
Spotted Owl	3	G3	S3
Barred Owl	3	G5	SU
Great Gray Owl	3	G5	S4
Long-Eared Owl	3	G5	S4?
Short-Eared Owl	3	G5	S4?
Boreal Owl	3	G5	S4?
N. Saw-Whet Owl	3	G5	S4?
Common Nighthawk	3	G5	S5
Common Poorwill	3	G5	S?
Black Swift	3	G4	S1B,S3?N
Vaux's Swift	3	G5	S5
White-Throated Swift	3	G5	S4?
Black-Chinned Hummingbird	3	G5	S4B
Anna's Hummingbird	3	G5	S4?
Costa's Hummingbird	3	G5	SZN
Calliope Hummingbird	3	G5	S4?
Broad-Tailed Hummingbird	3	G5	SUB
Rufous Hummingbird	3	G5	S4
Allen's Hummingbird	3	G5	S3?B
Belted Kingfisher	1	G5	S4
Lewis' Woodpecker	3	G5	S4B,S4N
Acorn Woodpecker	3	G5	S3?
Red-Breasted Sapsucker	3	G5	S4
Williamson's Sapsucker	3	G5	S4B,S3N
Red-Naped Sapsucker	3	G5	S4
Downy Woodpecker	3	G5	S4
Hairy Woodpecker	3	G5	S4
White-Headed Woodpecker	3	G4	S3
Three-Toed Woodpecker	3	G5	S3
Black-Backed Woodpecker	3	G5	S3
Northern Flicker	3	G5	S5
Pileated Woodpecker	3	G5	S4?
Olive-Sided Flycatcher	3	G5	S4
Western Wood-Pewee	3	G5	S4
Willow Flycatcher	2	G5	S4
Least Flycatcher	2	G5	SU
Hammond's Flycatcher	3	G5	S4
Dusky Flycatcher	3	G5	S4
Gray Flycatcher	3	G5	S4
Pacific Slope Flycatcher	3	G5	S4
Cordilleran Flycatcher	3	G5	S?
Black Phoebe	1	G5	S3B,S3N
Say's Phoebe	2	G5	S4?
Ash-Throated Flycatcher	3	G5	S4?
Western Kingbird	3	G5	S5
Eastern Kingbird	3	G5	S4
Horned Lark	3	G5	S5
Purple Martin	3	G5	S3B
Tree Swallow	2	G5	S5
Violet-Green Swallow	3	G5	S5
N. Rough-Winged Swallow	3	G5	S4
Bank Swallow	3	G5	S4B
Cliff Swallow	3	G5	S5
Barn Swallow	3	G5	S5
Gray Jay	3	G5	S4
Steller's Jay	3	G5	S5
Western Scrub-Jay	3	G5	S5
Pinyon Jay	3	G5	S3S4
Clark's Nutcracker	3	G5	S4

	Dependence	General Rank*	State Rank*
Black-Billed Magpie	2	G5	S5
American Crow	3	G5	S5
Common Raven	3	G5	S4
Black-Capped Chickadee	3	G5	S5
Mountain Chickadee	3	G5	S4
Chestnut-Backed Chickadee	3	G5	S5
Oak Titmouse	3	G5	S?
Juniper Titmouse	3	G5,TU	SU
Bushtit	3	G5	S5
Red-Breasted Nuthatch	3	G5	S5
White-Breasted Nuthatch	3	G5	S4
Pygmy Nuthatch	3	G5	S4?
Brown Creeper	3	G5	S4
Bewick's Wren	3	G5	S4
House Wren	3	G5	S4
Winter Wren	3	G5	S4
Marsh Wren	1	G5	S5
American Dipper	1	G5	S4
Golden-Crowned Kinglet	3	G5	S4
Ruby-Crowned Kinglet	3	G5	S4
Blue-Gray Gnatcatcher	3	G5	S3B
Western Bluebird	3	G5	S4B,S4N
Mountain Bluebird	3	G5	S4
Townsend's Solitaire	3	G5	S4
Veery	2	G5	S4?B
Swainson's Thrush	3	G5	S5
Hermit Thrush	3	G5	S4
American Robin	3	G5	S5
Varied Thrush	3	G5	S4
Wrentit	3	G5	S5
Gray Catbird	2	G5	S4?B
Mockingbird	3	G5	S4
Sage Thrasher	3	G5	S4
American Pipit	3	G5	SU
Bohemian Waxwing	3	G5	S4?
Cedar Waxwing	3	G5	S5
Northern Shrike	3	G5	S4N
Loggerhead Shrike	3	G5	S4B,S2N
European Starling	3	G5	SE
Cassin's Vireo	3	G5	S4?
Hutton's Vireo	2	G5	S4
Warbling Vireo	2	G5	S5
Red-Eyed Vireo	2	G5	S4
Tennessee Warbler	3	G5	SZN
Orange-Crowned Warbler	3	G5	S5
Nashville Warbler	3	G5	S4?
Yellow Warbler	2	G5	S4
Yellow-Rumped Warbler	3	G5	S5
Black-Throated Gray Warbler	3	G5	S5
Palm Warbler	3	G5	SZN
American Redstart	2	G5	SU
Northern Waterthrush	2	G5	S2?B
MacGillivray's Warbler	3	G5	S4
Common Yellowthroat	2	G5	S5
Wilson's Warbler	3	G5	S5
Yellow-Breasted Chat	3	G5	S4?
Western Tanager	3	G5	S4
Black-Headed Grosbeak	3	G5	S5
Lazuli Bunting	3	G5	S4
Green-Tailed Towhee	3	G5	S4
California Towhee	3	G4G5	S4?

	Dependence	General Rank*	State Rank*
Spotted Towhee	3	G5	S5
American Tree Sparrow	3	G5	S3N
Chipping Sparrow	3	G5	S4
Savannah Sparrow	3	G5	S5
Fox Sparrow	3	G5	S4
Song Sparrow	3	G5	S5
Lincoln's Sparrow	2	G5	S4
Swamp Sparrow	2	G5	S3N
White-Throated Sparrow	3	G5	S2N
Golden-Crowned Sparrow	3	G5	S5N
White-Crowned Sparrow	3	G5	S5
Harris' Sparrow	3	G5	SZN
Dark-Eyed Junco	3	G5	S5
Bobolink	2	G5	S2B
Red-Winged Blackbird	2	G5	S5
Tricolored Blackbird	2	G3	S2B
Western Meadowlark	3	G5	S4
Yellow-Headed Blackbird	1	G5	S5
Brewer's Blackbird	3	G5	S5
Brown-Headed Cowbird	3	G5	S5
Bullock's Oriole	3	G5	S4
Purple Finch	3	G5	S4
Cassin's Finch	3	G5	S4
House Finch	3	G5	S5
Pine Siskin	3	G5	S5
Lesser Goldfinch	3	G5	S4
American Goldfinch	3	G5	S4
Evening Grosbeak	3	G5	S5

Appendix H. Oregon Mammals that Use Wetland/ Riparian Habitats

Legend:

Dependence = Relative degree of dependence on wetland/ riparian habitat (based on McComb and Hagar 1992, McComb et al. 1993, Washington Dept. Fish & Wildlife 1995, Gomez and Anthony 1996):

1 = occurs almost exclusively in wetland/ riparian habitat

2 = occurs in other habitats as well, but has been documented as occurring disproportionately in wetland/ riparian habitats even when other undisturbed habitats were present, in at least one region of Oregon

3 = probably occurs regularly in wetland/ riparian habitats but disproportionate or essential use has not been documented for such habitats in any region of Oregon

Keep in mind that many species that characteristically are thought of being less aquatic (species assigned a "2" or "3" in the “Dependence” column) nonetheless are more abundant in wetland/ riparian sites than in uplands (McComb et al. 1993).

Status (from Oregon Natural Heritage Program): S1 or G1: Critically imperiled due to extreme rarity, imminent threats, or and/or biological factors; S2 or G2: Imperiled due to rarity and/or other demonstrable factors; S3 or G3: Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction; S4 or G4: Apparently secure, though frequently quite rare in parts of its range, especially at its periphery; S5 or G5: Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery. E: Exotic, H: primarily of historical occurrence; U: range poorly known.

	Dependence	General Rank	State Rank
Virginia Opossum	3	G5	SE
Preble's Shrew	3	G4	S3
Vagrant Shrew	3	G5	S4
Dusky Shrew	3	G5	S4
Pacific Shrew	2	G3G4	S3S4
Water Shrew	1	G5	S4
Pacific Water Shrew	1	G4	S4
Trowbridge's Shrew	3	G5	S4
Merriam's Shrew	3	G5	S3
Baird's Shrew	3	G4	SU
Fog Shrew	3	G5	SU
Shrew-Mole	2	G5	S4
Townsend's Mole	3	G5	S4
Coast Mole	3	G5	S5?
Broad-Footed Mole	3	G5	S4?
Little Brown Myotis	2	G5	S4
Yuma Bat	3	G5	S3
Long-Eared Bat	3	G5	S3
Fringed Bat	3	G5	S3
Long-Legged Bat	3	G5	S3
California Myotis	3	G5	S4
Western Small-Footed Bat	3	G5	S3
Silver-Haired Bat	3	G5	S4?
Western Pipistrelle	3	G5	S4
Big Brown Bat	3	G5	S4
Hoary Bat	3	G5	S4?
Western Red Bat	3	G5	S?
Spotted Bat	3	G4	S1
Townsend's Big-Eared Bat	3	G4	S4
Pallid Bat	3	G5	S3
Brazilian Free-Tailed Bat	3	G5	S2
Brush Rabbit	3	G5	S5

	Dependence	General Rank	State Rank
Eastern Cottontail	3	G5	SE
Nuttall's Cottontail	3	G5	S4
Snowshoe Hare	3	G5	S4
Pygmy Rabbit	3	G4	S2?
Mountain Beaver	3	G5	S4
Least Chipmunk	3	G5	S4
Yellow-Pine Chipmunk	3	G5	S4
Townsend's Chipmunk	3	G5	S4
Allen's Chipmunk	3	G5	S4?
Siskiyou Chipmunk	3	G4?	S4?
White-Tailed Antelope Squirrel	3	G5	S4?
Townsend's Ground Squirrel	3	G5	S4
Washington Ground Squirrel	3	G2	S2
Belding's Ground Squirrel	3	G5	S5
Columbian Ground Squirrel	3	G5	S4?
California Ground Squirrel	3	G5	S5
Golden-Mantled Ground Squirrel	3	G5	S4
Eastern Gray Squirrel	3	G5	SE
Western Gray Squirrel	3	G5	S4?
Eastern Fox Squirrel	3	G5	SE
Red Squirrel	3	G5	S4?
Douglas' Squirrel	3	G5	S5
Northern Flying Squirrel	3	G5	S4
Botta's Pocket Gopher	3	G5	S4?
Townsend's Pocket Gopher	3	G4G5	S4
Northern Pocket Gopher	3	G5	S4
Western Pocket Gopher	3	G4G5	S?
Camas Pocket Gopher	3	G4	S4
Little Pocket Mouse	3	G5	S4?
Great Basin Pocket Mouse	3	G5	S?
Dark Kangaroo Mouse	3	G5	S4?

	Dependence	General Rank	State Rank
Ord's Kangaroo Rat	3	G5	S4
Chisel-Toothed Kangaroo Rat	3	G5	S4?
California Kangaroo Rat	3	G4	S4?
American Beaver	1	G5	S5
Western Harvest Mouse	3	G5	S4
Deer Mouse	3	G5	S5
Canyon Mouse	3	G5	S4
Pinon Mouse	3	G5	S4?
Northern Grasshopper Mouse	3	G5	S4?
Desert Woodrat	3	G5	S4
Dusky-Footed Woodrat	3	G5	S4
Bushy-Tailed Woodrat	3	G5	S5
Southern Red-Backed Vole	3	G5	S4?
Western Red-Backed Vole	3	G5	S4
Heather Vole	3	G5	S4
White-Footed Vole	2	G3G4	S3
Red Tree Vole	3	G4T3	S3
Montane Vole	3	G5	S5
California Vole	3	G5	S4
Townsend's Vole	3	G5	S4
Long-Tailed Vole	3	G5	S5
Creeping Vole	3	G5	S4
Gray-Tailed Vole	3	G4	S4
Water Vole	1	G5	S4
Sagebrush Vole	3	G5	S4
Muskrat	1	G5	S5
Western Jumping Mouse	2	G5	S4
Pacific Jumping Mouse	2	G5	S4
Common Porcupine	3	G5	S5
Nutria	1	G5	SE
Coyote	3	G5	S5
Red Fox	3	G5	S4?
Kit Fox	3	G4	S?
Common Gray Fox	3	G5	S4
Black Bear	3	G5	S4
Ringtail	3	G5	S3
Common Raccoon	2	G5	S5
American Marten	3	G5	S3
Fisher	3	G5	S2
Ermine	3	G5	S5
Long-Tailed Weasel	3	G5	S5
Mink	2	G5	S5
Wolverine	3	G4	S2
Ameican Badger	3	G5	S4
Western Spotted Skunk	3	G5	S4
Striped Skunk	3	G5	S5
Northern River Otter	1	G5	S4?
Mountain Lion (Cougar)	3	G5	S4?
Canada Lynx	3	G5	S1
Bobcat	3	G5	S4
Elk	3	G5	S5
Black-Tailed Deer	3	G5	S5
White-Tailed Deer	3	G5	S?
Pronghorn	3	G5	S4
Bighorn Sheep	3	G4G5	S2