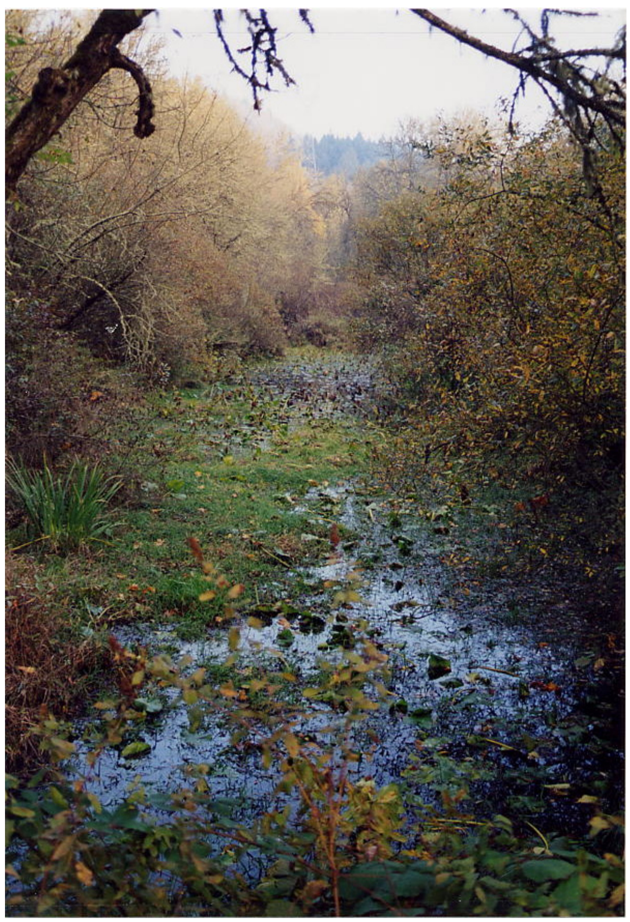
Guidebook for
Hydrogeomorphic (HGM)–based Assessment
of Oregon Wetland and Riparian Sites
I. Willamette Valley Ecoregion
Riverine Impounding and Slope/Flats Subclasses

Volume IB. Technical Report



Oregon Division of State Lands

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Volume IB. Technical Report

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

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Summary

This technical report describes the development of the wetland and riparian assessment methods presented in an accompanying document (Volume IA). Those methods are largely based on characteristics we observed at 109 wetland and riparian sites in the Willamette Valley region. This report describes the selection of those reference sites, the selection of least-altered (reference standard) sites, the selection of indicators of functions, and protocols used to assess those indicators at the reference sites. This report summarizes much of the field data, and describes preliminary results of testing the comparability and consistency of assessments using the indicators. The results cannot be statistically extrapolated to all wetlands of the Willamette Valley ecoregion, because private property issues make it impossible to select sites in a statistically random manner from the population of all sites in the ecoregion, and then visit and assess these. Nonetheless, the reference data set will be useful for helping develop performance standards for mitigation wetlands in the region. This report also describes initially promising results of use of some floristic (plant community) indicators of wetland condition. With continued testing and evaluation, these and other biological indicators may improve our knowledge of ecological condition in the region's riverine impounding and slope/flats wetland subclasses.

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Agencies represented by some of the above individuals include: Oregon Departments of Environmental Quality, Fish & Wildlife, Transportation; U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, USDA Natural Resources Conservation Service.

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Section 1. Introduction

This technical report (Volume IB) describes the overall context of the Oregon Wetland-Riparian Assessment (OWRA) Project, documents some of the assumptions and processes used in the development of the regional guidebook for the Willamette Valley, and presents details of the preliminary statistical analysis of data collected from 109 reference sites. This document is one of a three-volume series. Volume IA contains the assessment method whose development is described in this report. A third document provides a statewide perspective on wetIand and riparian hydrogeomorphic (HGM) classification and assessment. If some of the terms used in these documents are unfamiliar, refer to the Glossary (Appendix A) in Volume IA.

1.1 Project Background

In the early 1990's the federal agency responsible for issuing permits for wetland alteration – the U.S. Army Corps of Engineers – announced a "National Action Plan" (Federal Register 62(119):33607; internet address: http://www.epa.gov/OWOW/wetlands/science/hgm.html) to develop improved methods for quantitatively representing the functions of all wetlands. The new assessment methods would be developed region-by-region and be organized around hydrogeomorphic principles for classification and the calibration of models of wetland function based on data collected from regional reference sites. This approach was viewed as a scientifically-based alternative to categorizing wetlands as worthy or unworthy of protection based simply on their location or type. The initiative began with publication of a nationwide scheme for HGM classification (Brinson 1993), and guidance for developing regional HGM-based assessment methods (Smith 1993, Smith et al. 1995, Smith et al. *in draft*). Subsequently, "HGM projects" were initiated in over a dozen states, largely with funding from the USEPA, and guidebooks resulting from many of these efforts are beginning to be released. In 1997 Oregon's Division of State Lands (DSL), after meeting with other agencies and acting upon a key recommendation of a report (*Recommendations for a Nonregulatory Wetland Restoration Program for Oregon*, Good & Sawyer 1997), proposed this project for the purpose of developing HGM methods appropriate for various regions of Oregon. With partial funding from the USEPA, the DSL contracted with the author -- a specialist in wetland science and assessment -- to help DSL develop and test this guidebook in the Willamette Valley.

1.2 Purpose

The 3-volume guidebook is intended to help improve wetland planning and assessment procedures at the federal, state, and local levels in Oregon. Specifically, it is intended to make procedures for assessing wetland and riparian functions more transparent, rapid, quantitative, sensitive, systematic, scientifically acceptable, comprehensive, and consistent. The classification and methods are intended to help support Oregon's legal obligations for wetland assessment under Sections 401, 404, 305, and 319 of the Federal Clean Water Act and similar policy objectives of Oregon's Removal-Fill Law. It is hoped that routine use of the guidebook and complementary methods will help Oregon assess indicators of ecological health in wetland

(Morlan 2000) and riparian systems (Gregory 2000), as highlighted in Oregon's State of the Environment Report (Risser 2000):

- Change in diversity and distribution of wetland types
- Changes in hydrologic characteristics
- Change in native wetland plant and animal assemblages
- Degree of connectivity with other aquatic resources and upland habitats
- Amount of intact or functional riparian vegetation along streams and rivers

As explained in Section 1 of Volume IA, the guidebook is advisory, is intended only for assessing wetland functions and values, and has no effect on jurisdictional status of any wetlands. The guidebook's methods may be applied to all or part of a wetland. The guidebook is intended for use in assessing proposals for wetland alteration, compensatory mitigation projects (including mitigation banks), restoration projects, proposed acquisitions, and for resource planning at the city, county, watershed, and state levels. These volumes of the guidebook supercede all previous draft reports of the OWRA project.

1.3 Developing the Willamette Valley HGM Guidebook

The National Action Plan describes major tasks required for developing regional HGM guidebooks. That Plan, outlined below, was followed when developing this guidebook:

> *1. Identify and define functions associated with each wetland class. Review and summarize literature, databases, and scientific opinion on functions of regional wetlands, and indicators and methods that address those functions.* Such a "profile" was drafted at a statewide scale in July 1998. The completed version is titled, "Guidebook for Hydrogeomorphic (HGM)-Based Assessment of Oregon Wetland and Riparian Sites: Statewide Classification and Profiles" (Adamus 2001b).
>
> *2. Identify and define regional subclasses of the classes of wetlands described at a national level* (by Brinson 1993). This was completed simultaneously with (1), in July 1998.
>
> *3. Prioritize subclasses and ecoregions for development of methods for assessing functions.* The OWRA project's Policy Advisory Committee met in August 1998 and recommended that methods first be developed for the riverine impounding and slope/flats subclasses in the Willamette Valley ecoregion.
>
> *4. Identify reference wetland sites***.** An initial reconnaissance of the sites in the target region was completed in December 1998. Additional sites were identified just before the Fall 1999 and Summer 2000 field seasons.
>
> *5. Identify and define indicators and construct assessment models.* This was done during (1) and also during two DSL-sponsored workshops of regional scientists in July 1999.
>
> *6. Collect data from reference sites and identify reference standard (least-altered) sites.* This was done during Fall 1999 and Summer 2000 by two assessment teams organized for that purpose. Participants in the 1999 field effort endorsed the initial selection of reference standard sites in February 2000.
>
> *7. Calibrate assessment models using reference site data.* The calibrated models are presented in Volume IA (Adamus & Field 2001).
>
> *8. Verify and validate the assessment models.* The consistency (repeatability) of the methods was examined at three sites in Summer 2000, and additional verification efforts

are planned. True validation of the models is impossible without major long-term financial commitments.

The manner in which these tasks were implemented is described in following sections, which generally parallel the above:

Section 2. Development of the Classification
Section 3. Selection of Reference Sites
Section 4. Development of Assessment Protocols
Section 5. Collection of Reference Data
Section 6. Calibration of Scoring Models
Section 7. Verification of Consistency

Although a method for assessing *values* is part of the Willamette Valley guidebook (Volume 1A, Section 4), no value assessments (valuations) were conducted at any reference sites. This is because the valuation method is purely qualitative, and thus has no indicators or scoring models which require calibration. For the same reasons, the Judgmental Method for assessing functions as described in Appendix B of Volume 1A was not applied to the reference sites.

Section 2. Developing the Classification

Before developing a subclassification suitable for Oregon wetland/riparian sites, the following assumptions were made:

- One should begin with the seven major HGM classes developed nationally, consider their applicability to Oregon, and then define subclasses in a manner consistent with published guidance from federal agencies
- 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 available data;
- 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 that are hierarchical in terms both of geographic scale and effort.

A large number of previously-developed schemes for classifying wetland and riparian systems, especially in the Pacific Northwest, were first reviewed. Subsequently, the following HGM classes and subclasses applicable to the Willamette Valley ecoregion were proposed:

Riverine:
- Riverine Flow-through
- Riverine Impounding

Slope/Flats[1]:
- Headwater Slope
- Valley Flats

Lacustrine Fringe
- Valley

Depressional
- Closed Permanently Flooded
- Closed Nonpermanently Flooded
- Outflow

These are defined in the accompanying "Statewide Classification and Profiles" volume (Adamus 2001b), which also contains a review of existing classification methods with emphasis on the Pacific Northwest. That document also (a) describes the rationale for using hydrogeomorphic rather than vegetation classes as a basis for function assessment, (b) suggests subclasses appropriate to other ecoregions within Oregon, and (c) addresses some policy and technical issues associated with developing regional subclasses.

Riverine impounding sites. The one on the left was created by impounding water from an agricultural diversion ditch to improve waterfowl habitat. The one on the right is located in a city park and is mowed regularly.

In August 1998 the OWRA project Policy Advisory Committee met and recommended that, for the Willamette Valley, HGM-based assessment methods first be developed for Riverine Impounding and Valley Slope subclasses. However, while conducting a reconnaissance of potential reference sites during Fall 1998, it became apparent that many Valley Slope and Flat sites could not be distinguished without making detailed hydrologic measurements, which were not feasible, so these were combined into a "Slope/Flat" subclass, as shown above. The SF subclass includes ash swales, vernal pools, wet prairies, foothill springs, and many farmed

[1] In this guidebook pertaining to the Willamette Valley, we have combined the slope and flats HGM classes recognized at a national level because it was not possible to distinguish these classes at many of the reference sites. We have termed this joint classification -- slope/flats – a subclass rather than a class because it does not correspond exactly to the national list of HGM classes.

wetlands – sites that seldom (or less than once every two years) inundated by flow from a channel, but rather are fed by precipitation, runoff, groundwater, and lateral flow. These SF sites seldom contain recognizable channels. They often do not have surface outlets to other surface waters and many are thus considered "isolated" – although subsurface connections sometimes exist. They may be situated in sloping or flat terrain. In contrast, the RI subclass encompasses riverine sloughs, alcoves, cutoff oxbows, beaver ponds, stream-fed ponds (natural or excavated) with outlet control structures, and other stagnant-water areas that are inundated at least once every two years (and in some cases permanently) by water from a channel.

Section 3. Selecting Reference Sites

The term "reference site" has been used in a variety of ways by scientists and planners. As used in the HGM approach, reference sites are wetland and riparian sites that, together, encompass the variability of a regional wetland subclass. They may be used as standards to compare impacts among proposed alternatives, and to determine whether the level or severity of the preferred alternative is significant, whether a proposed mitigation project would effectively compensate for the impact, and whether the mitigation, once in place, has actually compensated for the impact (Brinson and Rheinhardt 1996).

At the outset it is vital to recognize that in the HGM approach (Smith et al. 1995), the term **reference site** is defined much more inclusively than its popular scientific connotation (e.g., Hughes et al. 1986, Warry and Hanau 1993, Omernik 1995). In the HGM Approach (Smith et al. 1995) the term reference site does not include only sites that are the "least disturbed," "highest functioning across a suite of functions" or "most representative of a particular wetland or riparian subclass." Instead, **reference site is defined to include all sites of a specified wetland/ riparian subclass within a specified ecoregion that will be assessed for purposes of calibrating models of wetland/riparian function**. The HGM Approach uses another term – **reference standard site** – that better fits the conventional definition of reference sites, i.e., the least-disturbed of all regional sites in the subclass. In the OWRA project, both reference sites and reference standard sites (which we also called **least-altered sites**) were selected.

3.1 Concepts for Selecting Reference Sites

The process by which reference sites are chosen is crucial because it ultimately defines the range of variation used to calibrate models of wetland/riparian function. As Brinson and Reinhardt (1996) note:

> … reference sites should be chosen, for the purposes of functional assessment, to encompass the known variation of a group or class of wetlands, including both natural and disturbance-mediated variations.

However, for any given group or class of wetlands there is considerable uncertainty regarding which, of the many variables that influence wetland/riparian function, should be used to predefine the "variation of …natural and human-related factors" (and thus be used to select reference sites) within a particular HGM subclass. Even if there was agreement as to which variable(s) to use, real estimates of the variation seldom exist in most regions. Consequently, investigators must make assumptions regarding the relative levels of the variables at individual sites that are candidates for inclusion as reference sites.

Although scenic, this riverine impounding site has been severely altered and has low capacity for most ecological functions.

Another important consideration is the number of chosen reference sites that will be sufficient to encompass the variation. No objective standards or procedures have been promulgated for defining what constitutes a sufficient sample of regional wetlands. Due to the large number of variables that can influence functions within a particular HGM subclass, traditional measures for recommending sample size (e.g., species accumulation curves, cluster analyses, and statistical power analyses) are likely to recommend sample sizes (numbers of reference sites) far in excess of what can practically be assessed. Moreover, such analyses often require the existence of large initial data sets before the site selection process can even begin. Thus, the few other states that have developed HGM procedures have instead relied on professional intuition in estimating the number of reference sites sufficient for capturing variation to an acceptable level. Most commonly, investigators have identified between 30 and 50 sites per HGM subclass per ecoregion for use in calibrating HGM models (e.g., Brinson et al. 1996, Hruby et al. 1999, Whigham et al. 1999). However, no published statistical analyses have demonstrated the sufficiency of this sampling intensity. This range of sampling intensity (per HGM subclass) typically has been used in development of HGM models in regions much larger than the

Willamette Valley. To calibrate this guidebook's methods in the Willamette Valley, we used 54 and 55 sites per HGM subclass.

Little precedent existed for selecting sets of reference wetland/riparian sites throughout the entire Willamette Valley. In the late 1980's and again in 1993, the USEPA Wetlands Research Program used a stratified random procedure based on land cover and National Wetlands Inventory (NWI) maps to select and sample a series of about 50 small palustrine emergent, naturally-occurring, wetlands located exclusively in the Portland Metropolitan area, for comparison with constructed wetlands there (Abbruzzese et al. 1987). In 1990 and 1991, another team of wetland scientists in the same geographic area surveyed plants and vertebrates in 215 wetlands (Poracsky et al. 1992) but they did not specifically use their data to identify a set of reference sites. In 1992 Alverson (1993) selected and sampled 9 wetland sites in the West Eugene area in order to quantify "reference conditions," with the goal of ultimately developing performance criteria for constructed/restored wetlands in that part of the Willamette Valley ecoregion.

In 1995-96, Titus et al. (1996) conducted botanical surveys in 172 wetland and riparian sites throughout the Willamette Valley. Survey sites were selected based on their anticipated likelihood of being of high botanical quality. From their data, Titus et al. identified and mapped 21 sites they felt best represented "high-quality remnants" of native plant communities:

> Benton County: Bull Run Cr. between Fern Rd. & Peterson Rd., Jackson-Frazier County Park, Finley National Wildlife Refuge and Muddy Cr.; Polk County: Luckiamute R. and Santiam Bar; Lane County: Buford Park, Willow Creek TNC Preserve, Long Tom River north of Fern Ridge Reservoir; Linn County: Bowers Rock State Park, Calapooia R., Courtney Cr. mudflats, Kingston Prairie TNC Preserve; N. Santiam R. at Geren Is.; Marion County: Grand Island area; Clackamas County: Peach Cove Bog, Molalla River State Park, McIver & Bonnie Lure State Parks, Mosier Cr.; Washington County: Banks Swamp.

In 1997, Eilers et al. (1998) used digital land cover data to systematically identify five general "habitat landscapes" in the west-central Willamette Valley, and then proposed "wetland candidate monitoring sites" in each landscape. The 14 proposed sites are quite locationally broad, include presumably least-disturbed and highly-disturbed sites, and were not stratified by HGM class. Half are in private ownership, and none have been subsequently monitored as part of any regionwide monitoring or model development program. The proposed sites are:

> Springfield urban wetlands, Marys River West Fork grazed wetlands, E.E. Wilson Wildlife Area wetlands (north & south), Ankeny Hill wetlands (north & south), Finley Wildlife Refuge wetlands, Luckiamute headwater wetlands, farmed wetlands near Cheshire, Bull Run Creek partially farmed wetlands, wetlands below Fern Ridge Reservoir, partially grazed Coyote Creek wetlands, and Long Tom Watershed wetlands near Veneta and Fern Ridge.

In 1999, Dykaar (2000) selected and assessed 9 riparian sites in the upper Willamette and McKenzie River watersheds which he considered to be the least disrupted by human activities. All his sites consist of a complex of riverine flow-through and riverine impounding subclasses. Along transects, he made single-visit observations of habitat type diversity, inundation duration, side channel connections, disturbances from humans, flow disruption, offsite riprap and mining, and adaptedness of the site to its current hydrologic regime. He then proposed a scoring model to combine these into a "hydrogeomorphic index."

Other sites sampled by wetland researchers in the Willamette Valley now and in the future could also be added to the database of reference sites assessed by this project.

3.2 Process Used for Selecting Reference Sites

The process used for identifying Willamette Valley reference sites in the two HGM subclasses was as follows. First, in consultation with the project advisory committee, I selected candidate reference sites just from public and Nature Conservancy (TNC) or Wetlands Conservancy (WC) lands, including sites on private lands only when I or persons known to me knew the landowner. The reasons for this decision are (a) this limits the number of sites to be screened from many thousand to fewer than 100 per HGM subclass, making site selection with limited resources feasible, (b) the extremely time-consuming process of identifying and contacting private landowners to request access permission is avoided, and (c) future access to the public sites, while not guaranteed, is less likely to change than access to private sites – this is an important consideration if DSL or other agencies ever wish to revisit the sites to improve the HGM models, calibrate other assessment models, or estimate temporal change.

Although it is often hypothesized that sites on public lands are "less disturbed" and thus not representative of all of a region's wetland/riparian sites, the assessments in 1999 and 2000 identified a number of public sites that are farmed, logged, excavated, surrounded by urban development, and even recently filled. Because the HGM model development process does not, for good reason, require proportional or random sampling, the number of publicly-owned disturbed sites that were assessed should have been sufficient to define the "disturbed" as well as the more natural end of the gradient of human influence.

Next, I visited as many parks and other public/TNC/WC lands as time allowed, covering all parts of the Willamette Valley ecoregion. This resulted in the identification of close to 150 candidate reference sites for possible future use in model calibration. The only public lands in the region that I did not attempt to visit were units that showed little likelihood of having wetland or riparian habitat, based on NWI maps (1:24,000 scale, early 1980s photography) and topographic maps, or that were more than 0.5 mile from a road. I located candidate sites mainly from (a) TNC and WC listings, (b) maps of the Willamette River Greenway, and (c) a USGS database containing park name, latitude and longitude. I then plotted potential sites on NWI maps. To help prioritize the reconnaissance efforts and to help insure more complete consideration of sites, I also reviewed previous lists of sites (see section 3.1 above) and visited many wetland experts in the region, asking them to nominate sites on public lands. I received nominations from 20 experts.

The process of systematically identifying suitable reference sites relied heavily on suggestions of sites from local experts, on review of available hard-copy maps, and on impressions gained during reconnaissance visits. Alternatively, a Geographic Information System (GIS) could have been used to facilitate the process. For example, digital land use and wetland data could have been used to provide more consistent and quantitative estimates of surrounding land uses and seral stages, thus augmenting site observations and allowing for more refined and perhaps more accurate assignments of "condition" classes (A, B, C, etc.) to individual sites. Digital soils information could have been used to identify sites with hydric soils located on public lands, thus uncovering some wetlands that possibly were missed during the 1998 field visits. And a more comprehensive digital portrayal of land ownership/management could have been used. In future regional HGM efforts, careful consideration should be given to expanded use of GIS technology for selection and preliminary characterization of candidate reference sites, as time and resources allow.

Due to time and budget constraints, the initial reconnaissance visit to each site generally lasted only from 10 (small sites) to 30 (large sites) minutes. The primary objectives were to (a) determine if the mapped wetland/riparian sites were indeed present, (b) tentatively assign spatial units within the sites to various HGM subclasses, and (c) assess the potential influences of humans on the site by visually estimating the type and proximity of surrounding land uses, type and extent of invasive flora, tree size, seral stage, and obvious physical characteristics, e.g., dams, berms, ditches. Secondarily, I photographed most of the sites. All public and TNC-owned wetland sites identified by Titus et al. (1996) or Eilers et al. (1998) were visited during this reconnaissance phase.

The reconnaissance visits eliminated several sites that, upon inspection, were found to better fit HGM subclasses other than the two target ones. The final number of reference sites selected was 109. This included 54 reference sites in the Riverine Impounding (RI) subclass and 55 in the Slope/flats (SF) subclass. These are believed to comprise nearly all the sites belonging to the RI and SF subclasses on public lands within Willamette Valley, with the exception of many extensive wetlands owned or leased by the U.S. Fish and Wildlife Service. An administrator responsible for such public lands absolutely refused us access for the purpose of collecting data that might be used as a reference point for judging the health of other Willamette Valley wetlands.

3.3 Highlights of the Reference Sites

Of the 109 reference sites we assessed, 79 (72%) are publicly managed, 8 (7%) are managed by non-profit conservation organizations, and 22 (20%) are managed by private landowners who granted us access (Table 1). ***Inclusion of a site in this report does not mean access is necessarily available to the public in the future.*** Always check first before entering any private lands.

Geographically, the sites span the region but there are clusters near Portland, Salem, Corvallis, and West Eugene. Most sites are on or near the valley floor – the farthest west being one in the McDonald State Forest (Corvallis) and the farthest east being two near Scio. Of the 54 RI sites, 23 are flooded at least biennially by the Willamette River, 3 by the Tualatin River, 2 by the Calapooia River, 2 by the Muddy River, and the remaining 45% by an assortment of smaller channels. Size distributions are shown in Figure 1. The sites encompassed the range of vegetation age, with 33% of the RI sites and 25% of the SF sites being predominantly wooded. Restored, “enhanced,” and constructed wetlands of various ages were included because these are becoming a prominent feature in the Willamette Valley landscape. Approximately 23 RI sites and 23 SF sites had evidence of previous earth-shaping or hydrologic modification typically associated with such projects.

Table 1. Reference sites whose functions were assessed

Inclusion of a site in this report does not mean access is necessarily available to the public in the future.
Abbreviations: RI = riverine impounding, SF= slope/flat; PR= private, Pu= public, NG= non-profit organization.

Sub-class	Site Name	Least-altered	Year	Area (acres)	Manage-ment	Mapped Soil	Mapped Soil is Hydric	Latitude (N)	Longitude (W)
RI	Adair pond		2000	1.63	PR	Waldo	X	44.6772	123.2109
RI	Alton Baker Park slough		1999	0.90	Pu	Newberg		44.0570	123.0740
RI	Anderson Park alcove	X	2000	6.44	Pu	Fluvents		44.3399	123.2360
RI	Anderson Park sloughs		1999	5.83	Pu	Fluvents		44.3415	123.2381
RI	Bowers Rock slough		1999	4.30	Pu	McBee		44.6339	123.1391
RI	Brown's Ferry pond		1999	2.60	Pu	Cove	X	45.3835	122.7358
RI	Brownsville constructed		1999	0.50	PR	Courtney	X	44.3661	122.9850
RI	Buford West slough		1999	4.40	Pu	Pengra	X	44.0023	122.9787
RI	Calapooia River 1		2000	1.32	PR	Fluvents		44.6327	123.1275
RI	Calapooia River 2		2000	20.18	PR	McBee		44.5326	123.1429
RI	Cascades Gateway slough		1999	12.00	Pu	Courtney	X	44.9148	122.9912
RI	Christensen Park slough		1999	4.70	Pu	Fluvents		44.1923	123.1446
RI	Coffin Butte pond		1999	1.90	PR	Waldo	X	44.7007	123.2228
RI	Cook Park slough		1999	1.50	Pu	Fluvents		45.3953	122.7698
RI	Coyote floodplain		2000	6.27	PR	Natroy	X	44.0209	123.2547
RI	Delta Ponds		1999	22.00	Pu	Newberg		44.0724	123.1117
RI	Fanno Creek duck donut		1999	1.90	Pu	Cove	X	45.4672	122.7890
RI	Finley floodplain	X	1999	18.00	Pu	Bashaw	X	44.4224	123.3202
RI	Gibson Creek enhanced slough		2000	1.22	Pu	McAlpin		44.9724	123.0807
RI	Grand Island slough		1999	9.00	Pu	Newberg		45.1072	123.0124
RI	Greenberry floodplain		2000	32.19	PR	Dayton	X	44.4621	123.3190
RI	Hedges Creek duck ponds		1999	0.30	Pu	Cove	X	45.3854	122.7626
RI	Hileman Park alcove		1999	0.10	Pu	Fluvents		44.1430	123.1239
RI	Hileman Park slough		1999	0.90	Pu	Fluvents		44.1391	123.1246
RI	Jackson-Frazier floodplain	X	1999	77.00	Pu	Bashaw	X	44.6077	123.2357
RI	Jasper Park slough		1999	2.00	Pu	Cloquato		43.9897	122.9034
RI	McDonald Forest ponds	X	2000	1.70	Pu	Price-Rittner		44.6384	123.3127

Sub-class	Site Name	Least-altered	Year	Area (acres)	Manage-ment	Mapped Soil	Mapped Soil is Hydric	Latitude (N)	Longitude (W)
RI	Minto-Brown big slough		2000	48.20	Pu	Wapato	X	44.9227	123.0746
RI	Minto-Brown slough 1		1999	6.70	Pu	Wapato	X	44.9196	123.0610
RI	Minto-Brown slough 2		1999	8.40	Pu	Wapato	X	44.9295	123.0571
RI	Mt.View enhanced slough		2000	2.80	PR	Waldo	X	44.6269	123.2289
RI	Oaks Bottom backwater		1999	88.00	Pu	Rafton	X	45.4775	122.6544
RI	Philomath Park slough		2000	1.42	Pu	Coburg		44.5367	123.3733
RI	Scio pond		1999	1.20	PR	Bashaw	X	44.6203	122.8427
RI	Shooting range pond		2000	0.10	Pu	Woodburn		44.7105	123.2660
RI	Snagboat Bend slough		2000	21.84	Pu	Newberg		44.4295	123.2111
RI	Spongs Landing slough	X	2000	26.00	Pu	Wapato	X	45.0150	123.0679
RI	Stayton Interchange restored		1999	7.50	Pu	Waldo	X	44.8154	122.7911
RI	Summerlake Park pond		2000	1.43	Pu	Cove	X	45.4382	122.8052
RI	Takena Park sloughs		2000	17.40	Pu	Newberg		44.6440	123.0895
RI	Timber-Linn pond		2000	9.35	Pu	Conser	X	44.6384	123.0536
RI	Truax gravelpit restoration		2000	0.76	Pu	Newberg		44.5824	123.1907
RI	Truax slough		2000	4.02	Pu	Wapato	X	44.5854	123.1829
RI	Tualatin Hills Big Pond		1999	1.60	Pu	Cove	X	45.4983	122.8461
RI	Tualatin Hills Lily Pond	X	1999	0.40	Pu	Cove	X	45.5011	122.8486
RI	Tualatin NWR beaverdam		2000	0.10	Pu	Quatama		45.3695	122.8282
RI	Tualatin NWR Chicken Cr.		2000	62.91	Pu	McBee		45.3843	122.8377
RI	Whitley Landing floodplain		1999	0.20	Pu	Fluvents		44.1164	123.1074
RI	Willamette Mission slough		1999	87.00	Pu	Wapato	X	45.0778	123.0502
RI	Willamette Park slough		2000	2.13	Pu	Fluvents		44.5461	123.2441
RI	Willow Creek riverine	X	1999	3.40	NG	Natroy	X	44.0364	123.1722
RI	Wilson Wildlife Area main pond		1999	7.60	Pu	Dayton	X	44.7070	123.2094
RI	Wilson Wildlife Area north pond		2000	13.24	Pu	Dayton	X	44.7190	123.2178
SF	Adair Park woods		2000	2.78	Pu	Dayton	X	44.6753	123.2085
SF	Adair pasture slope		2000	0.14	PR	Concord	X	44.6775	123.2177
SF	Albany powerline		2000	6.57	PR	Amity	X	44.6019	123.0814
SF	Aumsville slope		2000	13.82	PR	Waldo	X	44.8536	122.8543
SF	Balboa restored		1999	74.00	Pu	Natroy	X	44.0545	123.1804
SF	Bald Hill Park pond		1999	0.60	Pu	Bashaw	X	44.5738	123.3248

Sub-class	Site Name	Least-altered	Year	Area (acres)	Manage-ment	Mapped Soil	Mapped Soil is Hydric	Latitude (N)	Longitude (W)
SF	Beggars-tick marsh		1999	16.00	Pu	Wapato	X	45.4798	122.5493
SF	Brown's Ferry forest		1999	1.00	Pu	McBee		45.3834	122.7335
SF	Buford East hillslope	X	1999	13.00	Pu	Panther	X	43.9930	122.9429
SF	Champoeg Park flat		2000	4.29	Pu	Wapato	X	45.2532	122.8900
SF	Champoeg Park woods		2000	1.97	Pu	Wapato	X	44.2530	122.8961
SF	Cheyenne Way flat		2000	1.11	PR	McBee		45.3942	122.7751
SF	Coffin Butte flat		2000	2.59	PR	Waldo	X	44.6991	123.2222
SF	Coffin Butte upslope		2000	4.59	PR	Waldo	X	44.6981	123.2222
SF	Cook Park restored		1999	14.00	Pu	Cove	X	45.3987	122.7707
SF	Corvallis Airport flat		2000	27.24	Pu	Dayton	X	44.5039	123.2769
SF	Coyote Creek meadow		2000	0.89	Pu	Natroy	X	44.0465	123.2674
SF	Coyote Creek woods		2000	3.53	Pu	Natroy	X	44.0474	123.2672
SF	Dimple Hill seep		2000	0.99	Pu	Dixonville		44.5785	123.3724
SF	Ferry Street flat		2000	1.23	PR	Dayton	X	44.6171	123.1024
SF	Finley ash swale		2000	0.24	Pu	Hazelair		44.4147	123.3409
SF	Finley prairie	X	1999	233.00	Pu	Dayton	X	44.4192	123.3026
SF	Finley slope pond		2000	0.23	Pu	Bellpine		44.4152	123.3396
SF	Fisher Butte prairie	X	1999	68.00	Pu	Natroy	X	44.0557	123.2516
SF	Frazier-Cogswell forest	X	1999	34.00	NG	Conser	X	44.3346	123.1243
SF	Greenhill Road prairie		1999	43.00	Pu	Dayton	X	44.0601	123.2118
SF	Hunziker Road flat		2000	3.45	NG	Verboort	X	45.4302	122.7595
SF	Hyland Park pond		2000	0.78	Pu	Dayton	X	45.4621	122.8166
SF	Jackson-Frazier prairie	X	1999	18.00	Pu	Bashaw	X	44.6060	123.2395
SF	Jefferson pasture		2000	0.38	PR	Coburg		44.7048	123.0297
SF	Lebanon ODOT		2000	18.82	Pu	Whiteson	X	44.5522	123.0072
SF	Luckiamute floodplain		1999	10.00	Pu	Wapato	X	44.7398	123.1455
SF	Marion bank flat		2000	5.28	PR	Courtney	X	44.7597	122.9107
SF	Marion bank pond		2000	0.11	PR	Clackamas		44.7637	122.9094
SF	Marys River flat		2000	0.14	Pu	Conser	X	44.5421	123.2830
SF	Nimbus Drive slope		2000	1.69	Pu	Cove	X	45.4467	122.7915
SF	Oak Creek restoration		1999	53.00	PR	Dayton	X	44.4982	122.8974
SF	OSU Pasture forest		1999	2.60	NG	Bashaw	X	44.5743	123.3060
SF	OSU Pasture slope		1999	0.40	NG	Hazelair		44.5757	123.3044
SF	Philomath Industrial slope	X	2000	5.07	Pu	Bashaw	X	44.5505	123.3615
SF	Philomath Park meadow		1999	7.10	Pu	Coburg		44.5494	123.3726
SF	Rickreall flat		2000	48.15	PR	Bashaw	X	44.9599	123.1976
SF	Scio pasture		1999	14.00	PR	Bashaw	X	44.6153	122.8428

Sub-class	Site Name	Least-altered	Year	Area (acres)	Manage-ment	Mapped Soil	Mapped Soil is Hydric	Latitude (N)	Longitude (W)
SF	Seavy prairie		1999	9.60	Pu	Dayton	X	44.5927	123.2387
SF	Sherwood seeps		1999	2.40	Pu	McBee		45.3576	122.8435
SF	Shooting range woods		2000	6.14	Pu	Waldo	X	44.7099	123.2631
SF	Stewart Ponds		1999	13.00	Pu	Natroy	X	44.0521	123.1553
SF	Tampico forest	X	1999	22.00	Pu	Waldo	X	44.6881	123.2444
SF	Tice Park seeps		1999	10.00	Pu	Cloquato		45.2287	123.1969
SF	Tualatin NWR Steinborn		2000	60.02	Pu	Cove	X	45.3853	122.8405
SF	Walnut Park slope		2000	9.09	Pu	Bashaw	X	44.5930	123.3139
SF	West Waluga seeps		1999	20.00	Pu	Cove	X	45.4117	122.7265
SF	Willow Cr. prairie & woods	X	1999	79.00	NG	Natroy	X	44.0362	123.1701
SF	Wilson Wildlife Area prairie		1999	0.50	Pu	Dayton	X	44.7039	123.2149
SF	Winsor flat		2000	x11	NG	Urban Land		45.4540	122.6089
SF	Zenger Farm flat		1999	5.90	NG	Urban Land		45.4789	122.5400

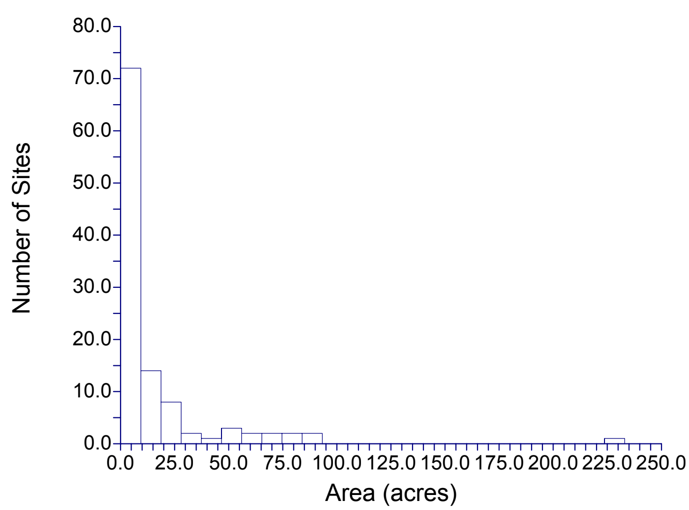

Figure 1. Size distribution of 109 Willamette Valley wetland/riparian reference sites

The overall locations of the 109 reference sites can be viewed on the CD-ROM accompanying this guidebook, and their names and geographic coordinates are given in Table 1. In addition, the CD includes enlarged USGS topographic maps of all sites. For 47 of the sites, the coordinates in Table 1 as well as coordinates of individual plots were determined to a precision of about 10 ft. using a Global Positioning System (GPS) during July 2000. The coordinates of the remainder of the sites were obtained by plotting and reading their position on fine-scale maps included in software produced by MapTech, Inc.

The reference sites encompass 11 of the 26 mapped soil series that are officially designated as hydric and occur in the Willamette Valley. Hydric soils not represented by our sites (at least not according to county soils maps) are Awbrig, Brenner, Delena, Faloma, Grande Ronde, Huberly, Labish, Minniece, Noti, Willanch, Wollent, and several non-hydric soils that often contain hydric inclusions. Some of these apparently unrepresented hydric soils were not included because they occur only at higher elevations in the region, or perhaps occur exclusively on inaccessible private land.

For users wishing more information on selected characteristics of the reference sites (data on 67 indicators of function and 320+ plant species), the databases on the CD-ROM can be imported into spreadsheets, sorted, and compiled. Of the 67 indicators of function, 23 (listed in Table 2) showed a statistically significant difference between RI and SF sites. This does not mean that one subclass functions "better" than the other.

Table 2. Comparison of 2 wetland/riparian subclasses using indicators of function

Columns are marked to indicate in which subclass the indicator was greater ($p<0.05$, Mann-Whitney test of difference in medians). This list contains only the indicators that differed significantly between subclasses.

Indicator (see Glossary in Volume IA for definitions)	**Greater in RI sites**	**Greater in SF sites**
Percent of site containing permanent surface water	●	
Percent of site that is inundated only seasonally	●	
Percent & distribution of pools (during high water, low water).	●	
Predominant vertical increase in surface water level	●	
Predominant depth category during biennial low water	●	
Percent in the 2-6 ft depth category during low water	●	
Presence of logs and/or boulders extending above the surface of permanent water	●	
Percent of seasonal zone that contains a closed canopy	●	
Percent shrub & vine cover in parts of the site that are inundated only seasonally	●	
Diameter of largest trees	●	
Number & distribution of vegetation forms	●	
Percent of woody cover within stratum that is comprised of non-native woody species	●	
Percent of woody species that are native.	●	
Number of woody species	●	
Number of kinds of dead wood	●	
Soil particle size	●	
Presence of hydric soils		●
Percent of surrounding land cover that contains water or wetlands	●	
Percent of site where soils are saturated but never inundated		●
Percent of site that is vegetated		●
Percent of site currently affected by mowing or extreme grazing		●
Percent of site affected by soil mixing, including plowing		●

3.4 Selecting Least Altered Sites

From the set of 109 reference sites we designated 7 RI sites and 8 SF sites as "least altered" (reference standard) sites. The numbers of "least altered" sites are similar to those used by HGM projects in other states. Data collected on the characteristics of these sites can provide a basis both for HGM assessment methods and for future design and monitoring of Willamette Valley restoration projects. As stated by Beschta (1997), reference standard sites (ideally) are:

> … relatively large and intact aquatic ecosystems that continue to function without the influence of anthropogenic impacts. They not only provide important examples of how hydrogeomorphic processes, geomorphic setting, and vegetation interact, but they also allow us an opportunity to understand and appreciate the interaction between disturbance regimes, plant communities, and aquatic habitats. As ecological benchmarks, reference sites provide an essential perspective of what degraded and riparian and aquatic ecosystems might become if the appropriate restoration activities are undertaken. …They also help predict the amount of time required for recovery.

However, from the very outset of the project it was apparent that even the "least altered" sites in the Willamette Valley have experienced significant impacts over the years, and for many, recovery is uncertain. Settlers in the mid-1800's drained thousands of acres of the region's wetland/riparian sites, beginning with wet prairie (Slope/flats subclass). Ditches were installed in prairies at intervals of 60-70 feet and by 1870, the first subsurface tile drains were being installed. Between 1937 and 1959, 376,000 acres were drained, and another 56,000 were drained between then and 1964. Drainage of Slope/flats sites by subsurface tile and other means has continued at a slower pace (Daggett et al. 1998, Bernert et al. 1999). Virtually all flatland soils were plowed at some time.

The mainstem Willamette River has been extensively straightened in order to make land available for farmland and development. For example, river channel lengths between Albany and Eugene have been reduced to 40-50% of their historical length (Benner and Sedell 1997). Many secondary side channels, backwater sloughs, midchannel bars, and oxbow lakes have been eliminated or isolated from biennial flooding by the river (Sedell and Froggatt 1984, Frenkel et al. 1993). Floodplains that once were flooded every 10 years may now be flooded only once every 100 (Benner and Sedell 1997). The concentration of flows into a single channel has increased the erosive power of the river, causing a degradation (lowering) of the channel relative to the elevation of the adjoining land (Klingeman 1973). This likely has dried up some of the remaining wetlands near the river, including many sites in the Riverine Impounding subclass, or has at least made their water levels less seasonally persistent. This trend of channel degradation may be lessening in recent years (Coulton et al. 1996). Farther south in the Valley, summer base flows are higher than historically, probably due to attenuated release from many headwater reservoirs constructed mostly during the 1940-1960 period (Coulton et al. 1996). The higher summer base flows might be sustaining water tables and wetlands near the river for a longer part of the growing season.

In the 1940s, low levees were constructed to separate floodplain wetlands (slough inlets and junctions with abandoned channels) from the main channel. The levees were constructed primarily to exclude floodwater from farmed wetlands, and were designed such that the floodplain wetlands would be flooded on the average no more often than once every two years (U.S. Army Corps of Engineers 1947). As a result many wetlands dried up or remain saturated for shorter parts of the growing season. Along the mainstem Willamette River, 24% of the banks that formerly were covered with vegetation (or in a few cases were bare) have been covered with rip-rapping rock for stabilization (Benner and Sedell 1997). At least 6% of the woodlands within the Willamette River Greenway were converted to other land cover types between 1972 and 1981 (Frenkel et al. 1985). However, at least along the upper Willamette, the total proportion of the floodplain that is vegetated has increased during the last 60 years, with a shift occurring away from a mosaic of bare area, herbs, and shrub cover toward more large contiguous patches of forest (Gutowsky & Jones 2000). Currently, even the seemingly least-altered sites are likely to be exposed to ecologically significant inputs of drifting pesticides and dust, as well as increasing disturbance from human visitors and invasions by non-native plants.

Given the fact that no pristine sites remain, one option is to try to reconstruct "reference standard conditions" from historical accounts (e.g., Pearl 1999). However, in this region there are no suitably old aerial photographs or data, at the scale of an individual site, that would allow quantification of such basic (to wetland function) factors as mean frequency and duration of flooding, patterns of interspersion of vegetation and water, and depth of inundation. Moreover, even if pristine sites were found in this region, it is unclear whether any would remain viable for long, due to indirect chronic impacts from widespread hydrologic alteration of the region's landscapes (Shaffer et al. 1999). Thus, this project has focused on assessing the least altered sites that could be found, while realizing that such sites may not represent full ecological potential.

Because natural vegetation has been removed, this riparian site no longer stabilizes sediments.
Photo courtesy of Tom Moser.

To select least-altered sites from the group of 109 reference sites, three factors were considered: (a) surrounding land uses, (b) within-site alterations, and (c) plant community (composition and dominance of non-native species, etc.). These factors were used because they are the most recognizable factors that logically define a "human influence gradient" in the Willamette Valley. Both the number and strength of factors that suggested good condition, and the absence of factors suggesting degraded condition, were considered when making the final selection of reference sites. As expected, even within their subclass the sites being proposed as Least Altered do not exclusively contain indicators of good condition (Appendix A). Primary factors used to disqualify sites as least-altered were: evidence that the site was constructed from upland or formerly belonged to a different HGM subclass (Gwin et al. 1999); evidence that the site is now wooded whereas historically (from 1850s General Land Office records) it probably was not; and evidence that more than 10% of the site has been affected by ditching, excavation, or artificial impoundment. Secondary factors used to eliminate sites as least-altered were: close proximity to a busy road; frequent visitation of a large part of the site by people on foot; relatively large percent of surrounding area comprised of cropland, lawns, pavement, and buildings; and relatively extensive cover of non-native herbs throughout the site. Positive selection factors included the extent of prairie microtopography (SF sites only) and/or a large number of types of dead wood (RI sites mostly). None of the secondary factors was sufficient cause to reject a site, but rather, selection/rejection was based on a "cumulative weight of evidence" approach. The final selection of least altered sites is indicated in Table 3.

Table 3. Willamette Valley sites selected as reference standards

These are the least altered sites that were accessible to us during this project.

Riverine Impounding subclass	Slope/flats subclass
Anderson Park alcove	Buford East hillslope
Finley floodplain	Finley prairie
Jackson-Frazier floodplain	Fisher Butte prairie
McDonald Forest ponds	Frazier-Cogswell forest
Spongs Landing slough	Jackson-Frazier prairie
Tualatin Hills Lily Pond	Philomath Industrial slope
Willow Creek riverine	Tampico forest
	Willow Creek prairie & woods

Section 4. Selecting Functions and Indicators

Functions are the ecosystem processes that wetlands and riparian sites normally do, such as intercepting runoff-borne sediment and helping it to settle. This guidebook highlights 13 functions (Table 4) but there are potentially dozens, depending partly on how one chooses to group or divide functions that are closely related. The particular functions considered by the guidebook are those believed most likely to occur in the RI and/or SF sites in the Willamette Valley ecoregion, and were limited to 13 partly to make the guidebook practical to use. Some functions were excluded because of their complexity and lack of suitable, rapidly-estimable indicators, e.g., the role of wetlands in recharging groundwater, and as sinks (vs. sources) for global carbon emissions. Other functions were excluded because they are always detrimental to other functions within a site, e.g., retention of heavy metals and toxic organic compounds. The 13 chosen functions, when acting at their naturally characteristic capacity, 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.

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	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 (RI sites only)	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 (RI sites only)	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 (RI sites only)	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

Function	Definition	Example of Quantification (but not quantified by this guidebook)	Associated Values
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
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 the Willamette Valley ecoregion.	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

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An initial set of indicators specific to each function were proposed based on the guidebook author's experience, as well as on reviews of (a) existing methods for assessing functions of wetland and riparian systems, (b) an EPA-sponsored interagency workshop on riparian indicators (Barker & Sackinger 2000), and (c) a review of Oregon wetland and riparian literature (Adamus 2001b). Indicators intentionally were not selected by using formal organizing frameworks such as conceptual models of ecosystem processes, because doing so would have been unnecessarily time-consuming and pretentious, given the paucity of good data. To be included, an indicator not only had to be relevant to a function, but also had to be estimable during a single half-day visit to a site at any season. This severe constraint is imposed by the very short legally-imposed deadlines agencies have for making decisions about applications for wetland alteration.

In July 1999, DSL hosted two workshops of regional wetland experts for the purpose of peer-reviewing the proposed indicators. Some indicators were added and others dropped based mainly on workshop discussions, and the workshop participants also made suggestions for formulating scoring models that combine the indicators into assessments of function. A second opportunity for input was provided in February 2000, when all persons who had been part of the assessment teams, as well as members of the project advisory committee, were invited to suggest any changes in the draft models and comment on the preliminary results from the 1999 field season. Table 5 shows the final list of indicators used.

Table 5. Indicators assessed and the functions to which they pertain

Symbols in last 2 columns: + = significantly greater at least-altered sites, - = significantly less at least-altered sites Blanks in these columns indicate that the difference between the least-altered and other sites was not statistically significant (p>0.05 for Mann-Whitney test for difference of medians).

Functions:

A= Amphibian & Turtle Habitat Support
AF= Anadromous Fish Habitat Support
BW= Breeding Waterbird Support
I= Invertebrate Habitat Support
N= Nitrogen Removal
PP= Primary Production
RF= Resident Fish Habitat Support
SB= Songbird Habitat Support
SS= Sediment Stabilization & Phosphorus Retention
T= Thermoregulation
V= Support of Characteristic Vegetation
WB= Wintering & Migratory Waterbirds
WS= Water Storage & Delay

Abbreviation (in database on CD-ROM)	**Indicator** (see Glossary in Appendix A of Volume IA for definitions and estimation protocols)	**Functions Applied To**	**At least-altered vs. other sites**	
			RI	**SF**
Area	Area of entire site (acres)	potentially all		+
AcPerm	Acreage of permanent water	RF,BW		
BareSeas%	Percent of seasonal zone that is bare during most of the dry season	SS,PP		
BuffCropG	Percent of land cover in 200 ft buffer zone that is grassland or cropland	WB		
BufCropGabc	Mean percent of land cover in 200, 1000, & 5280 ft buffer zones that is grassland or cropland	WB		
BuffGrass	Percent of land cover in 200-ft buffer zone that is grassland or wetland/water	SB		+
BufGrassAB	Mean percent of land cover in 200 & 1000 ft buffer zones that is grassland or wetland/water	SB		
BuffMix	Ratio of natural grass % to woodland % in 200-ft buffer zone	A		
BuffNat	Percent of land cover in 200-ft buffer zone that is “natural” (wooded or grass or wetland/water)	I,A,BW,V		
BufNatAB	Mean percent of land cover in 200 & 1000 ft buffer zones that is “natural” (wooded or grass or wetland/water)	I,A,BW,V	+	+
BuffWet	Percent of land cover in 200 ft buffer zone that is “water” or “wetland”	WB,BW	+	
BufWetABC	Mean percent of land cover in 200, 1000, & 5280 ft buffer zones that is “water” or “wetland”	WB,BW	-	
BuffWood	Percent of land cover in 200-ft buffer zone that is woodland (forested or shrubland or parkland)	SB	+	
BufWoodAB	Mean percent of land cover in 200 & 1000 ft buffer zones that is woodland (forested or shrubland or parkland)	SB	+	
Burned	Fire or harvest history	N		
Connec	Type of connection to other water bodies	T,AF,RF		
Create%	Percent of site created from upland	N,I,A,V		

Abbreviation (in database on CD-ROM)	**Indicator** (see Glossary in Appendix A of Volume IA for definitions and estimation protocols)	**Functions Applied To**	**At least-altered vs. other sites**	
			RI	**SF**
Deadwd	Number of kinds of dead wood	N,AF,A,SB,V	+	
DeepL	Percent in the 2-6 ft depth class during low water	RF		
Dep#Class	Number & evenness of depth category distributions during high water	BW,WB		
DepPre%L	Percent of site occupied by the most extensive depth category during biennial low water.	BW		
FCC%	Percent of site with closed-canopy woods (wooded sites only)	SB		+
FCC%Seas	Percent of seasonal zone with closed canopy	AF		
FishAcc	Accessible to anadromous fish	AF		
FluxMost	Difference between annual high & low predominating water levels	N,A,BW,WB		
H%Perm	Percent of permanent zone containing herbs	I,BW		
H%Seas	Herbs as % of seasonal zone	SS,A		
HcvNN	Relative spatial prevalence of non-native herbs	V	-	-
Hsp%NN	Percent of common herb species that are non-native	V		-
LevMaxL	Maximum water depth during low water	RF		-
LevMostL	Predominant depth class during low water	T,RF,BW,I		
LiveStor	Vertical increase in surface water level	WS		
Logs	Apparent presence of partly submerged logs & boulders	RF,AF,A		
Mow	Rating for mowing or extreme grazing	V		
Perm	Presence of permanent surface water	N,SB		
PermOpen%	Percent of permanent zone that lacks herbs	A		
Poolmix%H	Percent & distribution of pools during high water	SS,AF,A,BW		
Poolmix%L	Percent & distribution of pools during low water	SS,N,PP,I		
Puddle	Extent of puddles/ hummocks	SS,N,I,A,WB,SB		+
Redox	Presence of mottling &/or other features that indicate oxygen deficits in soils/ sediments	N		
RoadDis	Distance to nearest busy road	A,BW,SB,V		
Seas&P	Seasonal zone as percent of site in sites that also contain a permanent zone	I,WB		
Shade%P	Percent of permanent zone shaded by woody or aquatic plants*	T		
ShallowL	Percent in the 2-24 inch depth class during low water	I		
ShedNat%	Percent "natural" land cover in the contributing watershed within 200 ft. of the site	PP,I,RF,AF,A,V	+	
SoilComp	Percent of site currently affected by soil compaction	SS,N,PP,I,A,V	-	-
SoilHy	Mapped soil series is hydric (not simply a hydric inclusion)	I,A,WB,V		
SoilLev	Rating for soil leveling	SS,N,A,I		
Plow	Rating for soil mixing from plowing or other earth-moving	SS,SB,V		
SoilTex	Predominant texture of upper soil layer (particle size)	SS		-
SU%Seas	Understory shrub & vine cover as percent of seasonal zone (wooded sites only)	SS		+
SUcvsum	Percent understory shrub cover	SB		
TreeMaxD	Diameter of largest trees (wooded sites only)	N,A,SB,V		+
VegMixL	Number of vegetation forms & their distribution during low water	PP,I,SB,V		
VegPct	Percent vegetated (as viewed from above)	SB,V		
VegPre	Land cover in the vicinity of the site in 1800's	A,SB,V		
Vernal	Extent of vernal pools, mudflats or shorebird scrapes in shallow depressions	WB		

Abbreviation (in database on CD-ROM)	Indicator (see Glossary in Appendix A of Volume IA for definitions and estimation protocols)	Functions Applied To	At least-altered vs. other sites	
			RI	SF
Visits	Frequency of humans visiting on foot -- score on scale of 100 (most) to 500 (least)	BW,SB,V		
WdCv%NN	Percent of woody cover within stratum that is comprised of non-native species (greater of tree; understory shrub; or open shrub stratum)	V	-	
WdSp%Ntv	Percent of woody species that are native	V	+	
WdPct	Percent of site containing woody vegetation (as viewed from above)	SB		
WdNtvsp	Number of native woody plant species	V		
WdSpp	Number of woody plant species	SB		
WSfuncRI	Standardized score from assessment of Water Storage & Delay function in Riverine Impounding sites	SS		
WSfuncSF	Standardized score from assessment of Water Storage & Delay function in Slope/flats sites	SS		
ZoneP%	Percent of site in permanent zone	T		
ZoneSeas%	Seasonal zone as percent of total site	N,RF,WS		

Section 5. Collecting Reference Data

Selecting relevant indicators presents one challenge. Drafting protocols for estimating the indicators in a rapid and consistent (independently repeatable) manner is an ever greater challenge. A protocol for each indicator was initially developed, tested, and revised just before the 1999 field season. As expected, during the field work in 1999 many indicators were found to be too difficult to assess with confidence, relative to the amount of information gained. Simpler indicators were found to replace them, or their estimation protocols were modified, or they were dropped entirely. The final list of indicators used in the scoring models is given in Table 5.

To assess all 109 reference sites during two field seasons, two assessment teams in Fall 1999 and three in summer 2000 were required. Although the composition of the teams varied from day to day, the leader of each remained the same (leaders were Paul Adamus and Dana Field, plus Yvonne Vallette in 2000), and usually at least 3 people participated on each team on any date. Before the 1999 and 2000 field seasons, the leaders assessed a number of sites together in order to ensure consistency in interpreting instructions and estimating the indicators.

At each of the reference sites, an assessment team observed conditions of the indicators during a single visit, and recorded the information on a standard field form. A total of 66 indicators are used in the function scoring models, but many additional ones were assessed in order to properly identify sites that were least altered. At the time of year when sites were assessed, water levels were close to their annual minimum and some small plants were senescing (wilted and not obvious). In order to remain faithful to the requirement that this method be rapid, only the more common plants were identified at each site. Thus the data should not be treated as being a comprehensive botanical survey. See Section 8.2 (p. 31) for further discussion of this.

After all sites had been visited, data from field sheets were entered into an electronic database. Initial analyses of data were performed using Excel, PC-ORD, and NCSS software programs on a PC. When raw data for the indicators were analyzed, ***the analysis demonstrated a statistically***

significant difference between sites designated as least-altered and the other sites with regard to many indicators, as should be the case if the least-altered sites are to be used as the standard for calibrating the models of function.

Section 6. Calibrating Scoring Models

Estimates of various indicators (or variables) typically have disparate scales, e.g., one indicator expressed in units of feet, another as number of species, another as a percent. If these indicators are to be combined mathematically in scoring models that represent function capacity, their units must first be standardized to a common scale, i.e., "scaled." With the HGM Approach, an ordinal 0-to-1 scale is recommended for scaling each indicator (Smith et al. 1995). However, there is no consensus among wetland scientists as to whether the "1" should represent the condition present in least altered sites, or the condition believed to be most indicative of high levels of the function and present at many sites belonging to the target subclass, even if those sites are not perceived as being the least altered.

In this guidebook, conditions at the least altered sites were used *generally* as a guide for scaling each indicator. However, these conditions were not treated as inviolate standards primarily because (a) none of the least altered sites appeared to be in pristine condition, and (b) there was considerable variability among the least altered sites, confounding attempts to define specific numeric thresholds for distinguishing higher from lower functioning levels. Therefore, knowledge of conditions expected to be associated with naturally high levels of each function was also considered when scaling the indicators, provided such conditions were found in at least *some* of the least altered sites. Using this hybrid approach of considering both conditions found at least altered sites and conditions expected to indicate high function capacity, a scoring range (scale) was established for each indicator. This was done only after all sites had been assessed, at the end of the 2000 field season. For example, for the indicator, "Number of types of dead wood," the scale was set as follows:

0 types (no dead wood)	= 0
1-2 types	=.1
3-5 types	=.25
6-8 types	=.5
9-10 types	=.75
11-12 types	= 1.0

On one hand, the variety of dead wood types is expected to indicate sites that have relatively high capacity for several functions, e.g., amphibian habitat, songbird habitat. On the other hand, although the 7 RI sites designated as least altered had (as expected) a statistically greater variety of dead wood types than the other sites, the number of dead wood types varied greatly among the least-altered sites (between 2 and 12 types, with a median of 8). Rather than use the low end of this range as the reference standard, the high end was used because of its anticipated positive relationship to these functions.

The choice of a particular width for the intervals in an indicator's scale (e.g., whether each additional type of deadwood should add 0.1, 0.4, or whatever to the score) is subjective. For example, in the HGM models applied by Whigham et al. (1999), users are required to pick from only four choices for each indicator's scale:

0 = absence of the indicator with no potential for recovery
.1 = complete or near-complete absence of the indicator but with potential for recovery
.5 = significant deflection from conditions at least-altered sites

1.0 = conditions at least-altered sites

Unlike Whigham's models, this guidebook attaches no particular meaning to a particular score or interval of an indicator, and users are not asked to subjectively assess the "potential for recovery." Nonetheless, scales were established such that for most indicators, the median value calculated from all *least-altered* sites in that subclass would generally have an equivalent ordinal score of at least 0.5. Also, wide intervals (e.g., intervals >0.3) were generally used when estimation error for the particular indicator was expected to be especially great. Thus, users should not be too concerned about a seemingly large degree of imprecision and uncertainty when they estimate some indicator conditions, because the use of wide intervals (e.g., "multiple choice" responses) when assigning the standardized indicator scores compensates somewhat for that imprecision.

The scoring models themselves mostly use *addition* to combine the indicators. *Multiplication* is occasionally used when indicators are actually variables that have a controlling effect on the function. *Averaging* is used when several indicators are likely to be redundant, correlated, or are partly compensating. Averaging is especially used when data are likely to be missing or of poor quality for at least one indicator.

After these guidelines were applied to establish scoring ranges and thresholds for each indicator, all the raw data were converted to the specified ordinal values, inserted in the scoring models, and calculations necessary to compute function scores of each site were made. Although scores for different functions are not meant to be combined, results are easier to understand if all the function scores (as well as the indicators) are standardized to a scale having a maximum value of "1." There are three ways to accomplish this. One would involve dividing a site's score from a model of a particular function by the maximum score attainable from combining the model's indicators. For example, if a particular model contains 5 indicators, and the model specifies combination by simple addition, the maximum score from adding the standardized indicators would be 5. This approach was not used because there are no assurances that sites ever really existed which contain perfect conditions for every indicator. A second approach involves dividing a site's function score by the maximum score for that function calculated among all sites (Hruby et al. 1999). This is calibration according to a "highest functioning standard." A third approach involves dividing a function score by the maximum score for that function found among just the least-altered reference sites. This is calibration according to the "least altered standard." For this guidebook, *both* the "highest functioning standard" and the "least altered standard" were applied, separately, to the model outputs from each site. A comparison of the resulting scores using the three approaches found no statistically significant difference, suggesting that, at least with this assemblage of sites, it doesn't matter much whether users standardize the function scores by the "highest functioning" or "least altered" standard – as long as one approach is used consistently. Using the "highest function standard" as the basis for calibration, the function scores of all sites were standardized. Scores are given by function and site in Appendix C of Volume IA, and their distribution is portrayed in Appendix E of this volume (IB).

After standardizing the function scores of all sites, a comparison was made, within each subclass, between the standardized function scores of the least altered sites and the same scores from the other (more disturbed) sites. Results are shown in Table 6. It is evident from this table that, for 5-6 of the 13 functions, the ***least altered sites in each of the two subclasses had significantly higher levels of function than the other sites***. For the remaining functions, there was no statistically clear separation of least altered sites based on modeled function. One would not necessarily expect least altered sites to be better than altered sites for *all* functions, because rarely are all functions performed at high levels in a single site or among a small group of sites. Tables 7 and 8 show the correlations that were found among functions in RI and SF sites, respectively.

Table 6. Comparison of means of standardized function scores, least-altered vs. other sites

Numbers in this table are the means of the scores of the sites, standardized to a 0-1 scale within each subclass and function. The p-values that are less than .05 indicate situations where scores of least-altered sites were significantly greater than those of the other sites for that function, based on Mann-Whitney U test of difference in medians.

	Riverine Impounding sites			**Slope-Flat sites**		
Functions:	Least-altered (n = 7)	Others (n = 47)	p-value*	Least-altered (n = 8)	Others (n = 47)	p-value*
Water Storage & Delay	.40±.12	.42±.04	.5516	.19±.04	.36±.04	.9942
Sediment Stabilization & Phosphorus Retention	.65±.03	.72±.02	.9219	.62±.05	.72±.02	.9480
Nitrogen Removal	.84±.03	.78±.02	.1802	.90±.03	.73±.02	**.0016**
Thermoregulation	0	.21±.09	.8273	--	--	--
Primary Production	.88±.01	.74±.02	**.0147**	.78±.04	.65±.03	**.0449**
Resident Fish Habitat Support	.74±.09	.77±.03	.3967	--	--	--
Anadromous Fish Habitat Support	.85±.02	.77±.02	.1295	--	--	--
Invertebrate Habitat Support	.85±.03	.67±.02	**.0030**	.77±.04	.65±.02	**.0163**
Amphibian & Turtle Habitat Support	.87±.03	.75±.01	**.0010**	.84±.03	.75±.02	**.0231**
Breeding Waterbird Support	.42±.08	.44±.03	.5359	0	.02± 0	--
Wintering & Migratory Waterbirds	.50±.07	.58±.03	.8515	.45±.07	.40±.03	.2793
Songbird Habitat Support	.83±.05	.67±.02	**.0072**	.70±.04	.64±.02	**.0694**
Support of Characteristic Vegetation	.88±.04	.66±.02	**.0003**	.93±.05	.69±.14	**<.0001**
OVERALL	.71±.03	.66±.01	**.0012**	.67±.03	.60±.01	**.0026**

Table 7. Correlations among function capacity scores, riverine impounding sites (n = 54)

Subclass: Riverine Impounding correlations: ●● = strong positive ● = weak positive ◊◊ = strong negative ◊ = weak negative	Water Storage & Delay	Sediment Stabilization & Phosphorus Retention 2	Nitrogen Removal	Thermoregulation	Primary Production	Resident Fish Habitat	Anadromous Fish Habitat	Invertebrate Habitat	Amphibian & Turtle Habitat	Breeding Waterbird Support	Wintering& Migrating Waterbird Support	Songbird Habitat Support	Support of Characteristic Vegetation
Water Storage & Delay													
Sediment Stabilization & Phosphorus Retention													
Nitrogen Removal	●●	◊◊											
Thermoregulation	●●												
Primary Production		◊◊	●●										
Resident Fish Habitat Support													
Anadromous Fish Habitat Support	●●		●●		●	●●							
Invertebrate Habitat Support			●●	◊			●●						
Amphibian & Turtle Habitat			●●				●●						
Breeding Waterbird Support	◊◊	◊◊		●	●●			●					
Wintering & Migrating Bird Support				◊				●●		●●			
Songbird Habitat Support	●●		●●	◊◊	●●		●●	●●	●●	●	●●		
Support of Characteristic Vegetation				◊	●		●●	●●	●●			●●	

Table 8. Correlations among function capacity scores, slope/flats sites (n = 55)

Subclass: Slope/Flat correlations: ●● = strong positive ● = weak positive ◊◊ = strong negative ◊ = weak negative	Water Storage & Delay	Sediment Stabilization & Phosphorus Retention 2	Nitrogen Removal	Thermoregulation	Primary Production	Invertebrate Habitat	Amphibian & Turtle Habitat	Wintering& Migrating Waterbird Support	Songbird Habitat Support	Support of Characteristic Vegetation
Water Storage & Delay										
Sediment Stabilization & Phosphorus Retention										
Nitrogen Removal		◊◊								
Thermoregulation										
Primary Production		◊◊	●●							
Invertebrate Habitat Support			●●	◊	●●					
Amphibian & Turtle Habitat			●●		●●	●●				
Wintering & Migrating Bird Support	●	●		◊		●				
Songbird Habitat Support			●●	◊◊	●●	●	●	●		
Support of Characteristic Vegetation		◊	◊◊		●●	●●	●●			

In assessment, **sensitivity** describes the ability of a model's scores to reflect differences in sites (or changes in a single site over time). A comprehensive analysis of the sensitivity of this guidebook's models for scoring functions has not been performed. However, based on mathematical properties of the models one can expect that output scores from models that contain only a *few* indicators, and/or which include *multiplicative* operations, will be influenced the most by slight changes (or estimation errors) in the individual indicators. Results from models that *average* many of their indicators are probably less susceptible to estimation errors.

In assessment, **comparability** describes the tendency of model scores to reflect scores or rankings obtained by using other methods or models that have the same intended purpose. To assess comparability, at the completion of each site visit each assessment team indicated their spontaneous opinion of the assessment site's capacity to perform each of the 13 functions, relative to other regional sites in the same subclass. They indicated this on a scale of 1 (low capacity) to 5 (high capacity). No systematic checklist of indicators was used to reach a score. Subsequent comparison revealed a statistically significant ($p<0.05$) correlation between the guidebook-generated scores and the assessment team's ratings for 8 of the 13 functions. Functions for which the two approaches showed no statistically significant correlation were: Thermoregulation, Anadromous Fish Habitat, Nitrogen Removal, and Primary Production. The correlation or lack of it probably reflects the extent of the assessment team's knowledge of the function, precision of the definition of the function, number of variables that influence a function, and other factors.

Section 7. Verifying Consistency

In addition to considering sensitivity and comparability of the function scoring models, we also assessed the consistency (repeatability) of estimates of their indicators at three sites. Results are as follows.

Comparison Site #1: Corvallis Airport Flat

The standardized scores resulting from assessments of 43 indicators by two observers were compared. Results showed perfect agreement on scores of 33 indicators (77% agreement). The largest differences were for indicators related to the extent of seasonal flooding. Observers also differed with regard to perceptions of the extent of previous soil compaction and plowing. Among the indicators for which disagreements existed, the average difference in score was 0.46. With regard to assessment of the plant community, both observers agreed the site was dominated spatially by non-native herbs. The estimate for percent of the common herb species that are non-natives was 33% from one observer and 14% from the other. Of 40 herb species found at the site (cumulative list), 23 were identified by both observers, 13 only by "observer "A", and 4 only by "observer B."

Comparison Site #2: Truax Island Floodplain

The standardized scores that were assessed independently for 43 indicators by two observers were compared. Scores were in agreement for 25 indicators (58%). The largest disagreements concerned estimates of the percent of the contributing watershed that is undeveloped, soil texture and water level fluctuation that predominate at the site as a whole, number of types of dead wood, frequency and extent of visits by people on foot, and extent of shrub cover. Among the indicators for which disagreements existed, the average difference in score was 0.3. The estimate for percent of the common herb species that are non-natives was 67% from observer A and 28% from observer B. Of 39 herb species found at the site (cumulative list), 10 were identified by both observers, 19 only by "observer A", and 10 only by "observer B."

Comparison Site #3: Hunziker Road Flat

Estimates of 44 indicators were made independently by 3 observers. All 3 observers were in perfect agreement on 23 indicators (52%). Comparing just observer A vs. observer B, there was agreement on 31 indicators (70%). Comparing observer B vs. observer C, there was agreement on 29 indicators (66%). Comparing observer A vs. observer C, there was agreement on 27 indicators (61%). Among the indicators for which disagreements existed, the average difference in score between observers A and B was 0.41, between observers B and C was 0.33, and between observers A and C was 0.32. The largest disagreements were for the estimates of site access to anadromous fish, number of depth categories, frequency and extent of visits by people on foot, and extent of previous soil compaction and plowing. The estimate for percent of the common herb species that are non-natives was 80% from observer A, 71% from observer B, and 50% from observer C. Of 56 herb species found at the site (cumulative list), 10 were identified by all three observers, 12 were found by two of the three observers, 10 were found only by observer A, 20 only by observer B, and 4 only by observer C.

Conclusions About Consistency

Although the occurrence of *any* inconsistency may be distressing to some potential users, the repeatability rates we measured for our indicators of function are, overall, quite favorable. The consistency of our indicator estimates seems better than consistency of our floristic characterizations. For indicator estimates, compare our two-observer agreement rates of 58, 61, 66, 70, and 77% with the 64% agreement rate found between two teams that conducted a similar test of repeatability of indicator estimates focusing on 28 indicators used by an HGM project in the Delaware Coastal Plain (Whigham et al. 1999). Washington's HGM project has not assessed repeatability of individual indicators. Among research studies accepted for publication in scientific journals, many regression models that are based on statistically-based, laborious measurement of environmental variables are widely viewed as "acceptable" even though they commonly are able to explain less than 50% of the variance (which includes both measurement errors and natural variation) of their dependent variables. Samples of invertebrates collected from the same wetland using the same protocols and equipment on the same date often disagree (i.e., show statistically significant differences in taxa richness and abundance) (personal experience of the author). Thus, imperfect repeatability is not endemic to function assessment methods.

In addition, although we did not compare repeatability of *function* scores that are the outcome of using the indicators in scoring models, it is reasonable to expect, based partly on a similar result from the Delaware study, that consistency of these ultimate outputs will be even greater than the consistency rates for individual indicators, and that standardized function scores will differ by 0.2 or less (on a 0-to-1 scale) among diverse users. This will be examined by future DSL efforts that may include a larger number of test sites and testers. In a test of the Oregon Freshwater Wetland Assessment Method (OFWAM) using 7 assessment teams, Heigh (1995) reported agreement rates for functions ranging from poor (teams all differed in the function ratings they assigned some sites) to excellent (teams agreed at all sites), with an average among all functions of about 64% agreement.

There is ample opportunity for improving the agreement rates for estimates of indicators used in this guidebook. For example, many of the disagreements regarding the Hunziker Road Flat can be traced back to observers unknowingly delimiting the boundaries of the site differently. This kind of discrepancy can occur when using any function assessment method (including "best professional judgment"), and can easily be remedied by improved communication. Review of our field data has also led to refinement of the definitions of some indicators and their estimation procedures (Appendix A of Volume IA). Consistency can also be improved by encouraging the rigorous training and testing of potential users prior to their use of the guidebook's methods.

Section 8. Towards Bioassessment

8.1 Background

Using indicators and rapid estimation methods to assess functions and values, as described in most of this guidebook, is best viewed as a rudimentary step toward truly understanding the biological and geochemical processes occurring at a wetland/riparian site. Rapid methods for function assessment provide consistency, accountability, and a "safety net," so that the best available science – not just personal opinions and political influence – is incorporated into decisions. Nonetheless, the paucity of validated indicators and models of wetland function suggests that, whenever possible, supplemental data be collected and interpreted.

Acting partly under the federal Clean Water Act, Oregon recognizes "aquatic life support" as the primary attribute ("designated use" or "beneficial use") to be protected in most wetlands. Therefore it is logical, whenever funds are available for collecting additional data at a site, that attention normally be given to identifying and enumerating the species of plants and animals that use a site (termed *bioassessment*), and to interpret such data in terms of the site's biological *condition*, with "condition" meaning the site's present status with regard to *fully supporting aquatic life*. Full support of aquatic life is widely viewed as consisting of the presence of diverse and dynamically balanced assemblages of predominantly indigenous species (Karr and Chu 1999). Scientists have devised and tested "multimetric indices of biotic integrity" (IBI's) to represent relative attainment of full support of aquatic life in streams, and increasingly, in wetlands. For EPA's summary of current state efforts, general background on bioassessment, and potential applications, see: http://www.epa.gov/owow/wetlands/wqual/bio_fact/

Like the models this guidebook uses to score functions, multimetric indices are comprised of indicators (also termed "metrics") that are combined mathematically to score condition on a relative, ordinal scale. For example, one of many metrics in an IBI index might be "percent of all sampled invertebrate species that are dragonflies." Like function indices, (a) IBI's are developed and calibrated for (stratified by) different ecoregions and wetland classes, and (b) conditions of indicators *at least-altered sites* typically are used to quantify the highest score attainable by the IBI, i.e., "full support" of aquatic life. Unlike function indices, metrics used in IBI's consist entirely of sampled biological assemblages, rather than estimates of indicators that describe hydrogeomorphic features and habitat structure. Other differences and similarities of bioassessment and function assessment are summarized at the web site noted above.

Bioassessment and IBI's have important applications other than simply identifying the relative attainment of aquatic life support under the Clean Water Act. Biological monitoring (the repeated application of bioassessment) is perhaps more sensitive than rapid methods of function assessment for determining subtle trends in wetland condition, and is frequently used by consultants for monitoring the maturation of wetlands restored or constructed as compensation in the wetland permitting process. Data from bioassessments can also be used to prioritize restoration by identifying wetlands that are in the most ecologically degraded condition. In some cases, data from bioassessments are sufficient to diagnose the proximate causes of degradation, thus forming a basis for remedial actions and implementation of best management practices. Over time, the patterns that emerge from data collected during bioassessments should be used to help refine performance standards for restored/ constructed wetlands, as well as enforceable narrative or numeric criteria that are protective of the aquatic life designated use of wetlands.

Bioassessment of wetlands by state or federal agencies has not become routine in Oregon or in any other state. This has been due to funding constraints, bureaucratic inertia, and lack of technical know-how. Agency staff must have considerable taxonomic expertise, in addition to knowing which seasons, equipment, and methods are most cost-effective for sampling particular biological groups. This usually requires an initial, substantial investment in field research and experimentation. Also, before bioassessment becomes routine, an understanding must be gained of how best to distinguish the response of particular plants and animals to natural disturbances as opposed to their response to human-related activities whose influence sometimes mimics natural disturbances. To some degree the influence of natural disturbances can be “factored out” by stratifying the sampling by ecoregion and wetland subclass, but it cannot be eliminated entirely.

For rivers and lakes, most states have found that invertebrates and/or algae are the most cost-effective groups to examine when assessing support of aquatic life. However, the choice of which taxonomic group to use for monitoring condition is less certain when wetlands are the focus. This uncertainty is partly due to the fact that attempts to relate wetland assemblages to environmental degradation date back only a few years, whereas attempts to relate stream organisms to pollution date back to the early 1900’s. Knowledge of biological indicators useful in streams and lakes does not transfer well to wetlands (USEPA 2001).

Given limited resources, part of the dilemma in choosing what to monitor is due to a situation wherein the usefulness of a particular taxonomic group for detecting human-caused degradation of a wetland is perhaps inversely related to public recognition of its importance. Algae and vascular plants are at the foundation of many ecological processes and food webs, and are highly sensitive to many types of impacts to wetlands (particularly impacts from changes in nutrients, water residence time, water level fluctuation, and sediment runoff). Moreover, compilations of data on the sensitivities of many algal taxa (Stevenson et al. 1996) and wetland-associated vascular plants (Adamus & Gonyaw 2001) are available. However, the general public and agency bureaucrats with little biological training are likely to be skeptical about the relevance of spending taxpayer dollars to continually sample algae (or even plants) in wetlands. In contrast, waterbirds are appreciated and perceived as closely associated with wetlands by a relatively large segment of the public. Indeed, declining waterfowl populations in the 1960s and 1970s were largely behind the impetus to afford more protection to wetlands nationwide. However, because they often move long distances on a daily and hourly basis, most waterbirds have limited utility as an indicator of the condition of individual wetlands. Rather, they reflect wetland conditions and cumulative impacts at regional and continental levels, and those scales sometimes do not fit conveniently into the monitoring needs of Sections 303, 305, and 404 of the Clean Water Act. In terms of indicator value and public recognition, amphibians and invertebrates perhaps lie somewhere in between birds and algae.

Ideally, more than a single taxonomic group should be used to monitor wetland condition, because different groups vary in regard to the time scale, spatial scale, and sensitivity with which they respond to different types of degradation. No single taxonomic group can lay claim to representing "wetland health" for all. Assessing the condition of multiple groups, however, can stretch resources very thin.

8.2 Exploring a Bioassessment Protocol Featuring Wetland-associated Plants

An effort was made during this project to begin development of an index of biotic integrity (IBI) for wetland and riparian systems of the Willamette Valley, based on vascular plants. Funding priorities dictated that this effort be secondary to the development of scoring models for functions. The effort was nonetheless made because (a) methods for rapid assessment of functions and values address state responsibilities for determining the relative condition of aquatic life by assessing wetlands in only an indirect manner, by observing structural indicators, (b) methods for rapid assessment of functions and values, unlike bioassessment methods, are unable to detect moderate degradation of biological communities at sites due to chemical contamination, (c) the reference-site approach used in this project to calibrate indicators and scoring models for functions afforded an opportunity to also conveniently assess plant assemblages across gradients of natural disturbance and human influence, and (d) at the onset of the project, it appeared that complementary aspects of vegetation and hydrology might be measured at shared reference sites by the USEPA National Health and Environmental Effects Laboratory in Corvallis, thus potentially benefiting both projects; however, due to budget restrictions the EPA effort was not implemented.

Fundamental to the development of an operational IBI are practical procedures for assessing plant assemblages. With good reason, there is no single accepted approach for sampling wetland and riparian plants. That is because sampling design should depend largely on sampling objectives, i.e., for which particular attributes of plant community structure is information needed? Procedures used often when employing plants to characterize wetlands are summarized in Table 9, and include the following, applied either independently or in combination:

- Unstructured searches
- Systematic transects
- Random plots
- Stratified plot-based

If plant surveys must be limited to only a single half-day visit to a site, it is highly unlikely that enough plots can be surveyed to yield statistically-sound estimates of the percent of the site occupied by each species. This will be true regardless of whether plots are located systematically or randomly. On the other hand, a half-day visit, especially during the growing season, will usually be sufficient to determine presence of a large percentage of species occupying a site. However, this is probably true only if unstructured searches or stratified plots are used, and as noted above, both require substantial judgment. Adding this element of judgment potentially reduces the repeatability (consistency) of results, but makes these approaches faster to use.

Table 9. Types of procedures commonly used to characterize wetland and riparian plant assemblages

Unstructured searches have the advantage of being the quickest and least restrictive option. They generally involve one skilled botanist walking the entirety of a site while keeping a running list of species noticed (sometimes called a "random walk," Planty-Tabacchi et al. 1996). This approach is applicable when the only objective is to assess plant richness and species composition, not percent cover. Disadvantages include the fact that results are strongly influenced by (a) time spent searching per unit wetland area, (b) size and complexity of the site, (c) keenness and taxonomic skills of the searcher, (d) inaccessibility of parts of the site, e.g., deep water. To improve somewhat the comparability of estimates among different sites, searches can be restricted by time (e.g., 10-minutes per acre, or search until no more species found after 3 minutes of searching) and/or by stratifying the search by recognizable habitats within a site. Unstructured searches are used by Washington's HGM method (Hruby et al. 1999), but apparently have seldom been used by scientists developing plant-based wetland IBI's in other states.

Systematic transects are commonly used, especially in research studies, to assess wetland and riparian plant communities (e.g., Winward 2000). Transects consist of sample plots or observation ("intercept") points located, usually at even intervals, along generally straight lines. The transect lines also are usually spaced at even distances apart. They may be oriented perpendicular to the long axis of a site, may radiate from the centerpoint of the site, or be oriented in some other manner intended to span moisture gradients. If the number of transects and/or the number of plots or points per transect is sufficient, information on spatial dominance of particular species throughout the site can be obtained. The even spacing of an inadequate number of transects within a site can be a disadvantage because it is insensitive to (and may totally miss) important environmental gradients that influence a site's plant communities. This can be addressed somewhat by sampling large numbers of plots or points along the transects, and/or by using numerous transects per unit of wetland area. Transect approaches are specified for assessing relative dominance of wetland-associated plants in the Corps of Engineers wetland delineation manual. The manual's procedures, when applied to an average 2-acre site, would require 6 plots. At least 100 plots per site would be required using procedures employed in studies of Portland-area wetlands by EPA's National Health and Environmental Effects Research Laboratory (Magee et al. 1999). Researchers studying the West Eugene wetlands calculated that 200 intercept points, spaced equally throughout a site, are required to derive estimates of species cover that are confidently within 5-10% of the true values.

Random plots are typically used at sites perceived either as lacking recognizable environmental gradients, or with highly complex gradients. Standard-sized plots are situated according to X-Y coordinates generated by a random numbers table, or other random number generator. No assumptions are made regarding locations of particular gradients that may influence plant distribution. If the number of plots is sufficient, statistically-sound information on spatial dominance of particular species throughout the site can be obtained.

Stratified plot-based procedures also are sometimes used to assess wetland plant communities. This involves using professional judgment, rather than solely systematic or randomized designs, to situate plots or observation points. One option is to place plots in "representative" locations, using judgment to identify locations that seem most typical of the site. Another option is to stratify a site according to plant *associations* (i.e., commonly correlated assemblages of species), and then sample each association with one or more plots, located randomly or systematically within each association. This requires judgment to recognize and delimit what constitutes plant "associations," inasmuch as no generally-accepted list exists for the Willamette Valley. To avoid problems with defining associations, one can place plots to include every plant *species* that appears, from an initial site reconnaissance, to constitute more than a prespecified acreage or percent of the site. That is the approach used in this project. To conserve sampling effort, one can place plots at the fewest locations that will produce the largest species list. However, this requires careful screening of the site and strategic planning to identify – quite subjectively -- the most complementary and species-rich locations. Finally, one can stratify a site by observable physical and chemical features thought to influence plants, such as shade and/or expected duration of inundation (elevation), and then allocate plots randomly or systematically within each "zone." This also requires judgment.

As noted above, the choice of a sampling design or procedure depends on sampling objectives. For this exploratory study, the main objectives were simply to assess (a) the relative proportions of native and non-native herbs and woody species, and (b) percent cover of woody species. A precision of no greater than ±10% was anticipated for these estimates. To achieve these limited objectives, we specified the procedure described in Table 10. *Note that this procedure, although it uses plots, is not a conventional plot-based procedure for surveying plant cover.* Therefore, data from this procedure should not be compared to data collected from the same sites using standard plot or transect procedures. The procedure is not valid for estimating percent cover of individual species across an entire site, and its repeatability when used to estimate a site's herb richness is uncertain, so we did not use our estimates of herb richness in the function scoring models. We know of no *rapid* procedure that provides highly repeatable and comparable estimates of herb richness among sites, without being hopelessly confounded by differences in site area, habitat complexity, and searcher competency. Attempts to adjust for effects of site area, number of plots, and canopy cover, using regression and species accumulation analyses, were only moderately successful. The following variables were measured and examined for statistical correlation, but for the reasons given above, these results should be interpreted cautiously:

- *Herb species richness* (cumulative total of herb species in the plots) correlated with number of herb plots sampled, as expected. So did herb species richness (a) based on herbs outside as well as inside the plots, and (b) based on only herbs that were common (>20% cover within a plot).

- Among RI sites, *percent of herb species that are native* correlated with herb species richness of the plots, and richness of wetland-associated species[1], but only when "common" natives were the only herbs counted. The correlations were positive. This contrasts with another survey of mostly RI sites in part of the Willamette Valley, which found a smaller proportion of native species at sites with greater species richness (Planty-Tabacchi et al. 1996).

- Among SF sites, *percent of herb species that are native* correlated with herb species richness only when herbs outside as well as inside the plots were included. The correlation was negative, suggesting that total herb richness is less where the number of non-native herb species comprises a large percent of all herb species at a site. At SF sites, there was no correlation between number of wetland-associated herb species, and percent of herb species that are native.

We chose to use herb plots because we believe plots are more likely to detect less obtrusive herb species. By focusing mainly on common species, this procedure confines the number of plots to be surveyed at most sites to fewer than 15, a number that is feasible to survey in half a day.

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[1] Species categorized as FAC, FAC+, FACW-, FACW, FACW+, or OBL in the official state list of wetland-associated plant species published by the US Fish & Wildlife Service.

Table 10. Procedure specified by this project to assess wetland and riparian plant assemblages during 1999-2000 field seasons

This procedure can be classified as a "stratified plot-based" procedure for the manner in which it surveys herbs, and as an "unstructured search" for the way it surveys woody plants.

1. For *woody* vegetation (trees, shrubs, vines), identify each species while walking through the site. During and after the walk-through, visually estimate (a) the percent of all tree cover consisting of each tree species, (b) the percent of all open shrub cover consisting of each shrub species, and (c) the percent of all understory shrub cover consisting of each shrub species. (See Volume IA, Appendix A for definitions and procedures).

2. During the walk-through, identify all *herb* (non-woody) species that appear to occupy more than 100 sq. ft. of the site (not necessarily in one contiguous patch). These species are termed "common herbs."

3. Place a square-meter frame around each common herb species, such that the herb occupies at least 20% of the area within the frame. Record all other species present within the plot, and estimate their relative percent cover. Also record the percent of the plot occupied by bare ground or water, as viewed looking down from 1 m above.

4. Plots in #3 should be located not only to include the common herbs, but also so that, collectively with other plots, they will include the widest variety of habitats and species present at the site. This involves some judgment. Do not locate plots randomly or systematically.

5. Use *at least* the following number of plots, even if the site contains only one or two species:

Vegetated area	Minimum number of plots required
1-2 acres	4
2-4 acres	5
4-16 acres	6
16-256 acres	7
>256 acres	8

6. If the site contains some permanent water, visualize at least one plot in the most-vegetated part of the permanent water and survey this plot as best you can from "shore."

7. After completing the plots and your walk-through of the site, answer the question:

Is more of the herb cover on the site comprised of non-native than of native herbs?

Base this on your observations of the entire site, not just the herb plots.

Table 11. Relationships of candidate plant metrics to indicators of human influence

See footnote at end for abbreviations of indicators of human influence ("disturbance indicators"). See Glossary (Appendix A of Volume IA) for description of how some of these disturbance indicators were estimated. Only the indicators that were significantly associated with the plant metrics ($p<0.05$, Pearson correlation coefficient) are shown. /+ means an increase in the disturbance indicator was associated with an increase in the candidate metric; /- means an increase in the disturbance indicator was associated with a decrease in the candidate metric.

Candidate Metric	**Correlations with disturbance indicators at Riverine Impounding sites**	**Correlations with disturbance indicators at Slope/flats sites**	**Correlations when both subclasses combined -- additional correlations**
1. Native species as percent of all herb species found, both in & out of plots (H%NtvAll)	BufGrassWetAB/- BufWoodAB/+ BuffCropGrass/- BuffGrassWet/- BuffWet/- BuffWood/+ Deadwood/+ Mow/- Level/- Plow/- WoodPct/+	Compac/- Cut/- Deadwd/+ Drain/- FCC/+ NumHplots/+ Plow/- Plow/- TreeMaxD/+ WoodPct/+	HGMchange/-
2. Native species as percent of all herb species found in the herb plots (H%NtvPlots)	BufGrassWetAB/- BufWetAB/- BuffGrassWet/- BuffWet/- BuffWood/+ BuffNat/+ Mow/- ShedNat/+	Area/+ Compac/- Construcd/- Cut/- Deadwd/+ Drain/- FCC/+ Mow/- NumHplots/+ Plow/- Plow/- TreeMaxD/+ WoodPct/+	BufWoodAB/+ BuffNatMax/+ BuffCropGrass/- HGMchange/-
3. Native species that comprise at least 10% of any herb plot, as percent of all herb species found in the plots (H%NtvDom10)	BufNatAB/+ BufWetAB/- FlowReg/- ShedNat/+ TreeMaxD/-	Area/+ Deadwd/+ Drain/- FCC/+ HGMchange/- Plow/- TreeMaxD/+ WoodPct/+	BuffWet/- BuffNat/+ NumHplots/+
4. Native species that comprise at least 20% of any herb plot, as percent of all herb species found in the plots (H%NtvDom20)	BufNatAB/+ BufWetAB/- BuffNat/+ FlowReg/- RoadDis/+ ShedNat/+ TreeMaxD/- WoodPct/-	Area/+ Deadwd/+ Drain/- FCC/+ HGMchange/- Plow/- TreeMaxD/+ WoodPct/+	BuffWet/-

35

Candidate Metric	Correlations with disturbance indicators at Riverine Impounding sites	Correlations with disturbance indicators at Slope/flats sites	Correlations when both subclasses combined -- additional correlations
5. Sum of percent covers of non-native herbs among plots at a site, divided by sum of cover of all herbs at the site (Hcov%NNsp)	BufNatAB/- BufWetAB/+ BuffWet/+ FlowReg/+ ShedNat/- TreeMaxD/+	BufNatAB/- BuffWood/- BuffNat/- Deadwd/- Ditch/- Drain/+ FCC/- Puddle/- TreeMaxD/- WoodPct/-	BuffNat/- BuffNatMax/-
6. Sum of the percent covers of non-native herbs at a site (using only their maximum among plots), divided by similar sum for all herbs (HcovSum%NNsp)	BufNatAB/- BufWetAB/+ BuffWet/+ FlowReg/+ ShedNat/- TreeMaxD/+	Area/- Drain/+ FCC/- Puddle/- Plow/- RoadDis/- TreeMaxD/-	BuffNat/- BuffNatMax/-
7. Categorical dominance of non-native species: 3= non-natives dominate 2= mostly equal mix 1= natives dominate (HcovNN)	BufNatAB/- BufWetAB/+ BufWoodAB/- BuffGrassWet/+ BuffWet/+ BuffWood/- BuffNat/- Downcut/+ RoadDis/- ShedNat/- TreeMaxD/+	BuffNat/- Compac/+ Dams/+ FCC/- Plow/+	
8. Percent of herb species at the site that also occurred at any of the least-altered (reference standard) sites	BuffCropGrass/- BuffGrassWet/- BuffWood/+ NumPlots/- Plow/- Visits/-	Constructd/- Ditch/+ Puddle/+	BufWetABC/+
9. Percent of herb species at the site that also were common (>20% cover in any plot) at any of the least-altered (reference standard) sites	BuffCropGrass/- BuffGrassWet/- BuffWood/+ Level/- Plow/- Visits/-	BufCropGrassAB/- BufGrassWetAB/- Pipes/+ TreeMaxD/+ WoodPct/-	BufWetABC/+ Deadwood/+ Drain/- Mow/-
10. Number of species of trees, shrubs, & vines in the entire site (WoodSpRich)	BufGrassWetAB/- BufWoodAB/+ BuffCropGrass/- BuffGrassWet/- BuffWood/+ FCC/+ Mow/- Pits/- TreeMaxD/+ WoodPct/+	BufGrassWetAB/- BuffCropGrass/- BuffGrassWet/- BuffWood/+ Deadwood/+ Drain/- FCC/+ NumHplots/+ Pipes/+ Plow/- TreeMaxD/+	Area/+ BufWetABC/+ Compac/-

Candidate Metric	Correlations with disturbance indicators at Riverine Impounding sites	Correlations with disturbance indicators at Slope/flats sites	Correlations when both subclasses combined -- additional correlations
11. Percent of woody species that are native (WoodSp%N)	Area BufNatAB/- BufGrassWetAB/- BufWoodAB/+ BuffWet/- BuffWood/+ BuffNat/+ Deadwd/+ Mow/- Pits/- TreeMaxD/+ WoodPct/+	Compac/- Plow/- TreeMaxD/+ WoodPct/+	BufWoodAB/+ BuffCropGrass/- BuffGrassWet/- Deadwd/+ FCC/+ Mow/- Pits/-
12. Percent cover of non-native woody plants -- maximum of tree, open shrub, & closed shrub strata (WoodCovMax%NN)	BufNatAB/- BuffNat/- Dams/+ RoadDis/- ShedNat/-	Cut/+ Deadwd/+ NumHplots/+	BufWoodAB/+ BuffNatMax/- TreeMaxD/+ WoodPct/+
13. Number of woody species that are native (WdRichN)	FCC/+ Mow/- Pits/- WoodPct/+	Area/+ BufGrassWetAB/- BuffCropGrass/- BuffGrassWet/- BuffWood/+ Deadwd/+ Drain/- FCC/+ NumHplots/+ Pipes/+ Plow/- TreeMaxD/+ WoodPct/+	BufWetABC/+ BufWoodAB/+ BuffNatMax/- Compac/-

Abbreviations: **Area**= acreage of site; **BuffCropGrass**= % of land cover within 200' that is row crops or grass; **BuffGrassWet**= % of land cover within 200 ft that is grass, wetland, or water; **BuffNat**= % of land cover within 200 ft that is NOT row crops, lawn, or pavement ; **BuffNatMax**= like BuffNat, but maximum of %'s in 200, 1000, and 5280 ft zones; **BuffWet**= % of land cover within 200 ft that is wetland or water; **BuffWood**= % of land cover within 200 ft that is woodland or shrubland; **BufGrassWetAB**= % of land cover that is grass, wetland, or water; sum of %'s in 200 & 1000 ft zones; **BufNatAB**= % of land cover that is NOT row crops, lawn, or pavement; sum of %'s in 200 & 1000 ft zones; **BufWetAB**= % of land cover that is wetland or water; sum of %'s in 200 & 1000 ft zones; **BufWoodAB**= % of land cover that is woodland or shrubland; sum of %'s in 200 & 1000 ft zones; **Compac**= extent of site where soil compacted; **Construcd** = extent of site constructed from upland; **Dams**= extent of site physically affected by onsite impoundment; **Downcut**= site's hydrology is affected by downcutting channels; **Deadwd**= number of types of dead wood; **Drain**= extent of site physically altered by onsite drainage; **FCC**= % canopy closure; **FlowReg**= water level or flow to/from site is artificially regulated (yes/no); **HGMchange**= extent of site that was once a different HGM subclass; **Level**= extent of site physically altered by leveling; **Mow**= extent of site recently mowed or cut; **NumHplots**= number of herb plots surveyed at the site; **Pipes**= stormwater pipes are present onsite; **Pits**= extent of site containing excavations; **Plow**= extent of site containing plowed or recontoured soils; **Puddle**= extent of microtopographic variation (hummocks & puddles); **RoadDis**= distance to the nearest major road or residence; **ShedNat**= % of contributing watershed within 200 ft. that is NOT row crops, lawn, or pavement; **TreeMaxD**= diameter of largest tree at the site; **Visits**= frequency of human visitation; **WoodPct**= % of the site containing trees or shrubs.

A review of correlation coefficients (not presented here) suggests that plant metric #4 (common *native* herb species in plots, as a percent of all common herb species in plots) has the statistically strongest relationships with indicators of human influence. Among both RI and SF sites, values for #4 did not differ significantly from those of #1 (which includes native species outside of plots, as well) or #2 (all herb species in plots)(Mann-Whitney U-test, $p<0.05$). This suggests that the deviations which occurred when the assessment teams interpreted parts of the Table 10 procedure differently probably were inconsequential, in the context of the project's narrow objectives. Appendix D presents a ranking of the sites based on metric #4.

Overall, the results shown in Table 11 document the degradation of wetland biotic integrity, as represented by plants, in association with a wide variety of human activities in the Willamette Valley. This has long been suspected, and the results of our study lend support to similar results reported from localized parts of the region by Magee et al. (1999) and O'Neill & Yeakley (2000). In particular, our results suggest (a) a site's flora is more homogenized (less similar to the flora of reference standard sites) when human visitation of the site increases and surrounding land cover is not woodland, (b) the proportion of non-native herbs is greater at sites that were converted from another HGM subclass, are surrounded by developed landscapes, are closer to busy roads, and/or have been plowed, mowed, and subjected to altered drainage patterns. The results also demonstrate that some plant metrics are more sensitive to particular human activities than others, so that if the goal is to assess multiple natural and human-related disturbaces using plants, multiple metrics should be used in a complementary manner.

Additional plant metrics might be computed from our data set and examined statistically, and/or examined in data from future botanical surveys. With supplemental surveys and analysis, all common Willamette Valley species might be assigned scores that reflect their relative tolerance of general or particular human influences. These scores could then be combined into a "floristic index" which indicates the relative botanical condition at a site, independent of plant species richness (e.g., Andreas & Lichvar 1995). Through review of our data and discussions with local experts, an assemblage of "remnant-dependent" species is presented in Table xx. Such species would be at the "upper end" (highest quality) of a floristic index in this region. Also, species tolerance information from elsewhere in North America, which has been compiled and can be downloaded from the internet (Adamus & Gonyaw 2000), could be used to help formulate a local floristic index useful for bioassessments.

Table 12. Native herb species ("remnant-dependent" species) considered by local authorities to be indicative of sites with relatively minimal human influence

List is not comprehensive.

Scientific Name	Common Name
Aster hallii	Hall's aster
Beckmannia syzigachne	American slough grass
Camassia quamash, C. leichtlinii	camas
Cardamine penduliflora	Willamette Valley bittercress
Carex densa	dense sedge
Carex obnupta	slough sedge
Carex unilateralis	one-side sedge
Danthonia californica	California oatgrass
Delphinium pavonaceum	larkspur
Delphinium trolliflolium	larkspur
Deschampsia cespitosa	tufted hairgrass
Downingia elegans	common downingia
Eleocharis acicularis	least spikerush

Scientific Name	Common Name
Eleocharis palustris	creeping spikerush
Eriophyllum lanatum	wooly sunflower
Eryngium petiolatum	coyote thistle
Grindelia integrifolia	gumweed
Hordeum brachyantherum	meadow barley
Juncus acuminatus	taper-tip rush
Juncus patens	spreading rush
Juncus tenuis	slender rush
Lotus pinnatus	bog trefoil
Montia spp.	montia species
Myosotis laxa	bay forget-me-not
Oenanthe sarmentosa	water-parsley
Plagiobothrys figuratus	popcornflower
Potentilla gracilis	Northwest cinquefoil
Ranunculus lobbii	Lobb's water buttercup
Saxifraga oregana	Oregon saxifrage
Sidalcea campestris	meadow sidalcea
Spiraea douglasii	Douglas' spiraea
Vaccinium caespitosum	dwarf blueberry
Veronica scutellata	marsh speedwell

Although this project did not comprehensively characterize species composition of Willamette Valley wetland and riparian habitats generally or the study sites specifically, the floristic data does identify species that were found most widely and which thus may be the most opportunistic (Table 12). Also, a few species were found only at our least-altered sites. These are:

> **At least-altered RI sites**: *Adiantum pedatum, Angelica genuflexa, Aster chilensis, Carex pellita, Glyceria elata, Gnaphalium uliginosum, Grindelia integrifolia, Holcus mollis, Juncus oxymeris, Lindernia anagallidea, Lomatium triternatum, Lycopus uniflorus, Lysichiton americanum, Mimulus moschatus, Myosotis discolor, Petasites frigidus, Senecio jacobaea, Tiarella trifoliata*
> **At least-altered SF sites**: *Arenaria capillaris, Carex echinata. Carex ovalis, Carex pellita, Festuca megalura, Lotus formosissimus, Mentha piperita, Potentilla anserina, Pteridium aquilinum*

Low frequency of encounter of these species at other sites might reflect suboptimal survey conditions, rather than true scarcity or narrow habitat requirements. Due partly to the cursory nature of our surveys and our limited objectives, we found none of the species categorized by Titus and Christy (1996) as "rare" in the Willamette Valley[1], although some of these have been reported from some of our sites by other investigators.

Before a plant-based wetland IBI is finalized for the Willamette Valley, additional statistical tools should be applied to this and other data sets to examine the above metrics and indicators in more detail, as well as to address other questions related to gradients of human influence, multispecies associations, survey procedures, and appropriate survey intensity. Moreover, if future projects are initiated to survey invertebrates, birds, or algae at a large number of sites in the region, similar attempts should be made to classify the sites using the HGM classification, quantify potential human influences at multiple scales, and then identify useful metrics and develop multimetric IBI's for quantifying site condition, especially relative to restoration goals and/or aquatic life "uses" designated by the Clean Water Act.

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[1] *Agrostis howellii, Aster curtus, Carex retrorsa, Erigeron decumbens, Horkelia congesta, Howellia aquatilis, Hydrocotyl verticillata, Lomatium bradshawii, Montia howellii, Romanzoffia thompsonii, Sidalcea nelsoniana, Sphaerocarpos hians, Sullivantia oregana, Utricularia gibba, Wolffia borealis, W. columbiana*.

Table 13. Plant species with widest distributions: results of surveys of multiple Willamette Valley wetland or riparian sites by six projects

Project	Number & type of sites surveyed	**Most widely distributed plants (in approximate order of frequency)** These were not necessarily dominant <u>within</u> particular sites. Numbers in parentheses are % of sites (or # of sites for ONHP and O'Neill & Yeakley list) where found, if reported. Species in **bold** were categorized as non-native.
This one	7 "least altered" riverine impounding	<u>Herbs</u>: 5 sites: *Carex obnupta* , ***Phalaris arundinacea****;* 4 sites*: Bidens frondosa* , ***Holcus lanatus****, Oenanthe sarmentosa,* ***Solanum dulcamara****;* 3 sites: *Agrostis sp, Alisma plantago-aquatica, Bidens cernua,, Carex densa, Eleocharis palustris, Epilobium ciliatum, Juncus effusus, Myosotis laxa, Polygonum hydropiperoides, Rumex salicifolius* <u>Woody</u>: 7 sites: *Fraxinus latifolia*; 5 sites: *Spiraea douglasi, Symphoricarpos albus;* 4 sites*: Populus trichocarpa,* ***Rubus discolor****, Rubus ursinus*
	49 other riverine impounding	<u>Herbs</u>: ***Phalaris arundinacea*** *(46),* ***Solanum dulcamara*** (37), *Carex obnupta (30), Bidens frondosa (28), Epilobium ciliatum, (28), Agrostis* sp. *(25), Ludwigia palustris (22)* <u>Woody</u>: ***Rubus discolor*** (40), *Fraxinus latifolia* (39), *Cornus sericea* (26), *Symphoricarpos albus* (25), *Populus trichocarpa* (24), *Rubus ursinus* (24), *Salix lasiandra* (24)
	8 "least altered" slope/flat	<u>Herbs</u>: 7 sites: *Carex unilateralis,* ***Rumex crispus****;* 6 sites*: Carex densa,* ***Holcus lanatus****, Juncus effusus, J. patens, J. tenuis,* ***Mentha pulegium****, Veronica scutellaria;* 5 sites*: Carex obnupta, Deschampsia cespitosa, Epilobium ciliatum, Galium sp.,* ***Parentucellia viscosa****,* ***Phleum pratense****, Polystichum munitum;* 4 sites*: Agrostis sp., Beckmaniella syzigachne,* ***Briza minor****, Carex ovalis, Danthonia californica,* ***Daucus carota****, Festuca sp., Hordeum brachyantherum, Juncus oxymeris, Madia glomerata,* ***Phalaris arundinacea****, Poa sp.,* ***Polygonum aviculare****,* ***Prunella vulgaris*** <u>Woody</u>: 7 sites: *Fraxinus latifolia;* 6 sites*:* ***Rubus discolor****, Spiraea douglasii;* 5 sites: *Crataegus douglasii*, ***Crataegus monogyna***, *Rubus ursinus*, *Symphoricarpos albus*
	45 other slope/flats	<u>Herbs</u>: ***Holcus lanatus*** (32), ***Phalaris arundinacea*** (30), *Juncus effusus* (29), *Epilobium ciliatum* (27), Agrostis sp. (24), Poa sp. (22) <u>Woody</u>: ***Rubus discolor*** (41), *Fraxinus latifolia* (35), *Crataegus douglasii* (27), *Spiraea douglasii* (20)
Oregon Natural Heritage Program (ONHP) (*unpublished*)	21 "natural" (least altered) sloughs & prairies	*Camassia quamash (17), Epilobium ciliatum (17), Oenanthe sarmentosa (16),* ***Hypochaeris radicata*** *(15), Myosotis laxa (15), Brodiaea sp. (14), Polygonum hydropiperoides (14), Carex densa (13),* ***Galium parisiense*** *(13), Rubus spectabilis (13), Veronica scutellaria (13),* ***Callitriche heterophylla*** *(11), Deschampsia cespitosa (11), Mentha arvensis (11), Carex unilateralis (10), Eleocharis palustris (10)*
USEPA-NHEERL	17 alcoves of the Willamette R.	***Phalaris arundinacea****, Rubus ursinus,* ***R. discolor****,* ***Agrostis alba****,* ***Lotus corniculatus,*** *Bidens frondosa,* ***A. tenuis****,* ***Solanum dulcamara****, Symphoricarpos albus, Salix sitchensis,* ***Tanacetum vulgare***
Magee et al. 1999	51constructed emergent (mean age= 5 yrs)	***Phalaris arundinacea*** (86), ***Holcus lanatus*** (78), ***Rubus discolor*** (75), ***Agrostis alba*** (71), ***Agrostis tenuis*** (71), ***Festuca arundinacea*** (66), *Lemna minor* (66), *Typha latifolia* (65), *Juncus effusus* (63), *Carex stipata* (61), ***Ranunculus repens*** (53), ***Solanum dulcamara*** (49), ***Alopecurus pratensis*** (49)
	45 naturally-occurring emergent	***Phalaris arundinacea*** (82), ***Holcus lanatus*** (64), ***Rubus discolor*** (62), *Juncus effusus* (60), ***Agrostis gigantea*** (53), ***Solanum dulcamara*** (51), ***Alopecurus pratensis*** (49), ***Ranunculus repens*** (47), ***Festuca arundinacea*** (44), *Lemna minor* (44), *Carex stipata* (40), ***Agrostis tenuis*** (37), *Typha latifolia* (31)

Project	Number & type of sites surveyed	**Most widely distributed plants (in approximate order of frequency)** These were not necessarily dominant <u>within</u> particular sites. Numbers in parentheses are % of sites (or # of sites for ONHP and O'Neill & Yeakley list) where found, if reported. Species in **bold** were categorized as non-native.
O'Neill & Yeakley 2000	18 urban riparian	<u>Herbs:</u> *Polystichum munitum (12),* ***Phalaris arundinacea*** *(11),* ***Solanum dulcamara*** *(10), Agrostis stolonifera (9), Carex obnupta (8),* ***Ranunculus repens*** *(7),* ***Holcus lanatus*** *(7),* ***Hedera helix*** *(7)* <u>Woody</u>*:* ***Rubus discolor*** *(18),* ***Crataegus monogyna*** *(13), Rosa nutkana (13), Fraxinus latifolia (13), Rubus ursinus (12), Corylus cornuta (9), Cornus sericea (8)*
	17 rural riparian	<u>Herbs</u>*:* ***Phalaris arundinacea*** (11), ***Urtica dioica*** *(10), Tellima grandiflora (9), Acer circinatum (9), Rosa nutkana (9),* ***Solanum dulcamara*** *(8), Polystichum munitum (7), Lonicera involucrate (7), Hydrophyllum tenuipes (6)* <u>Woody:</u> *Symphoricarpos albus (17), Rubus ursinus (15),* ***Rubus discolor*** *(12), Cornus sericea (10), Rubus parviflora (8), Corylus cornuta (8), Fraxinus latifolia (8), Physocarpus capitatus (7)*
Poracsky et al. 1992	24 forested wetlands in Metro parks	<u>Herbs</u>*:* ***Phalaris arundinacea,*** *Polystichum munitum, Crataegus* sp., *Equisetum* sp., ***Urtica dioica****, Ranunculus repens, Solanum dulcamara* <u>Woody</u>: *Fraxinus latifolia,* ***Rubus discolor****, Salix* sp., *Cornus sericea, Spiraea douglasii, Populus trichocarpa*
	12 shrub wetlands in Metro parks	<u>Herbs</u>*:* ***Phalaris arundinacea****, Juncus effusus, Epilobium ciliatum, Equisetum* sp., *Carex ovalis,* ***Poa pratensis****, Spiraea douglasii,* ***Galium aparine****, Symphoricarpos albus* <u>Woody:</u> ***Rubus discolor****, Populus trichocarpa, Salix lasiandra, Cornus sericea, Fraxinus latifolia,*
	24 meadow wetlands in Metro parks	<u>Herbs</u>*:* ***Phalaris arundinacea****, Festuca* sp., *Juncus effusus* <u>Woody</u>*: Fraxinus latifolia,* ***Rubus discolor***

Section 9. Towards Performance Standards

9.1 Background

Performance standards or performance criteria are measurable physical, chemical, and biological features that may be used as benchmarks for monitoring the ecological development of restored or constructed sites. With engineering input, they also may be used as specifications in the design of restored or constructed sites. For example, a performance standard might state, "surface water of at least 6 inches depth should cover 10% of the site during an average May-June." Applied to project design, this might be translated as "the site should receive at least 1 acre-foot of water during the May-June period." Performance standards may be narrative or numeric. They may pertain to site selection (landscape-scale considerations) and to site construction and maintenance (onsite scale). They are the reflection of goals and objectives for wetland and riparian systems generally, or goals and objectives can be specific to a particular site. Performance standards sometimes reflect specific functions and values desired by a permitting agency or land manager, but often reflect only a vaguely defined goal of creating and sustaining a "healthy" system. Performance standards should be used as tools, not as rigid rules.

Bioassessments (Section 8, this volume) and function assessments (Volume IA) can provide data helpful for establishing performance standards. Most commonly, wetland managers or consultants involved in restoring or constructing a wetland designate a minimally-altered, nearby wetland as a "reference" site, and seek to emulate its hydrogeomorphic and biological conditions. However, wetlands and their watersheds are highly variable and unique, so creating an "identical twin" is seldom practical. Thus, rather than rely entirely on a single reference site, a more prudent approach is to identify a *series* of sites belonging to the same HGM class, and then seek to design and maintain the restored/constructed site so its features fall somewhere within the range of conditions ("design envelope") present in the series of reference sites.

This guidebook project has estimated the condition of 66 features in 15 of the least altered sites in the Willamette Valley, so potentially that series of sites and the data we collected from them could be used to establish performance standards. However, for many features important to system function, we found extensive variation among the least altered sites belonging to each of the two HGM subclasses we assessed. Consequently, one might either (a) select just <u>one</u> site in each HGM subclass as the "<u>very</u> least altered" and base performance standards on its characteristics, or (b) use the average, median, minimum, or maximum condition of each feature found among the set of least altered sites. The first approach is easiest but puts unsupportable faith in one's ability to make very fine distinctions among sites with regard to their degree of previous alteration. The second approach, because it draws from the characteristics of several sites, may ultimately describe a combination of conditions that never actually exist together in nature. Moreover, in a region as developed as the Willamette Valley, one can never be certain that sites identified as least-altered are, in fact, minimally altered, so if reference site data alone are used to define performance standards, one runs the risk of setting too low the expectations for restored/constructed sites.

Thus, data from a series of least-altered reference sites, while useful as a very general guide for defining performance standards, cannot be converted seamlessly into performance standards or design specifications. As wetland specialists discovered while attempting to develop performance standards in western Washington (Azous et al. 1998), data from HGM reference sites need to be tempered with a broader understanding of wetland function and design, and with data for variables that cannot be measured in the "rapid assessment" context of an HGM approach.

There are basically three approaches to developing performance standards. The first – using data from a series of sites that span a gradient of natural disturbance and human influence – has been described above. A second approach is to determine historical conditions, ideally at the site targeted for restoration, or if that information is lacking, then in the region generally (see Runyon 1999 for procedures). Problems with this approach include (a) lack of quantitative data on characteristics of wetlands historically present in the Willamette Valley, and (b) subjectivity of the decision of which time period to use as the historical "benchmark" (pre-settlement by any humans? pre-settlement by Europeans? sites that were restored 5 or 10 years ago?). A third approach is to review results of scientific research – especially controlled experiments – for information on response thresholds of wetland and riparian systems; much of this has been compiled in Adamus and Brandt (1990). Some technical information relevant to performance standards also has been incorporated into engineering manuals for wetland design (Table 14). Problems with reliance on scientific literature and journal articles to develop performance standards include (a) lack of published findings (especially of clear "thresholds") that are transferable to the types of Willamette Valley sites addressed by this project, and (b) time and cost involved in monitoring many of the variables used in published research studies. Thus, because each approach has both assets and limitations, performance standards are best developed by considering information from all three approaches. Narrative descriptions of conditions in the region's wetland and riparian systems prior to European settlement can be found several sources (e.g., Habeck 1961, Johannessen et al. 1971, Sedell & Froggatt 1984, Boyd 1986, Davis 1995, and Benner & Sedell 1997), but is seldom quantitative. Data from our highest-scoring reference sites, as well as information from published research studies, especially from the Pacific Northwest, is included selectively in the following sections.

9.2 Information Relevant to Performance Standards for Plant Communities

In the Willamette Valley, even sites that appear to be minimally altered by humans have a wide range of conditions with regard to pattern, density, and species composition of vegetation. Historically, tree and shrub cover appears to have dominated at most RI sites, whereas SF sites historically were dominated either by herbs (e.g., wet prairies) or woody vegetation (e.g., ash swales). At least within RI sites, interspersion of herbs, shrubs, trees, and bare ground was probably great at some scales, i.e., forest stands were often interrupted by more open patches where river currents had removed trees and shrubs via erosion or deposition of enormous amounts of alluvium (Gutowsky & Jones 2000). At SF sites, patches in otherwise unbroken herb cover were created by burns initiated by native tribes, and by seasonally high water tables. Species composition of plant communities was of course quite different from today, because European settlers had not yet introduced large numbers of non-native species.

Table 14. Examples of performance assessment and design guides for wetlands

These also can assist in the drafting of performance standards. However, caution is advised because some of these focus solely on designing sites for one or a few functions, do not distinguish among HGM subclasses, and/or may not be applicable to Willamette Valley systems.

Campbell, C. and M. Ogden. 1999. Constructed Wetlands in the Sustainable Landscape. John Wiley & Sons, New York, NY.

FISRWG. 1998. Stream Corridor Restoration: Principles, Processes, and Practices. Federal Interagency Stream Restoration Working Group (FISRWG). Internet address: http://www.usda.gov/stream_restoration/

Hammer, D.A. 1996. Creating Freshwater Wetlands. Lewis Publishers, New York, NY.

Hammer, D.A.(ed.). 1989. Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, New York, NY.

Hymanson, Z.P. and H. Kingma–Rymek. 1995. Procedural Guidance for Evaluating Wetland Mitigation Projects in California's Coastal Zone. California Coastal Commission, Sacramento, CA. Internet address: http://www.coastal.ca.gov/weteval/wetc.html

Kadlec, R.H. and R.L. Knight. 1996. Treatment Wetlands. Lewis Publishers, New York, NY.

Kentula, M.E., R.P. Brooks, S.E. Gwin, C.C. Holland, A.D. Sherman, and J.C. Sifneos. 1992. An Approach to Improving Decision Making in Wetland Restoration and Creation. EPA/600/R-92/150.

King County Dept. of Natural Resources. 1998. King County Surface Water Design Manual. Water & Land Resources Div., Dept. of Natural Resources. Internet address: dnr.metrokc.gov/wlr/dss/manual.htm

Marble, A. 1990. A Guide to Wetland Functional Design. FHWA-IP-90-010. Federal Highway Administration, McLean, VA.

Ossinger, M. 1999. Success Standards for Wetland Mitigation Projects – A Guideline. Washington Dept. of Transportation, Olympia, WA. Internet address: http://pnw.sws.org/forum/mitigation.html

Schueler, T.R. 1992. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region. Metropolitan Washington Council of Governments.

USDA Natural Resources Conservation Service (NRCS). 1998. Wetland National Practice Standards. Engineering Field Handbook. USDA NRCS, Fort Worth, TX.. Internet address: http://www.pwrc.usgs.gov/wli/wetres.htm

USEPA. 1998. Design Manual for Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment. EPA/625/1-88/022. USEPA, Washington, DC. Internet address: http://www.epa.gov/owow/wetlands/wwater.html#Restoration

USEPA. A Guide for Stormwater Best Management Practices.
Internet address: http://www.epa.gov/owow/wetlands/wwater.html#Restoration
Handbook of Constructed Wetlands.
Internet address: http://www.epa.gov/owow/wetlands/wwater.html#Restoration
Subsurface Flow Constructed Wetlands for Wastewater Treatment: A Technology Assessment .
Internet address: http://www.epa.gov/owow/wetlands/wwater.html#Restoration
Guiding Principles for Constructed Treatment Wetlands: Providing Water Quality and Wildlife Habitat.
Internet address: www.epa.gov/owow/wetlands/constructed.html

USEPA. 1993. Created and Natural Wetlands for Controlling Nonpoint Source Pollution. Lewis Publishers, Ann Arbor, MI.

Recent efforts to monitor "success" of restored or constructed sites have typically focused first on plant establishment, estimating overall percent cover for a site, and sometimes survival rates and species composition. For judging restored wetlands in the west Eugene area, Alverson (1993) proposed performance criteria based partly on data he collected from a few local "representative" reference sites of each vegetation form (Table 15).

Table 15. Alverson's vegetation performance criteria for West Eugene wetlands

EMERGENT/ OPEN WATER SITES (data from 3 sites)	Low Quality site	Medium Quality site	High Quality site
% cover of native species	>50%	>75%	>90%
Number of dominant native species	1-2	2-5	>5
Number of different plant communities with different hydrologic regimes	1	1-2	>2
% cover, nonnative species	<50%	<25%	<10%

WET PRAIRIE SITES (data from 3 sites)	Low Quality site	Medium Quality site	High Quality site
Tufted hairgrass cover	25 - 50%	50 - 75%	25 - 50%
Pioneer species cover	25 - 75%	<25%	<25%
Matrix species cover	0 - 2 other species with mean cover 25 - 50%	2 - 5 other species with mean cover 25 - 50%	>5 other species with mean cover >50%
Other perennial species	0 - 2 other species within established patches	2 -5 other species within established patches	>5 other species within established patches
% cover, nonnative species	<50%	<25%	<25%

SCRUB-SHRUB SITES (data from 1 site)	Low Quality site	Medium Quality site	High Quality site
Shrub density	individual plants forming >30% total cover	individual plants or scattered clumps with 30 - 60% total cover	individual plants or scattered clumps with >60% total cover
Number of dominant shrub species	1 species	2 - 3 species	>3 species
Number of grass/forb species between shrubs	1 - 2 species	2 - 5 species	>5 species
% cover of grass/forbs	>25%	>50%	>75%
% cover of nonnative grass/forbs	<75%	<40%	<25%
proximity to other wetland types	not near	adjacent	adjacent

FORESTED SITES (data from 2 sites)	Low Quality site	Medium Quality site	High Quality site
Number of canopy tree species	1	1 - 2	>2
Total canopy cover	>50% after 10 yrs.	>30% after 10 yrs.	>30% after 10 yrs.
Density of canopy trees	~ 50/acre	20 - 50/acre	20 - 50/acre
Number of tall shrub species	0	1 - 2	>2
Total tall shrub cover	-	10 - 25%	25 - 50%
Number of low shrub species	0	0	2+
Total low shrub cover	-	-	>25%
Number of native grass/forb species with well-established colonies	1 - 2	3 - 5	6+
Total native grass/forb cover	25 - 50%	>50%	>75%

For constructed/ restored Depressional Outflow sites in western Washington, Azous et al. (1998) recommended the following performance standards for supporting "Plant Community Functions:"

(1) Total plant species should equal or exceed 60.
(2) Number of dominant plant species present (dominant being defined as >10% cover over the entire wetland) is no more than 50% of the total number of species *within each Cowardin class*, with an exception for the aquatic bed and bog classes, in which dominants may range up to 80% and 70% of total species, respectively.
(3) The percent of area covered by weed species should not exceed 15% of the wetland or 0.5 acre of contiguous cover, whichever is greater.
(4) In the emergent zones a minimum of 55% of the plant species should be obligate or facultative-wet. In the forested zones a minimum of 40% of the plant species should be obligate or facultative-wet.

This was based partly on surveys of 19 sites of this subclass; the sites varied in their probable degree of human-related disturbance, and contained 17-94 species per site.

Our project, at the highest-scoring of our least-altered sites, found conditions shown in Table 16.

Table 16. Condition of vegetation at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for Support of Characteristic Vegetation (first figure) or Primary Production (second figure, if different from first)

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered <u>Riverine Impounding</u> site**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was <u>wooded</u>**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was NOT wooded**
Percent of site vegetated	100, 80	100, 99	100
Percent of site currently affected by soil compaction	0	0	0
Number & distribution of vegetation forms	3 forms, well-interspersed	2 forms, somewhat interspersed	2 forms, somewhat interspersed
Maximum annual extent (%) of puddles & hummocks	N/A	0, 2	3
Percent of site affected by soil leveling	0	0	0
Percent & distribution of pools at *biennial low water*	conditions 0, 1 (see Vol.1 glossary)	conditions 0, 1 (see Vol.1 glossary)	0
Percent of land cover in *<u>contributing watershed</u>* & within 200 ft that is not cropland, lawns, pavement, or buildings	99, 100	100	100
Percent of seasonal zone that is bare during most of the dry season	0	0	0
Mapped soil series is hydric (not simply a hydric inclusion)	yes	yes	yes
Spatial predominance of non-native herbs	native species predominate; equal dominance of natives & non-natives	native species predominate	native species predominate
Percent of common herb species that are non-native	25, 12	0, 28	0
Number of native woody species	16, 14	9, 10	N/A
Percent of woody **species** that are native	80, 93	90, 83	N/A

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered <u>Riverine Impounding</u> site**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was <u>wooded</u>**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was NOT wooded**
Maximum percent of woody **cover** within *stratum* that is comprised of non-native species	4, 1	20, 10	N/A
Number of deadwood types	9	6, 7	N/A
Diameter (inches) of largest trees	32, 15	45, 16	N/A
Percent of site that was constructed from upland	0	0	0
Percent of site affected by soil mixing	0	0	0
Percent of site currently affected by mowing or extreme grazing	0	0	0
Frequency of humans visiting on foot -- score on scale of 100 (most) to 500 (least)	190, 380	490, 380	490
Distance to nearest busy road (ft)	600, 2430	590, 670	6300
Percent of surrounding land cover within 200 ft that is not cropland, lawn, buildings, or pavement	99, 100	100	100

We found non-native herb species to comprise between 0 and 100% of the herb species at both our RI and SF sites (median for RI = 60%, for SF = 67%). Non-native herb species comprised 39% of the 216 herb species we found among all RI sites, and 37% of the 244 herb species found among all our SF sites. Additional floristic data from our study are summarized in Appendix D. Surveys by the USEPA of 17 alcoves of the Willamette River found a larger proportion of non-natives – they nearly equaled the percentage of native species on the cumulative species list. By comparison, in the lower McKenzie River watershed, Planty-Tabacchi et al. (1996) reported only 25-35% of all plant species were non-natives, and on three other floodplains in the Pacific Northwest, about 24-30% of plant richness per site consisted of non-natives (Hood & Naiman 2000).

Riverine impounding wetland at high water, with a predominance of reed canarygrass.
(Photo courtesy of Tom Moser)

Although numbers such as those from Alverson or from our reference wetlands can provide useful benchmarks or standards, there remains a question: *What hydrologic and other environmental conditions do we need to move substandard plant communities toward such benchmarks, and to sustain those conditions?* For this, the most useful data are from plant surveys where soil hydrology was regularly measured, and from experimental studies where water regime was manipulated and response of individual plants or plant communities was simultaneously monitored. For example:

- At two West Eugene SF sites dominated by *Deschampsia cespitosa,* water level stood above the soil surface during 10-18 weeks, but was more than 5 cm above the surface during only 1-4 weeks. At a site dominated by *Rosa nutkana*, water level stood above the soil surface during 19 weeks, but was more than 5 cm above the surface during only 6 weeks. In contrast, *Eleocharis palustris* flourished at a site where water levels stood above the surface for 22 weeks and water was more than 5 cm above the surface during 21 of these weeks (Finley 1995).
- For seedling establishment and survival, several cottonwood species must have bare ground that is above stream baseflow elevation, plus a water table that drops at a rate of no more than 1 inch per day following spring flooding (Rood & Mahoney 1990, Rood et al. 1998), and inundation to a depth of about 20 cm sometime during fall, winter, and spring (Azous & Cooke 2001).
- Using data collected during a 5-year study of 26 Seattle-area wetlands, Azous & Cooke (2001) quantified the hydrologic conditions under which 14 wetland plant species common in the Pacific Northwest were found to occur[1]
- Two common sedges (*Carex rostrata* and *C. stipata*) were found to not only tolerate 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).
- Western sloughgrass (*Beckmannia syzigachne*) can survive 45 days of inundation to a depth of 15 inches (T. Flessner, NRCS, Corvallis; *pers. comm*.).
- Whether a riverine site supports woody vegetation or herbaceous (emergent) vegetation is determined in some regions of North America more by the *last date of the first flood* during the growing season, than by the *onset date of the second flood* during the growing season (Toner and Keddy 1997).
- Wetland plant richness among 6 Seattle-area wetlands was less at sites where water levels increased more than 0.5 ft above monthly mean depth for longer than 3-6 days, even when such inundation occurred less than 6 times annually (Azous et al. 2000).

Additional information of this type – mostly from other regions – has been compiled in a downloadable database (Adamus & Gonyaw 2000) at: www.epa.gov/owow/wetlands/bawwg/publicat.html#two. Unfortunately, hydrologic requirements and drought tolerances of most wetland herbs are unknown, and requirements for (or tolerance of) nutrients and sediments is known for even fewer species.

9.3 Information Relevant to Performance Standards for Fish Habitat

In the Willamette Valley, slope/flats wetlands generally do not support resident fish unless the site has been altered to maintain water year-round. In contrast, riverine impounding (RI) sites are essential to many fish species, particularly anadromous salmon. However, although

[1] The species are: *Populus trichocarpa, Spiraea douglasii, Alnus rubra, Fraxinus latifolia, Salix scouleriana, S. sitchensis, Juncus acuminatus, J. effusus, Carex obnupta, C. exsiccata, Scirpus microcarpus, S. atrocinctus, Phalaris arundinaceae*, and *Typha latifolia*. The hydrologic variables were measured during 4 seasons (early growing, intermediate growing, senescence, dormant) and include maximum depth, instantaneous depth, and magnitude of water level fluctuation.

salmonids and other fish have been surveyed and monitored extensively in the region, most sampling has been done in main channels (riverine flow-through subclass). When backwater sloughs, floodplains, and other RI sites are sampled, data are typically combined with data from the mainstem, making it difficult to discern relative degree of use of the different habitats under various conditions. An exception is ongoing work by Bayley (*pers. comm*., Oregon State University), Lavigne (*pers. comm*., Oregon State University), and Andrus (2000), who published characterizations of fish assemblages at sites that could be classified as RI. In 38 riverine flow-through sites in the Tualatin River watershed, a multiseason survey reported that 6% of the catch was comprised of nonnative species. A relatively tolerant species, the reticulate sculpin (*Cottus perplexus*), comprised 68% of the catch. Species richness per stream ranged from 5 to 15 (4 to 10 if only native species are counted). Intolerant species comprised 2% of the total catch, and 2% of the total catch had parasites or physical anomalies (Friesen and Ward 1996). Additional quantitative data, especially from least-altered riverine impounding sites, are needed regarding composition and frequency of use by fish assemblages, and quantification of physical habitat features at RI sites (e.g., wood densities, water regimes). Only then can meaningful performance standards be proposed. In the interim, the following information from our data set may be of some use.

Table 17. Condition of fish habitat indicators at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for Resident Fish Habitat (first figure), or Anadromous Fish Habitat (second figure, if different from first). Slope/flats sites are not included because fish habitat is seldom a function of unaltered slope/flats sites in the Willamette Valley.

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered <u>Riverine Impounding</u> site**
Accessible to anadromous salmonids	N/A, yes
Number of types of dead wood	2, 9
Percent & distribution of pools at *biennial high water*	>60%, undivided or not
Percent of land cover in <u>*contributing watershed*</u> & within 200 ft that is not cropland, lawns, pavement, or buildings	100
Percent of part of the site that is inundated only seasonally and contains a *closed canopy*	1
Percent of site that is inundated only seasonally	90
Percent of surface water in the 2-6 ft depth category during *biennial low water*	0
Permanent water is present	yes
Predominant depth category during *biennial low water*	0
Presence of logs &/or boulders extending above the surface of permanent water	yes; no
Type of connection to associated channel	seasonal only; permanent

9.4 Information Relevant to Performance Standards for Amphibian and Invertebrate Habitat

Controlled experiments in Seattle-area wetlands have begun to provide information useful for establishing performance standards for amphibians (Richter 1997). During the early spring, amphibians native to wetlands in the Pacific Northwest require up to one month of relatively stable water levels in order for eggs to hatch successfully. The eggs of some species are attached to stems of wetland herbs, generally less than 2 inches below the water surface. Thus, if there is not a period of time during the spring when water levels at a site fluctuate less than 2 inches during a 30-day period, the eggs of these amphibians will become dried out. A related survey of 19 Seattle-area wetlands found that when mean annual water level fluctuation exceeded 8 inches, only 3 or 4 amphibian species remained (Richter and Azous 1997).

Only recently have local researchers begun to quantify seasonal densities and richness of amphibians, turtles, and invertebrates in a variety of wetland and riparian sites in the Willamette Valley. Amphibian studies sponsored by EPA, USGS, and Oregon State University are expected to yield useful data on habitat requirements and interspecific competitive relationships (Mike Adams, Chris Pearl, Selina Heppell, *pers. comm*.). In the Seattle area, a survey of 19 wetlands found 1-8 species per site; most sites had 5 species (Richter and Azous 1997). Specific guidelines for protecting Seattle-area amphibians in the context of mitigation decisions were published by Richter (1997). For supporting amphibians in western Oregon, Gomez and Anthony (1996) recommended protection of a zone of natural woody vegetation 75-100 m on either side of a channel.

Invertebrate sampling supervised by Drs. Susan Haig and Judy Li is expected to yield data on invertebrate use of SF sites in the Willamette Valley. In the Seattle area, a survey of 19 wetlands yielded 7-13 taxonomic Orders of macroinvertebrates per site per year (one Order was split by taxonomic Family). Most restricted among sites were Odonata (absent from 16 sites), Plecoptera (absent from 11 sites), and Neuroptera (absent from 8 sites); most abundant were Aphididae (Richter et al. 1997).

Additional data will be needed to refine performance standards because the above efforts (a) include very few sites, (b) have not necessarily used sampling sites that encompass a gradient of human influence, and/or (c) have used equipment and methods that undersample many taxa. Also lacking are data on *historical use* of regional wetlands by amphibians and invertebrates, and quantitative spatial data from RI and SF sites on basic habitat variables important to invertebrates and amphibians, e.g., depth of soil litter layer, water quality, water duration. In the interim, the following information from our data set may provide a beginning foundation for performance standards.

Table 18. Condition of amphibian and invertebrate habitat indicators at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for Amphibian & Turtle Habitat Support (first figure), or Invertebrate Habitat Support (second figure, if different)

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered Riverine Impounding site**	**Condition at highest-functioning, least-altered Slope/flats site that historically was wooded**	**Condition at highest-functioning, least-altered Slope/flats site that historically was NOT wooded**
Diameter (inches) of the largest trees	21, 9	16	N/A
Difference between biennial high and low *predominating* water levels	difference of one depth category	no change	no change
Distance (ft) to nearest busy road	2100, 550	670	1260, 6300
Evenness (ratio) of wooded and natural grass cover classes within 200 ft of the site	0.98, 5.13	1.04	0.98, 13.29
Herbs as a percent of the parts of the site that are inundated only seasonally	80, 70	70	80, 100
Mapped soil series is hydric (not simply a hydric inclusion)	yes	yes	yes
Maximum annual extent (%) of puddles and hummocks	N/A	2	2, 3
Number & distribution of vegetation forms	2 forms, somewhat interspersed	2 forms, somewhat interspersed	2 forms, somewhat interspersed
Number of types of deadwood	3, 2	7	N/A
Percent & distribution of pools during *biennial high water*	conditions 6, 9 (see Vol.1A, Glossary)	condition 5 (see Vol.1A, Glossary)	condition 3 (see Vol.1A, Glossary)
Percent of land cover in *contributing watershed* & within 200 ft that is not cropland, lawns, pavement, or buildings	90, 100	90	100
Percent of site affected by soil leveling	0	0	0
Percent of site that is inundated only seasonally	29, 90	45	20, 10
Percent of site that was constructed from upland	0	0	0
Percent of surrounding land cover within 200 ft that is not cropland, lawn, buildings, or pavement	90, 99	100	100
Predominant depth category during *biennial low water*	0 inches	0 inches	0 inches
Presence of logs &/or boulders extending above the surface of permanent water	Yes	Yes	N/A
Percent of site currently affected by soil compaction	0	0	<10% of site; 0
Type of connection to associated channel	seasonal connection to/from onsite seasonal pools	none	none

Seasonally inundated Slope wetland altered by excavating down to the water table.

9.5 Information Relevant to Performance Standards for Bird Habitat

Recent studies that span a range of sites within the region are expected to help define benchmarks useful for riparian and wetland performance standards for birds. For example, Adamus and Fish (2000), in the series of 76 point counts in riparian habitat in the McKenzie-Willamette River confluence area, found between 6 and 22 breeding species per point per visit (median= 14). In contrast, at three May-June visits to a series of 54 riparian sites of various widths in the Portland metropolitan area, a recent study found 4 to 9 species per point per visit (median= 6.6) (L. Hennings, *in preparation*). That study also found:

	Median	Range
Number of native species	5.9	3.2 – 8.5
Number of Neotropical migrant species (a reputedly sensitive group)	1.6	0.7 - 3
Percent native species	92	73 - 100
Percent Neotropical migrant species	25	11 - 39

Other studies that might provide similar benchmarks include USEPA-sponsored studies of wintering birds (Adamus, *in preparation*), and wintering and migratory shorebirds (S. Haig and others*, in preparation*). See also the CD-ROM accompanying this report for breeding bird data collected from 5 of our reference sites. Additional analysis of the Poracsky et al. (1992) database covering Portland-area wetlands could also produce useful benchmarks for breeding birds and plants. In the Seattle area, a multi-year survey of 19 wetlands found 16 to 57 species per site during the breeding season (Richter and Azous 1997).

Habitat features likely to be important to wetland-associated birds are relatively well understood, but a lack of historical data on habitat structure of the region's wetlands makes it difficult to know if "cookbook" designs intended to optimize waterbird production are, in fact, appropriate and desirable for Willamette Valley wetlands. For wetlands in western Washington, Azous et al. (1998) proposed the following:

- There should be a minimum of 14 cavity trees per hectare with an average of 11 cavities per tree for a minimum total of 154 cavities per hectare.
- The average number of snags should equal or exceed 115 per hectare.

This was based partly on surveys of 19 sites. The sites varied in their probable degree of human-related disturbance, and contained 58 to 282 cavities per hectare (mean = 154), and 4-24 cavity trees per hectare.

Based on data collected in the Coast Range, Hagar (1999) recommended maintenance of unlogged buffers no narrower than 40 m (131 ft) along headwater streams, in order to provide the most benefit to some canopy-sensitive birds. Although even small birds regularly fly over large expanses of unwooded landscape, evidence from eastern North America suggests that many bird species (including those occurring in Oregon as well) are averse to doing so and instead prefer to follow wooded corridors along streams and field edges (Haas 1995, Machtans et al. 1996, Desrochers and Hannon 1997). If such corridors are unavailable, bird populations may suffer greater losses from predation. For a wooded area to be considered a corridor, it should be separated from nearby patches or corridors of woodland by unwooded gaps of no more than about 100 ft (Rail et al. 1997). However, isolated patches of woodland separated by wider gaps may nonetheless be very important to migrating birds (Skagen et al. 1998)

In the Willamette Valley, the American Bird Conservancy's recommendations for riparian songbirds, based on biological opinion and published research from other states, include the following (Altman 2000):

- Maintain all tracts of contiguous cottonwood or floodplain woodlands or tall shrublands more than 50 acres in extent.
- Retain all cottonwood trees with diameter of greater than 22 inches regardless of landscape context. Maintain mean canopy tree heights of >50 ft, with sapling trees occupying >10% ground cover in the understory.
- Seek to maintain or restore more than 30% of the historical extent of riparian habitat in the lowlands of each of the major watersheds. Maintain riparian trees in stands of widths of at least 164 ft.
- Retain large (>12 inch diameter) snags with cavities, in or adjacent to open water, at densities of at least 3 per acre.
- Maintain patchy (30-80% cover) shrub layers, with <20% cover by canopy trees, located >0.6 mile from urban/residential areas and >3 miles from pastures and feedlots.

These recommendations are based mainly on needs of four "indicator" species: Purple Martin, Willow Flycatcher, Bullock's Oriole, and Red-eyed Vireo. Survey data from the McKenzie-

Willamette River confluence area suggests the following species may also be possibly indicative of riparian forests of relatively good ecological integrity in the Willamette Valley: Band-tailed Pigeon, Hairy Woodpecker, Pileated Woodpecker, MacGillivray's Warbler (Adamus and Fish (2000).

In summary, data from a significant number of altered and unaltered sites are scarce for key habitat features important to birds, such as typical snag densities, water regimes, and seasonal food availability. In the interim, it is hoped that some of the above information, plus the following information from our data set, may provide a beginning foundation for performance standards for bird habitat.

Table 19. Condition of bird habitat indictors at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for wetland-associated Songbirds (first figure), Wintering & Migrating Waterbirds (second figure, if different), or Breeding Waterbirds (third figure, if different). No figures are given for the Breeding Waterbird function in Slope/flats sites because no sites identified as least-altered met the minimum criterion for this function (>0.5 acre of permanent water).

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered Riverine Impounding site**	**Condition at highest-functioning, least-altered Slope/flats site that historically was wooded**	**Condition at highest-functioning, least-altered Slope/flats site that historically was NOT wooded**
Diameter (inches) of largest trees	45, 20, 31	16	N/A
Difference between biennial high and low *predominating* water levels	difference of 2 classes; difference of 1 class; difference of 3 classes	no change	difference of 1 class; difference of 2 classes
Distance (ft) to nearest busy road	1130, 2130, 6840	670	6300, 1220
Frequency (score) of humans visiting on foot	450, 460, 490	380	490, 370
Herbs as a % of the parts of the site that are inundated permanently	0, 0, 80	100	--
Mapped soil series is hydric (not simply a hydric inclusion)	Yes	Yes	Yes
Maximum annual extent (%) of puddles & hummocks	N/A	2	2, 3
Maximum annual extent of vernal pools/ shorebird scrapes and mudflats	0, 100-1000 sq. ft., 0	0	1000 – 10,000 sq. ft.
Number &distribution of vegetation forms	2 or 3 forms, somewhat interspersed	2 forms, weakly interspersed	2 forms, somewhat interspersed
Number of deadwood types	12, 3, 9	7	N/A
Number of depth categories during *biennial high water.*	4, 3, 4	2	2
Number of woody species	14, 5, 8	12	N/A
Percent & distribution of pools during *biennial low water*	condition 1 (see Vol.1A, Glossary)	condition 1 (see Vol.1A, Glossary)	conditions 0, 1 (see Vol.1A, Glossary)

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered <u>Riverine Impounding</u> site**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was <u>wooded</u>**	**Condition at highest-functioning, least-altered <u>Slope/flats</u> site that historically was NOT wooded**
Percent of site currently affected by mowing or extreme grazing	0	0	0, 1
Percent of site with closed-canopy woods	95, 18, 80	35	N/A
Percent of surrounding land cover that is grassland or water/wetland (average of 200 & 1000 ft zones)	0, 20, 40	51	93, 99
Percent of surrounding land cover that is not cropland, lawn, buildings, or pavement (average of 200 and 1000 ft zones)	75, 99, 90	99	100, 99
Percent of surrounding land cover that is water or wetland, averaged among 3 zones (200, 1000, and 5280 ft)	4, 1, 17	0	3, 2
Percent of surrounding land cover that is wooded (average of 200, 1000, & 5280 ft zones)	70, 48, 35	46	N/A
Percent of surrounding land cover within 200 ft that is grassland or water/wetland	0, 20, 40	51	93, 99
Percent of surrounding land cover within 200 ft that is water or wetland (not including this site)	0, 0, 6	0	0
Percent of surrounding land cover within 200 ft that is woodland	91, 51, 60	49	N/A
Percent of surrounding land that is grassland or row crops, averaged among 3 zones (200, 1000, and 5280 ft)	35, 53, 55	57	87, 88
Percent of surrounding land within 200 ft that is grassland or row crops	0, 20, 34	51	93, 99
Percent understory shrub & vine cover in wooded areas	60, 0, 20	30	N/A
Percent vegetated	95, 99, 80	99	100
Percent woody vegetation	90, 21, 40	70	13, 8
Predominant depth category during *biennial low water*	1	1	1
Presence of permanent surface water	Yes	Yes	No
Seasonal zone as percent of site in sites that also contain *permanent* surface water	95, 29, 80	45	--
Percent of site affected by soil mixing	0	0	0

9.6 Information Relevant to Performance Standards for Water Storage Functions

In the Willamette Valley, naturally-occurring riverine impounding (RI) sites span a wide range of conditions, from sites of less than 0.1 acre that store a few inches of surface water for only a few minutes, to sites that store 20 or more feet of water for several months in depressions that are tens or perhaps hundreds of acres in size. Naturally-occurring slope-flat (SF) sites span a narrower range, with most appearing to store only a few inches of surface water (although substantial amounts of subsurface storage can occur). Both RI and SF subclasses contain basically-unaltered sites whose surface water persists year round, but most unaltered sites are inundated only seasonally. No representative, quantitative data exist on "normal" water fluctuation rates in this region's RI and SF wetlands, e.g., number of rise-fall events per season, their typical magnitude, usual seasonal timing, and hourly or daily rate of change. Given the amounts of surface runoff that are typical of the Pacific Northwest, soils with water percolation rates (inches per minute) greater than a particular threshold amount would be unlikely to support wetlands (i.e., are unlikely to remain saturated to within 12 inches of the soil surface for significant periods) unless wetland water table is substantial subsurface inflow occurs from groundwater. This rate may be available in published technical manuals[1]. Longer percolation rates would be needed to support all functions and values desired of a site.

Table 20. Condition of water storage indicators at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for Water Storage, and had also been deemed "least altered."

Indicator: (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered <u>Riverine Impounding</u> site**	**Condition at highest - functioning, least-altered <u>Slope/flats</u> site**
Percent of site that is inundated only seasonally	95	15
Vertical increase in surface water level (ft) in most of the site's seasonal zone	15	1

[1] For constructed/ restored Depressional Outflow sites in western Washington, Azous et al. (1998) recommended a performance standard for sediment permeability of 1 x 10^{-6} m/ s or 0.14 inches per hour, as sufficient to maintain water table levels on glacial till, lacustrine silts or clays, or bedrock.

Ditching of slope/flats wetlands removes capacity to store water and can thus aggravate downslope flooding and water quality problems. (photo courtesy of Tom Moser)

9.7 Information Relevant to Performance Standards for Nutrient Processing

Detention times and other characteristics required for effective removal or retention of phosphorus and nitrogen have not been measured across a range of RI and SF sites in this region, nor have detention times even been measured in a series of least-altered sites. Nutrient processing rates are also influenced by water level fluctuations and accompanying patterns of anoxia (absence of dissolved oxygen), but there no data from a regional series of least-altered RI or SF sites that relate anoxia or redox potential (an indicator of anoxia) to water level and duration of inundation. Soil organic matter additionally influences nutrient processing. Organic carbon content of 499 soil samples from western Oregon is summarized by Homann et al. (1995), who found highest content in warm, wet, clayey, valley-bottom soils. In the upper layers of mineral soils, organic carbon ranged from 0.9 to 24 kg C/ m^2. Considering just wetland and riparian areas, data from the Pacific Northwest are summarized as follows:

- At soil depths of 0-5 cm, organic carbon in 45 naturally-occurring, Portland-area sites averaged 9.75%, but was only 5.83% in 50 mitigation sites. At soil depths of 15-20 cm, the figures were (respectively) 6.85 and 4.68% (Shaffer & Ernst 1999).
- At three West Eugene sites, soil organic matter was 10.81% in a RI site, and 2.97% and 7.18% in the two SF sites (Finley 1995).
- Among 70 Seattle-area wetlands, soil organic content was almost always >10%, and usually >25% (median was about 15%) (Horner et al. 2000).

However, no data are available that relate these measurements to anoxia or nitrogen or phosphorus cycling. Moreover, organic matter "quality" and seasonal timing of its breakdown into various forms of carbon may be more important to nutrient cycling than *total* organic content (Brown 2000).

Table 22. Condition of nutrient retention/removal indicators at least-altered sites with highest function scores

See Glossary (Vol. IA, Appendix A) for procedures used to estimate indicators. "Highest Functioning" site is the site that scored the highest using the Vol. IA model for Sediment Stabilization & Phosphorus Retention (first figure), or Nitrogen Removal (second figure, if different from first)

Indicator (see Vol. IA for rationales)	**Condition at highest-functioning, least-altered Riverine Impounding site**	**Condition at highest-functioning, least-altered Slope/flats site**
Score from Water Storage & Delay assessment	1.00	0.15, 0.20
Maximum annual extent (%) of puddles & hummocks	N/A	3
Percent & distribution of pools at *biennial high water*	>60% of site, undivided	<30% of site, interspersed
Predominant soil texture	loam	clay
Percent of site affected by soil leveling	0	0
Percent of site affected by soil mixing	0	0
Percent of seasonal zone that is bare during most of the dry season.	0	0
Difference between biennial high and low predominating water levels	2 category difference	2 category difference, 0 category difference
Percent of site currently affected by soil compaction	0	0
Percent of site that was constructed from upland	0	0
Number of kinds of dead wood *	12	1, 7
Diameter of largest tree (inches) *	45	15, 16
Burned or harvested	N/A	no

* for Slope/flats sites, these numbers apply only to sites that historically were wooded

Section 10. Performance Standards in the Context of Watersheds and Landscapes

Paradoxically, if every wetland and riparian site was managed or designed such that its features became identical to those defined by the best performance standards or by data from the highest functioning of the least-altered sites, a net loss of function could still occur at a regional scale. That is because the ***diversity*** of wetlands in a watershed, landscape, or region is key to supporting most biological functions[1]. Implementing a "one size fits all" design or management regime no matter how optimal for most functions, will potentially imperil several species whose needs don't coincide with the optimal design, as well as species that require diverse types in close proximity to meet all their life requirements. No individual sites in the Willamette Valley are large enough to support all functions at their potentially highest level, as well as support all species.

[1] Also, reduced dispersion of wetlands in a watershed will likely reduce value of water storage and water quality functions at a watershed or landscape scale, because of reduced likelihood that sites will be strategically positioned to intercept runoff. However, there is no evidence to suggest that diversity of wetland HGM subclasses at a watershed or other landscape level provides more effective storage of water or improvement of water quality. Benefits of HGM subclass diversity accue mainly to biodiversity functions.

Thus, performance standards and designs applied to individual sites should be considered just one piece of a larger mosaic, and complementary standards should be developed and applied, that define the ideal diversity and configuration of sites at watershed and broader scales (Bedford 1996). As a preliminary basis for these, watershed demographic profiles that quantify variables such as the following could be prepared:

- Wetland/ riparian polygon acreage, by HGM subclass and hydric soil type
- Wetland/ riparian polygon perimeter, by HGM subclass and hydric soil type
- Interface lengths and acreages of adjoining upland polygons, by HGM subclass and hydric soil type

Data for these indicators and other landscape-level indicators could then be compiled into variables such as:

- Diversity and clustering index of subclasses
- Diversity and clustering index of sizes
- Diversity and clustering index of surrounding land cover settings
- Diversity of geologic settings
- Diversity of climatic settings

Once landscape profiles have been developed, the challenge becomes: how best to use the information to define performance standards at landscape scales. One can attempt to use the same three approaches as were used to develop site-specific performance standards (p.42), namely:

(a) Identify *least-altered* existing areas (in this case, watersheds or other landscapes), quantify their diversity and configuration of HGM subclasses, and use this "landscape profile" as a performance standard or benchmark for decisions affecting wetlands in other watersheds,

and/or

(b) Review *historical* descriptions (in this case, of diversity and configuration of wetland types throughout whole watersheds or landscapes), quantify the historical conditions, and attempt to restore them (through individual projects and regulatory decisions) in today's landscape,

and/or

(c) Conduct computer *modeling*, employing climatological, edaphic, and land use spatial data, to predict wetland distribution across landscapes, and simultaneously review scientific literature for response thresholds of wetland and riparian species to landscape-scale factors[1]. Managers would use model outputs to catalog and map the diversity of wetland/ riparian templates, and compare that to what wetland/ riparian sites currently exist, so as to define site potential and then plan the most realistic and useful *long term* goals for restoration and management. In much of eastern Oregon some work of this nature has already been accomplished for *riparian* systems by the Interior Columbia Basin Ecosystem Management Project (ICBEMP, Quigley & Arbelbide 1997) using water surplus values, vegetation/ climate models, remotely sensed imagery, and GIS tools. Water surplus values

[1] Such modeled wetland distributions have been termed "templates" and they essentially address "site potential" -- the ability of a particular landscape to sustain a particular type and size of wetland over the long term. A template might specify, for example, that landscapes within a given region that are relatively wet and cool and mostly contain soils derived from volcanic material would, over centuries, produce or support one kind of wetland/ riparian site with different levels of functions than sites produced in landscapes that are relatively dry and warm and contain glacial outwash soils.

(ratio of annual evapotranspiration to precipitation) were 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.

Obstacles to implementing any of the above three approaches at watershed and broader scales are even more formidable than those encountered when defining performance standards at the scale of an individual site. Using *landscape HGM profiles* (that describe the diversity and configuration of wetlands in a few least-altered watersheds within the Willamette Valley, e.g., Tiner et al. 2000) to establish standards for wetland diversity and configuration in *all* watersheds in the region is scientifically untenable, because of significant within-region variation in geology and unknown degrees of human alteration of runoff and subsurface flow patterns. Using *historical information* on diversity and configuration of wetlands in a particular watershed is impractical, because there exist no pre-settlement wetland maps of sufficient detail. This forces one to only speculate as to whether particular subclasses have increased or decreased proportionately, e.g., depressional wetlands in the Portland metropolitan area (Gwin et al. 1999).

Using the third approach – and computer modeling and literature review– also has limits. There simply is no way to adequately check the accuracy of maps of wetlands predicted (modeled) using this approach, and any model-based predictions are likely to be confounded by numerous unknown (unmappable) alterations to existing drainage patterns. Moreover, only recently have local researchers begun to focus on needs of species or species assemblages for particular combinations of wetland types, or for wetland subclass diversity generally. Examples include ongoing local studies of landscape-scale habitat use by (Dr. Susan Haig of USGS) and amphibians (Dr. Selina Heppell of Oregon State University). Spatially-explicit simulation models for predicting thresholds of vertebrate biodiversity response to changing land cover patterns in the Willamette Valley are also being tested (J. Baker, USEPA National Health & Environmental Effects Research Laboratory, *pers. comm.*; M. Santelmann, Oregon State University, *pers. comm.*, Hulse et al. 2000, Adamus 2000). As outputs from such efforts become available, they should help address the challenge of defining performance standards for wetland diversity and configuration at watershed and broader scales.

Farmed wetlands add diversity to the landscape and are vital to many waterbird species.

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Appendix A. Evidence for selection or rejection of reference sites as least altered

Legend: Sites in **bold** ultimately were considered to be the least-altered and thus were used as reference standard sites. The list of conditions shown below is not comprehensive, i.e., does not describe the condition of all indicators at each site, but rather focuses on ones that best distinguish each site from other sites.

1. Riverine Impounding subclass sites

Site	Evidence for GOOD Condition	Evidence for POOR Condition
Adair pond		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition. Woody vegetation has been greatly reduced from presettlement condition. Only a small percent of the herb species were also found at the least-altered sites of this subclass.
Alton Baker Park slough		>10% of site's water regime is influenced by artificial impoundment within the site. Reducing conditions were not found in the site's soils. A large percent of the common herbs are non-natives.
Anderson Park alcove	Native woody species comprise a large percent of all woody species at the site. The site is relatively far (>1 mile) from a well-traveled road. Human visitation of most of the site is relatively infrequent.	Non-native herb species predominate spatially.
Anderson Park sloughs	A large percent of the common herbs are natives. Native woody species comprise a large spatial portion of all 3 woody strata. The site is relatively far (>1 mile) from a well-traveled road. Some very large diameter (>49 inch dbh) trees are present. Human visitation of most of the site is relatively infrequent.	
Bowers Rock slough	Native woody species comprise a large spatial portion of all 3 woody strata. Some very large diameter (>49 inch dbh) trees are present.	Non-native herb species predominate spatially. A large percent of the common herbs are non-natives. Water is apparently pumped out of the site directly. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% developed and/or cropland. A large portion of the contributing watershed within 200 ft of the site is not cropland, pavement, buildings, or lawns.
Brown's Ferry pond		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition. Woody vegetation has been greatly reduced from presettlement condition. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% developed and/or cropland.
Brownsville constructed		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime is possibly influenced by ditches within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Buford West slough	Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland. A large portion of the contributing watershed within 200 ft of the site is not cropland, pavement, buildings, or lawns.	>10% of site's water regime is influenced by artificial impoundment within the site.
Calapooia River 1	Water levels in associated river or stream are not controlled. Native woody species comprise a large percent of all woody species at the site.	Site's water regime is probably influenced by downcutting in associated channel). Non-native herb species predominate spatially.
Calapooia River 2		>10% of site's soils may have been plowed or reshaped in recent years.

Site	Evidence for GOOD Condition	Evidence for POOR Condition
Cascades Gateway slough		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Christensen Park slough	Native herb species predominate spatially in the herb stratum. A large percent of the herb species were also found at the least-altered sites of this subclass. Native woody species comprise a large spatial portion of all 3 woody strata. Human visitation of most of the site is relatively infrequent. The site is relatively far (>1 mile) from a well-traveled road.	Land cover in the 200-ft buffer zone around the site is >70% developed and/or cropland.
Coffin Butte pond		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition. A large portion of the contributing watershed within 200 ft of the site is cropland, pavement, buildings, or lawns.
Cook Park slough	Native woody species comprise a large spatial portion of all 3 woody strata.	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% developed and/or cropland. Stormwater pipes discharge into the site. The site is relatively near (within 300 ft of) a well-traveled road. Human visitation of most of the site is relatively frequent.
Coyote floodplain	Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site may have been mowed, severely grazed, or clearcut in recent years.
Delta Ponds		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition. Woody vegetation has been greatly reduced from presettlement condition.
Fanno Creek duck donut		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. >10% of the soils at the site may have been leveled. >10% of site's water regime may have been influenced by artificial excavation within the site. >10% of site's soils may have been plowed or reshaped in recent years. Woody vegetation has been greatly reduced from presettlement condition.
Finley floodplain	Water levels in associated river or stream are not controlled. A large percent of the common herbs are natives. Human visitation of most of the site is relatively infrequent. Native woody species comprise a large percent of all woody species at the site. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	
Gibson Creek enhanced slough		A large portion of the site was constructed from upland.
Grand Island slough	Some very large diameter (>49 inch dbh) trees are present. Native woody species comprise a large percent of all woody species at the site.	Non-native herb species predominate spatially. The site is relatively near (within 300 ft of) a well-traveled road. A large portion of the contributing watershed within 200 ft of the site is not cropland, pavement, buildings, or lawns.

Site	Evidence for GOOD Condition	Evidence for POOR Condition
Greenberry floodplain	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Native woody species comprise a large spatial portion of all 3 woody strata. Human visitation of most of the site is relatively infrequent. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland.	Little or no closed-canopy forest is present in this historically wooded site.
Hedges Creek duck ponds		>10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Hileman Park alcove	The site is relatively far (>1 mile) from a well-traveled road. Human visitation of most of the site is relatively infrequent. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	Non-native herb species predominate spatially. A large percent of the common herbs are non-native.
Hileman Park slough	Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. A large percent of the herb species were also found at the least-altered sites of this subclass.	>10% of site's water regime is influenced by artificial impoundment within the site.
Jackson-Frazier floodplain	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Human visitation of most of the site is relatively infrequent. Native woody species comprise a large percent of all woody species at the site. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland.	
Jasper Park slough		Human visitation of most of the site is relatively frequent.
Luckiamute floodplain	The site is relatively far (>1 mile) from a well-traveled road. Human visitation of most of the site is relatively infrequent.	Herb cover is more non-native than native species. Only a small percent of the herb species were also found at the least-altered sites of this subclass.
McDonald Forest ponds	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Human visitation of most of the site is relatively infrequent. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland. A large percent of the common herbs are natives. A large portion of the contributing watershed within 200 ft of the site is not cropland, pavement, buildings, or lawns. Native woody species comprise a large percent of all woody species at the site. Native woody species comprise a large spatial portion of all 3 woody strata.	
Minto-Brown big slough		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of the soils at the site may have been leveled. >10% of site's soils may have been plowed or reshaped in recent years. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Minto-Brown slough 1		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of the soils at the site may have been leveled. >10% of site's soils may have been plowed or reshaped in recent years. Woody vegetation has been greatly reduced from presettlement condition.
Minto-Brown slough 2		>10% of site's soils may have been compacted. A large percent of the common herbs are non-natives.

Site	Evidence for GOOD Condition	Evidence for POOR Condition
Mt.View enhanced slough		>10% of site's water regime is possibly influenced by ditches within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. >10% of site's soils may have been plowed or reshaped in recent years. A large portion of the site was constructed from upland.
Oaks Bottom backwater		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition Woody vegetation has been greatly reduced from presettlement condition.
Philomath Park slough		>10% of site's water regime is influenced by artificial impoundment within the site.
Rickreall flat	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Human visitation of most of the site is relatively infrequent. Land cover in the 200-ft buffer zone around the site is >95% undeveloped and not cropland. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	>10% of site's water regime may have been influenced by artificial excavation within the site. A large portion of the site was constructed from upland.
Scio pond		>10% of site's water regime may have been influenced by artificial excavation within the site.
Shooting range pond		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Snagboat Bend slough	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland. Human visitation of most of the site is relatively infrequent.	Non-native herb species predominate spatially. Only a small percent of the herb species were also found at the least-altered sites of this subclass. The site is relatively near (within 300 ft of) a well-traveled road.
Spongs Landing slough	Human visitation of most of the site is relatively infrequent. Native woody species comprise a large spatial portion of all 3 woody strata. Some very large diameter (>49 inch dbh) trees are present.	
Stayton Interchange restored		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. >10% of the soils at the site may have been leveled. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Summerlake Park pond		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Woody vegetation has been greatly reduced from presettlement condition.
Takena Park sloughs	Some very large diameter (>49 inch dbh) trees are present. Native woody species comprise a large spatial portion of all 3 woody strata.	Non-native herb species predominate spatially. Human visitation of most of the site is relatively frequent.
Timber-Linn pond		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.

Site	Evidence for GOOD Condition	Evidence for POOR Condition
Truax gravelpit restoration		>10% of the soils at the site may have been leveled. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition. Woody vegetation has been greatly reduced from presettlement condition.
Truax slough		Non-native herb species predominate spatially. A large percent of the common herbs are natives.
Tualatin Hills Lily Pond	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	Human visitation of most of the site is relatively frequent
Tualatin Hills Big Pond	Water levels in associated river or stream are not controlled. Native herb species predominate spatially in the herb stratum. Native woody species comprise a large percent of all woody species at the site. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	Human visitation of most of the site is relatively frequent.
Tualatin NWR beaverdam	A large percent of the herb species were also found at the least-altered sites of this subclass.	>10% of site's water regime is possibly influenced by ditches within the site. Woody vegetation has been greatly reduced from presettlement condition.
Tualatin NWR Chicken Cr.	Human visitation of most of the site is relatively infrequent at present.	Land cover in the 200-ft buffer zone around the site is >70% developed and/or cropland. Little or no closed-canopy forest is present in this historically wooded site. Largest tree has small diameter (<18 inches). Only a small percent of the herb species were also found at the least-altered sites of this subclass.
Whitley Landing floodplain		>10% of site's water regime is influenced by artificial impoundment within the site. >10% of site may have been mowed, severely grazed, or clearcut in recent years. >10% of the soils at the site may have been leveled. A large percent of the common herbs are non-native. Only a small percent of the common herb species were also common at the least-altered sites of this subclass.
Willamette Mission slough	Some very large diameter (>49 inch dbh) trees are present. Native woody species comprise a large spatial portion of all 3 woody strata.	Non-native herb species predominate spatially. A large portion of the contributing watershed within 200 ft of the site is cropland, pavement, buildings, or lawns. A large percent of the common herb species are non-native.
Willamette Park slough	A large percent of the herb species were also found at the least-altered sites of this subclass.	>10% of site's water regime may have been influenced by artificial excavation within the site.
Willow Creek riverine	Water levels in associated river or stream are not significantly controlled. A large percent of the common herbs are natives. Native woody species comprise a large spatial portion of all 3 woody strata. Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >90% undeveloped and not cropland.	Largest tree has small diameter (<18 inches).
Wilson Wildlife Area north pond		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition.
Wilson Wildlife Area main pond		>10% of site's soils may have been compacted. >10% of site's water regime is influenced by artificial impoundment within the site. >10% of site's water regime may have been influenced by artificial excavation within the site. Apparently the site once belonged to a different HGM subclass but was altered to its present condition

2. Slope/flats subclass sites

	Evidence for Good Condition	Evidence for Poor Condition
Acker pasture	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site.	>20% of site's soils have apparently been compacted. >20% of site has been mowed or heavily grazed in recent years. The site is relatively near (within 300 ft of) a well-traveled road. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Only a small percent of the site's herb species were also found at the least-altered sites of this subclass. Woody vegetation has been greatly reduced from presettlement condition. A large percent of the woody cover is non-native species.
Adair Park woods	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Human visitation of most of the site is relatively infrequent.	Herb cover is more non-native than native species.
Adair pasture slope	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement.	>20% of site has been altered by artificial drainage. Herb cover is more non-native than native species. >20% of site has been mowed or clearcut in recent years. >20% of site's soils have been plowed or reshaped in recent years. A large percent of the woody cover is non-native species. Native woody species comprise a small percent of all woody species at the site.
Albany powerline	At least 100 sq. ft. of vernal pool habitat is present.	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% cropland, lawns, & pavement. Land cover within 200 ft of the site is largely cropland, lawns, or pavement. Herb cover is more non-native than native species. >20% of site's soils have been plowed or reshaped in recent years.
Aumsville slope		>20% of site's water regime is influenced by ditches within the site. Herb cover is more non-native than native species. Woody vegetation has been greatly reduced from presettlement condition. Native woody species comprise a small percent of all woody species at the site.
Balboa restored	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	>20% of site's soils have been plowed or reshaped in recent years.
Bald Hill Park pond	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	>20% of site's water regime is influenced by artificial excavation within the site. >20% of site's soils have been plowed or reshaped in recent years. Woody vegetation has been greatly reduced from presettlement condition. Human visitation of most of the site is relatively frequent.
Beggars-tick marsh		Land cover within 200 ft of the site is largely cropland, lawns, or pavement. >20% of site's water regime is influenced by artificial impoundment within the site. Herb cover is more non-native than native species. Stormwater pipes discharge into the site.
Brown's Ferry forest	Native woody species comprise a large percent of all woody species at the site.	The site is relatively near (within 300 ft of) a well-traveled road. Soils in the vicinity are generally non-hydric, although the site has reducing conditions.
Buford East hillslope	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	

	Evidence for Good Condition	Evidence for Poor Condition
Champoeg Park flat	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. At least 100 sq. ft. of vernal pool habitat is present. Native woody species comprise a large percent of all woody species at the site.	Herb cover is more non-native than native species. >20% of site has been mowed or clearcut in recent years. Woody vegetation has been greatly reduced from presettlement condition.
Champoeg Park woods	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Human visitation of most of the site is relatively infrequent.	Herb cover is more non-native than native species.
Cheyenne Way flat	A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site.	A portion of the site was constructed from upland. >20% of site has been altered by artificial drainage. Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. Herb cover is more non-native than native species. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Woody vegetation has been greatly reduced from presettlement condition.
Coffin Butte flat	At least 100 sq. ft. of vernal pool habitat is present. Native woody species comprise a large percent of all woody species at the site.	>20% of site's water regime is influenced by artificial impoundment within the site. Herb cover is more non-native than native species. >20% of site's soils have been plowed or reshaped in recent years. A large percent of the woody cover is non-native species.
Coffin Butte upslope		>20% of site's soils have apparently been compacted. >20% of site's water regime is influenced by artificial impoundment within the site. Herb cover is more non-native than native species. A large percent of the woody cover is non-native species. Native woody species comprise a small percent of all woody species at the site.
Cook Park restored		Land cover within 200 ft of the site is largely cropland, lawns, or pavement. >20% of site's soils have apparently been compacted. Herb cover is more non-native than native species. >20% of site's water regime is influenced by artificial excavation within the site. >20% of site's soils have been plowed or reshaped in recent years. Woody vegetation has been greatly reduced from presettlement condition.
Corvallis Airport flat	A large percent of the dominant herbs are natives. At least 100 sq. ft. of vernal pool habitat is present. Human visitation of most of the site is relatively infrequent.	>20% of site's soils have apparently been compacted. Herb cover is more non-native than native species. Only a small percent of the site's herb species were also found at the least-altered sites of this subclass. >20% of site has been mowed or clearcut in recent years. More than 20% of the soils at the site have apparently been leveled. >20% of site's soils have been plowed or reshaped in recent years.
Coyote Creek meadow	Native woody species comprise a large percent of all woody species at the site.	>20% of site's water regime is influenced by artificial impoundment within the site. Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. Herb cover is more non-native than native species.
Coyote Creek woods	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site. Human visitation of most of the site is relatively infrequent.	Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years.

	Evidence for Good Condition	Evidence for Poor Condition
Dimple Hill seep	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. The site is relatively far (>1 mile) from a well-traveled road. Native woody species comprise a large percent of all woody species at the site.	Soils in the vicinity are generally non-hydric, although the site has reducing conditions.
Ferry Street flat		Herb cover is more non-native than native species. >20% of site's soils have been plowed or reshaped in recent years. The site is relatively near (within 300 ft of) a well-traveled road.
Finley ash swale	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site. Human visitation of most of the site is relatively infrequent.	Soils in the vicinity are generally non-hydric, although the site has reducing conditions.
Finley prairie	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site. The site is relatively far (>1 mile) from a well-traveled road. At least 100 sq. ft. of vernal pool habitat is present. Human visitation of most of the site is relatively infrequent.	
Finley slope pond	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. >20% of site's water regime is influenced by artificial excavation within the site. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Woody vegetation has been greatly reduced from presettlement condition.
Fisher Butte prairie	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site. At least 100 sq. ft. of vernal pool habitat is present.	
Frazier-Cogswell forest	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site. Human visitation of most of the site is relatively infrequent.	
Greenhill Road prairie	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site. At least 100 sq. ft. of vernal pool habitat is present.	>20% of site has been mowed or clearcut in recent years.

	Evidence for Good Condition	Evidence for Poor Condition
Hunziker Road flat	Native woody species comprise a large percent of all woody species at the site.	Land cover within 200 ft of the site is largely cropland, lawns, or pavement. Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. Stormwater pipes discharge into the site. Woody vegetation has been greatly reduced from presettlement condition.
Hyland Park pond	Native woody species comprise a large percent of all woody species at the site.	Only a small percent of the site's herb species were also found at the least-altered sites of this subclass. A portion of the site was constructed from upland. >20% of site's water regime is influenced by artificial impoundment within the site. Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. >20% of site's water regime is influenced by artificial excavation within the site. Human visitation of most of the site is relatively frequent.
Jackson-Frazier prairie	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	>20% of site's water regime is influenced by ditches within the site. >20% of site's soils have been plowed or reshaped in recent years.
Lebanon ODOT	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. At least 100 sq. ft. of vernal pool habitat is present. Native woody species comprise a large percent of all woody species at the site.	A portion of the site was constructed from upland. The site is relatively near (within 300 ft of) a well-traveled road.
Marion bank flat	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. At least 100 sq. ft. of vernal pool habitat is present. Human visitation of most of the site is relatively infrequent.	Herb cover is more non-native than native species. Only a small percent of the site's herb species were also found at the least-altered sites of this subclass. >20% of site has been mowed or clearcut in recent years. >20% of site's soils have been plowed or reshaped in recent years. Woody vegetation has been greatly reduced from presettlement condition. A large percent of the woody cover is non-native species.
Marion bank pond	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement.	>20% of site's water regime is influenced by artificial excavation within the site. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Woody vegetation has been greatly reduced from presettlement condition. Native woody species comprise a small percent of all woody species at the site.
Marys River flat	Native woody species comprise a large percent of all woody species at the site.	>20% of site's soils have been plowed or reshaped in recent years. The site is relatively near (within 300 ft of) a well-traveled road.
Nimbus Drive slope	At least 100 sq. ft. of vernal pool habitat is present.	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% cropland, lawns, & pavement. Land cover within 200 ft of the site is largely cropland, lawns, or pavement. >20% of site's soils have apparently been compacted. >20% of site's water regime is influenced by artificial impoundment within the site. Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. Herb cover is more non-native than native species. Stormwater pipes discharge into the site. The site is relatively near (within 300 ft of) a well-traveled road. Woody vegetation has been greatly reduced from presettlement condition. Human visitation of most of the site is relatively frequent.

	Evidence for Good Condition	**Evidence for Poor Condition**
OSU Pasture forest	Native woody species comprise a large percent of all woody species at the site.	Woody vegetation has been reduced from presettlement condition. >20% of site has been mowed or heavily grazed in recent years.
OSU Pasture slope	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site.	Herb cover is more non-native than native species. Only a small percent of the common herb species were also common at the least-altered sites of this subclass. >20% of site's soils have been plowed or reshaped in recent years. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. A large percent of the woody cover is non-native species.
Oak Creek restoration	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. At least 100 sq. ft. of vernal pool habitat is present. A large percent of the herb species were also found at the least-altered sites of this subclass.	>20% of site's soils have been plowed or reshaped in recent years. Native woody species comprise a small percent of all woody species at the site.
Philomath Industrial slope	Native woody species comprise a large percent of all woody species at the site. Human visitation of most of the site is relatively infrequent.	
Philomath Park meadow	Native woody species comprise a large percent of all woody species at the site.	Apparently, the site once belonged to a different HGM subclass but was altered to its present condition >20% of site has been mowed or clearcut in recent years. >20% of site has been mowed or clearcut in recent years. Soils in the vicinity are generally non-hydric, although the site has reducing conditions.
Seavy prairie	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. A large percent of the herb species were also found at the least-altered sites of this subclass. Native woody species comprise a large percent of all woody species at the site.	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% cropland, lawns, & pavement.>20% of site has been mowed or clearcut in recent years. The site is relatively near (within 300 ft of) a well-traveled road.
Sherwood seeps		Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is >50% cropland, lawns, & pavement. Herb cover is more non-native than native species. Soils in the vicinity are generally non-hydric, although the site has reducing conditions.
Shooting range woods	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	
Stewart Ponds		>20% of site's water regime is influenced by artificial excavation within the site. Human visitation of most of the site is relatively frequent. A large percent of the woody cover is non-native species.
Tampico forest	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. A large percent of the dominant herbs are natives. Native woody species comprise a large percent of all woody species at the site. Human visitation of most of the site is relatively infrequent.	
Scio pasture	Land cover averaged among the 200, 1000, and 5280-ft buffer zones around the site is <10% cropland, lawns, & pavement. Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	>20% of site's soils have apparently been compacted. >20% of site has been mowed or clearcut in recent years. >20% of site's soils have been plowed or reshaped in recent years.
Tice Park seeps		Stormwater pipes discharge into the site. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Woody vegetation has been greatly reduced from presettlement condition.

	Evidence for Good Condition	**Evidence for Poor Condition**
Tualatin NWR Steinborn	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. At least 100 sq. ft. of vernal pool habitat is present. Human visitation of most of the site is relatively infrequent.	>20% of site's soils have been plowed or reshaped in recent years. A large percent of the woody cover is non-native species.
Walnut Park slope		>20% of site's water regime is influenced by ditches within the site. Herb cover is more non-native than native species. Human visitation of most of the site is relatively frequent. Native woody species comprise a small percent of all woody species at the site.
West Waluga seeps		>20% of site's soils have apparently been compacted. Herb cover is more non-native than native species.
Willow Creek prairie	Land cover within 200 ft of the site is NOT mostly cropland, lawns, & pavement. Native woody species comprise a large percent of all woody species at the site.	Woody vegetation in parts of the site has increased from presettlement condition.
Wilson Wildlife Area prairie	A large percent of the dominant herbs are natives. A large percent of the herb species were also found at the least-altered sites of this subclass.	>20% of site's soils have apparently been compacted.
Winsor flat		Stormwater pipes discharge into the site. Soils in the vicinity are generally non-hydric, although the site has reducing conditions. Native woody species comprise a small percent of all woody species at the site.
Zenger Farm flat	Native woody species comprise a large percent of all woody species at the site. Only a small percent of woody cover is non-native species. A large percent of the common herb species were also common at the least-altered sites of this subclass.	Land cover within 200 ft of the site is largely cropland, lawns, or pavement. >20% of site's soils have apparently been compacted. >20% of site's water regime is influenced by artificial impoundment within the site. Herb cover is more non-native than native species. Stormwater pipes discharge into the site. Soils in the vicinity are generally non-hydric, although the site has reducing conditions.

Appendix B. Fish Species That Use Willamette Valley Wetland/Riparian Habitats

Species	Anadromous	Resident
chiselmouth		•
chub, Oregon		•
dace, leopard		•
dace, longnose		•
dace, speckled		•
lamprey, Pacific	•	
lamprey, river	•	
mountain whitefish		•
peamouth		•
salmon, chinook	•	
salmon, coho	•	
salmon, sockeye	•	
sand roller		•
sculpin, prickly		•
shad, American	•	
shiner, redside		•
squawfish, northern (pikeminnow)		•
steelhead	•	
stickleback, threespine		•
sturgeon, white		•
sucker, largescale		•
trout, coastal cutthroat	•	

Appendix C. Bird Species That Use Willamette Valley Wetland/Riparian Habitats

Species	Wintering/Migrating Waterbirds	Breeding Waterbirds	Songbirds & others
Pied-billed Grebe	•	•	
Horned Grebe	•		
Eared Grebe	•		
Western Grebe	•	•	
Double-crested Cormorant	•	•	
American Bittern	•	•	
Great Blue Heron	•	•	
Great Egret	•		
Green Heron	•	•	
Black-crowned Night-Heron	•		
Tundra Swan	•		
Trumpeter Swan	•		
Canada Goose	•	•	
Greater White-fronted Goose	•		
Snow Goose	•		
Wood Duck	•	•	
Green-winged Teal	•	•	
Mallard	•	•	
Northern Pintail	•	•	
Blue-winged Teal	•	•	
Cinnamon Teal	•	•	
Northern Shoveler	•	•	
Gadwall	•	•	
Eurasian Wigeon	•		
American Wigeon	•		
Canvasback	•		
Redhead	•		
Ring-necked Duck	•	•	
Lesser Scaup	•		
Common Goldeneye	•		
Bufflehead	•		
Hooded Merganser	•	•	
Common Merganser	•	•	
Ruddy Duck	•		
Turkey Vulture			•
Osprey		•	
Bald Eagle	•	•	
White-tailed Kite			•
N. Harrier			•
Sharp-shinned Hawk			•
Cooper's Hawk			•
Red-shouldered Hawk			•
Red-tailed Hawk			•
Rough-legged Hawk			•
Golden Eagle			•
Am. Kestrel			•
Merlin			•
Peregrine Falcon			•
Ring-necked Pheasant			•
Ruffed Grouse			•
Wild Turkey			•
California Quail			•
Virginia Rail	•	•	
Sora	•	•	
Am. Coot	•	•	
Sandhill Crane	•		
Killdeer	•	•	

Species	Wintering/Migrating Waterbirds	Breeding Waterbirds	Songbirds & others
Black-bellied Plover	•		
Semipalmated Plover	•		
Greater Yellowlegs	•		
Lesser Yellowlegs	•		
Western Sandpiper	•		
Least Sandpiper	•		
Dunlin	•		
Spotted Sandpiper	•	•	
Long-billed Dowitcher	•		
Common Snipe	•	•	
Wilson's Phalarope	•	•	
Mew Gull	•		
Ring-billed Gull	•		
California Gull	•		
Glaucous-winged Gull	•		
Black Tern	•	•	
Band-tailed Pigeon			•
Mourning Dove			•
Barn Owl			•
W. Screech-Owl			•
Great Horned Owl			•
N. Pygmy-Owl			•
Barred Owl			•
Long-eared Owl			•
Short-eared Owl			•
N. Saw-whet Owl			•
Common Nighthawk			•
Vaux's Swift			•
Anna's Hummingbird			•
Rufous Hummingbird			•
Belted Kingfisher	•	•	•
Acorn Woodpecker			•
Red-breasted Sapsucker			•
Downy Woodpecker			•
Hairy Woodpecker			•
N. Flicker			•
Pileated Woodpecker			•
Olive-sided Flycatcher			•
W. Wood-Pewee			•
Willow Flycatcher			•
Pacific-slope Flycatcher			•
W. Kingbird			•
E. Kingbird			•
Horned Lark			•
Purple Martin			•
Tree Swallow			•
Violet-green Swallow			•
N. Rough-winged Swallow			•
Cliff Swallow			•
Barn Swallow			•
Steller's Jay			•
W. Scrub-Jay			•
Am. Crow			•
Black-capped Chickadee			•
Chestnut-backed Chickadee			•
Bushtit			•
Red-breasted Nuthatch			•
White-breasted Nuthatch			•
Brown Creeper			•
Bewick's Wren			•
House Wren			•
Winter Wren			•

Species	Wintering/Migrating Waterbirds	Breeding Waterbirds	Songbirds & others
Marsh Wren			•
Golden-crowned Kinglet			•
Ruby-crowned Kinglet			•
W. Bluebird			•
Swainson's Thrush			•
Hermit Thrush			•
Am. Robin			•
Varied Thrush			•
Western Bluebird			•
American Pipit			•
Cedar Waxwing			•
Northern Shrike			•
European Starling			•
Cassin's Vireo			•
Hutton's Vireo			•
Warbling Vireo			•
Red-eyed Vireo			•
Orange-crowned Warbler			•
Nashville Warbler			•
Yellow Warbler			•
Yellow-rumped Warbler			•
Black-throated Gray Warbler			•
Townsend's Warbler			•
MacGillivray's Warbler			•
Common Yellowthroat			•
Wilson's Warbler			•
Yellow-breasted Chat			•
W. Tanager			•
Black-headed Grosbeak			•
Lazuli Bunting			•
Spotted Towhee			•
Chipping Sparrow			•
Vesper Sparrow			•
Savannah Sparrow			•
Grasshopper Sparrow			•
Fox Sparrow			•
Song Sparrow			•
Lincoln's Sparrow	•		•
Swamp Sparrow	•		•
Golden-crowned Sparrow			•
White-crowned Sparrow			•
White-throated Sparrow			•
Dark-eyed Junco			•
Red-winged Blackbird	•		•
W. Meadowlark			•
Yellow-headed Blackbird	•		•
Brewer's Blackbird			•
Brown-headed Cowbird			•
Bullock's Oriole			•
Purple Finch			•
House Finch			•
Pine Siskin			•
Lesser Goldfinch			•
Am. Goldfinch			•
Evening Grosbeak			•

Appendix D. Sites ranked according to plant metrics

Sites are ranked according to data in the 5th column (Hdom20, the % of common herbs that are native).
Other columns are:

Area= area of the site, in acres
Nplots= number of herb plots surveyed at that site
TotSp= total number of herb species found
OlapRef= number of herb species also found at one or more of the least-altered reference sites of the same subclass
OlapDom= number of herb species found that were common at one or more of the least-altered reference sites of the same subclass
WdSp= number of woody species
WdSp%N= percent of woody species that are native

Sites designated as least-altered are in bold.

1. Riverine Impounding sites

Site	Area	Nplot	TotSp	Hdom20	OlapRef	OlapDom	WdSp	WdSp%N
Hileman Park alcove	0.10	3	41	0.00	80.00	42.86	8	75.00
Whitley Landing floodplain	0.20	3	13	0.00	60.00	10.00	11	72.73
Willamette Mission slough	87.00	9	34	0.00	77.27	40.91	19	84.21
Truax slough	4.02	6	40	28.57	67.86	32.14	13	84.62
Alton Baker Park slough	0.90	3	17	33.33	81.82	27.27	2	50.00
Bowers Rock slough	4.30	5	20	33.33	68.75	25.00	11	72.73
Minto-Brown slough 2	8.40	4	12	33.33	75.00	25.00	12	83.33
Minto-Brown big slough	48.20	4	21	40.00	70.59	35.29	19	78.95
Takena Park sloughs	17.40	5	15	40.00	83.33	33.33	11	72.73
Timber-Linn pond	9.35	7	34	42.86	62.50	25.00	11	72.73
Cascades Gateway slough	12.00	4	22	50.00	85.00	55.00	19	89.47
Cook Park slough	1.50	3	13	50.00	72.73	45.45	26	80.77
Coyote floodplain	6.27	7	35	50.00	58.82	8.82	0	--
Delta Ponds	22.00	6	36	50.00	80.00	52.00	9	77.78
Grand Island slough	9.00	4	14	50.00	81.82	45.45	12	91.67
Hedges Creek duck ponds	0.30	12	22	50.00	71.43	57.14	11	54.55
Minto-Brown slough 1	6.70	6	34	50.00	76.00	32.00	21	71.43
Spongs Landing slough	26.00	3	19	50.00	100.00	40.00	14	85.71
Tualatin NWR beaverdam	0.10	3	8	50.00	100.00	40.00	6	66.67
Tualatin NWR Chicken Cr.	62.91	6	33	55.56	55.17	31.03	2	0.00
Brownsville constructed	0.50	6	39	57.14	80.00	46.67	4	75.00
Snagboat Bend slough	21.84	9	35	57.14	57.14	34.29	11	72.73
Stayton Interchange restored	7.50	11	57	57.14	77.50	30.00	10	90.00
Mt.View enhanced slough	2.80	11	43	57.89	75.00	36.11	4	50.00
Calapooia River 2	20.18	7	31	58.33	75.00	25.00	17	88.24
Wilson Wildlife Area north pond	13.24	11	42	58.33	72.22	44.44	10	70.00
Willamette Park slough	2.13	7	18	62.50	100.00	70.00	7	85.71
Brown's Ferry pond	2.60	6	28	66.67	77.27	50.00	8	50.00
Christensen Park slough	4.70	5	18	66.67	92.31	69.23	10	80.00
Oaks Bottom backwater	88.00	7	20	66.67	81.25	56.25	16	75.00
Scio pond	1.20	3	16	66.67	72.73	45.45	5	40.00
Summerlake Park pond	1.43	5	17	66.67	66.67	33.33	12	75.00
Greenberry floodplain	32.19	14	51	68.18	65.12	23.26	14	85.71
Calapooia River 1	1.32	6	11	71.43	87.50	50.00	7	57.14
Gibson Creek enhanced slough	1.22	8	31	71.43	83.33	58.33	13	69.23
Jasper Park slough	2.00	6	31	71.43	84.00	52.00	14	78.57

Site	Area	Nplot	TotSp	Hdom20	OlapRef	OlapDom	WdSp	WdSp%N
Philomath Park slough	1.42	5	14	71.43	83.33	41.67	14	78.57
Tualatin Hills Big Pond	1.60	7	23	71.43	80.95	61.90	22	95.45
Anderson Park alcove	6.44	8	38	75.00	100.00	55.88	8	62.50
Fanno Creek duck donut	1.90	6	25	75.00	64.71	35.29	12	75.00
Hileman Park slough	0.90	3	35	75.00	96.67	56.67	8	62.50
Truax gravelpit restoration	0.76	5	15	75.00	76.92	38.46	0	--
Tualatin Hills Lily Pond	0.40	9	31	75.00	100.00	59.09	20	80.00
Jackson-Frazier floodplain	77.00	6	39	77.78	100.00	30.56	5	100.00
Finley floodplain	18.00	7	20	80.00	100.00	41.18	10	90.00
Adair pond	1.63	7	22	83.33	52.94	29.41	3	66.67
Anderson Park sloughs	5.83	7	40	83.33	71.88	43.75	17	82.35
Wilson Wildlife Area main pond	7.60	10	41	84.62	84.85	42.42	13	76.92
Buford West slough	4.40	6	19	85.71	83.33	44.44	16	87.50
Shooting range pond	0.10	4	25	85.71	82.35	47.06	0	--
Willow Creek riverine	3.40	6	40	85.71	100.00	50.00	6	83.33
McDonald Forest ponds	1.70	7	32	87.50	100.00	47.62	15	93.33
Coffin Butte pond	1.90	3	33	100.00	87.10	38.71	2	0.00

2. Slope/flats sites

Site	Area	Nplot	TotSp	Hdom20	OlapRef	OlapDom	WdSp	WdSp%N
Zenger Farm flat	5.90	5	5	66.67	75.00	75.00	2	100.00
Winsor flat	3.61	8	20	75.00	60.00	46.67	19	73.68
Wilson Wildlife Area prairie	0.50	4	23	100.00	94.12	35.29	2	0.00
Willow Creek prairie	79.00	16	68	78.57	87.50	35.71	18	77.78
West Waluga seeps	20.00	11	17	60.00	69.23	53.85	20	75.00
Walnut Park slope	9.09	5	42	54.55	76.92	28.21	5	80.00
Tualatin NWR Steinborn	60.02	8	41	72.73	66.67	30.56	0	
Tice Park seeps	10.00	7	28	83.33	73.91	30.43	18	72.22
Tampico forest	22.00	7	19	100.00	81.25	50.00	10	90.00
Stewart Ponds	13.00	8	32	66.67	82.14	53.57	0	
Shooting range woods	6.14	7	27	87.50	72.22	33.33	8	87.50
Sherwood seeps	2.40	7	26	75.00	66.67	33.33	19	68.42
Seavy prairie	9.60	7	18	100.00	100.00	75.00	5	80.00
Scio pasture	14.00	8	44	66.67	76.47	26.47	5	60.00
Rickreall flat	48.15	11	72	76.92	53.85	20.00	8	75.00
Philomath Park meadow	7.10	7	49	66.67	78.38	35.14	7	71.43
Philomath Industrial slope	5.07	10	64	66.67	100.00	30.61	7	57.14
OSU Pasture slope	0.40	3	15	0.00	62.50	12.50	2	0.00
OSU Pasture forest	2.60	6	29	75.00	65.00	35.00	6	66.67
Oak Creek restoration	53.00	9	32	66.67	95.45	54.55	10	70.00
Nimbus Drive slope	1.69	5	24	50.00	66.67	38.10	10	90.00
Marys River flat	0.14	4	31	40.00	68.00	24.00	2	50.00
Marion bank pond	0.11	5	17	80.00	58.33	25.00	2	50.00
Marion bank flat	5.28	6	32	28.57	44.44	14.81	0	
Luckiamute floodplain	10.00	14	29	66.67	40.00	16.00	17	76.47
Lebanon ODOT	18.82	6	36	75.00	53.57	25.00	6	100.00
Jefferson pasture	0.38	4	17	16.67	46.67	20.00	1	0.00
Jackson-Frazier prairie	18.00	16	45	84.62	100.00	41.67	10	70.00
Hyland Park pond	0.78	4	10	75.00	44.44	22.22	11	63.64
Hunziker Road flat	3.45	7	46	71.43	85.71	47.62	10	60.00
Greenhill Road prairie	43.00	9	59	62.50	81.13	24.53	5	80.00

Site	Area	Nplot	TotSp	Hdom20	OlapRef	OlapDom	WdSp	WdSp%N
Frazier-Cogswell forest	34.00	7	28	100.00	78.95	47.37	9	77.78
Fisher Butte prairie	68.00	8	29	77.78	100.00	61.54	5	80.00
Finley slope pond	0.23	6	21	60.00	81.25	43.75	2	100.00
Finley prairie	233.00	8	40	100.00	93.33	46.67	4	75.00
Finley ash swale	0.24	5	13	100.00	66.67	41.67	9	88.89
Ferry Street flat	1.23	6	29	55.56	75.00	39.29	2	50.00
Dimple Hill seep	0.99	4	24	66.67	52.63	31.58	3	66.67
Coyote Creek woods	3.53	8	39	50.00	77.78	33.33	6	100.00
Coyote Creek meadow	0.89	6	37	63.64	73.53	38.24	5	80.00
Corvallis Airport flat	27.24	7	27	14.29	42.86	14.29	4	50.00
Cook Park restored	14.00	11	42	44.44	51.61	22.58	9	66.67
Coffin Butte upslope	4.59	9	25	71.43	69.57	34.78	4	25.00
Coffin Butte flat	2.59	6	43	44.44	81.08	32.43	1	0.00
Cheyenne Way flat	1.11	4	25	0.00	77.78	38.89	1	100.00
Champoeg Park woods	1.97	8	31	66.67	73.91	39.13	20	75.00
Champoeg Park flat	4.29	12	24	87.50	65.00	45.00	6	83.33
Buford East hillslope	13.00	7	55	71.43	89.58	35.42	12	83.33
Brown's Ferry forest	1.00	6	19	75.00	62.50	37.50	19	78.95
Beggars-tick marsh	16.00	6	20	83.33	70.59	29.41	8	62.50
Bald Hill Park pond	0.60	6	44	66.67	81.25	31.25	4	50.00
Balboa restored	74.00	8	50	81.82	84.44	42.22	9	66.67
Aumsville slope	13.82	12	39	61.54	59.38	34.38	4	75.00
Albany powerline	6.57	8	40	66.67	70.97	22.58	4	75.00
Adair pasture slope	0.14	4	33	12.50	60.00	10.00	3	33.33
Adair Park woods	2.78	6	22	85.71	82.35	41.18	13	92.31

Appendix E. Distributions of Standardized Function Scores, by Subclass and Function

<u>Note:</u> Scores of different functions should not be compared, nor scores of the same function compared between the two subclasses, due to different model structures and unequal score distributions.

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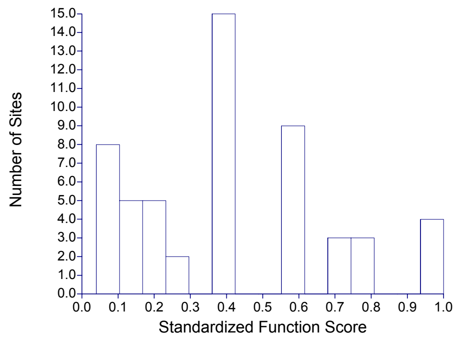
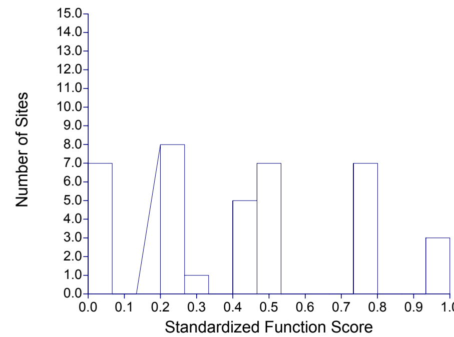
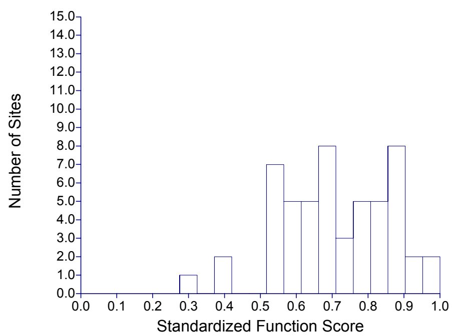
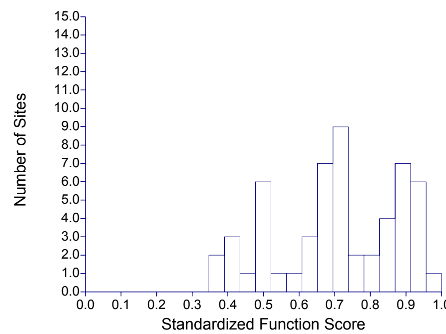
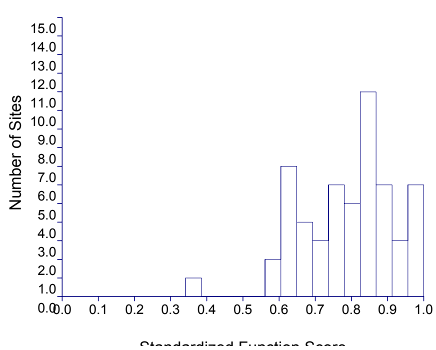
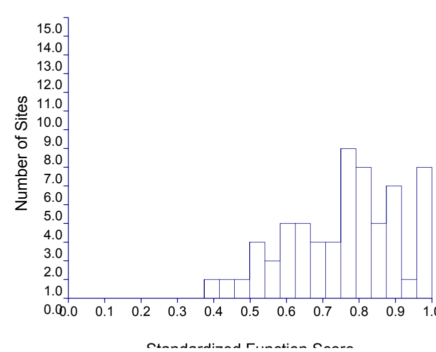
<tr><td>

Water Storage & Delay</td><td>

Water Storage & Delay</td></tr>
<tr><td>

Sediment Stabilization & Phosphorus Retention</td><td>

Sediment Stabilization & Phosphorus Retention</td></tr>
<tr><td>

Nitrogen Removal</td><td>

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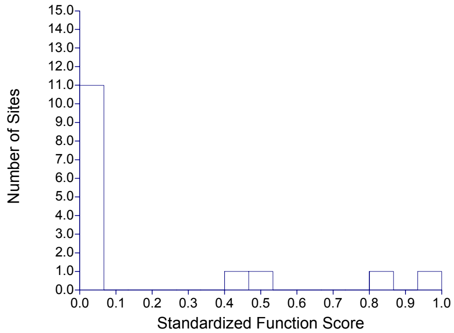
<tr><td>

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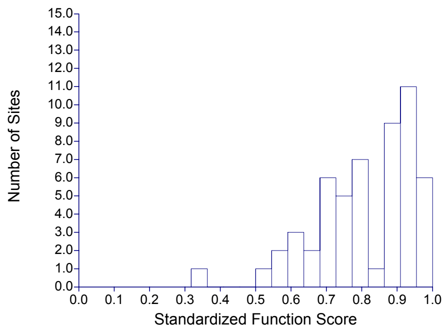
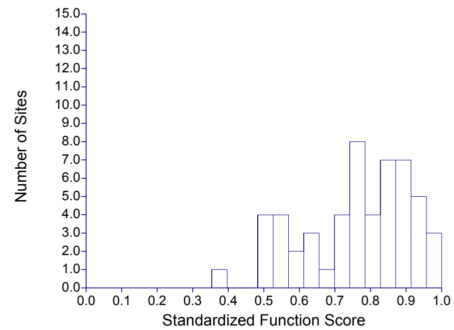
<tr><td>

Primary Production</td><td>

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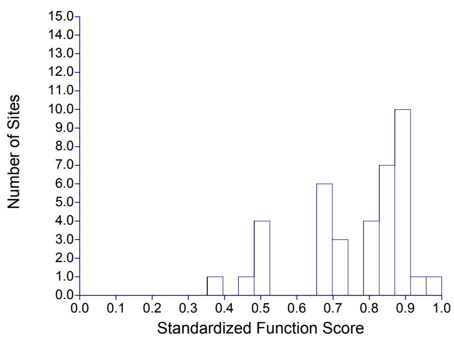
<tr><td>

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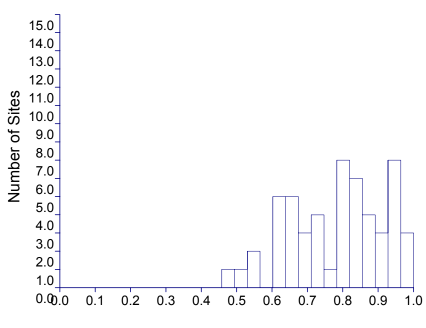
<tr><td>

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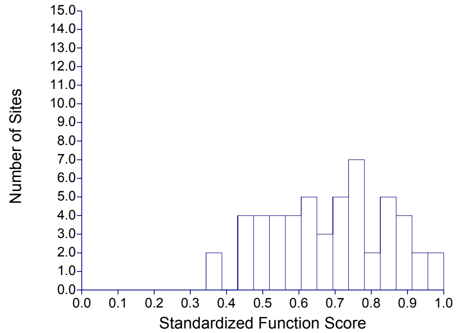
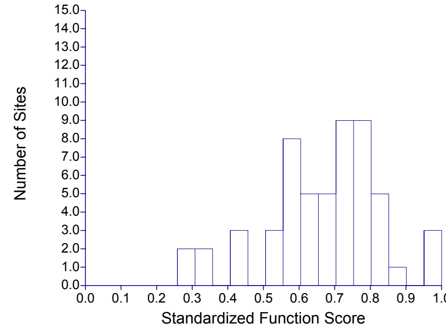
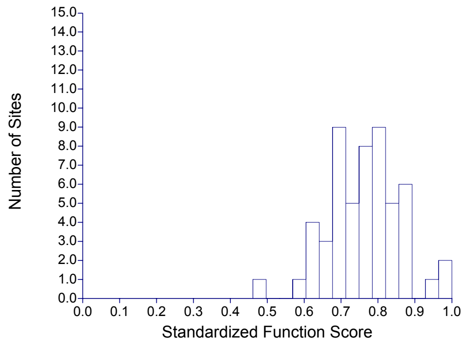
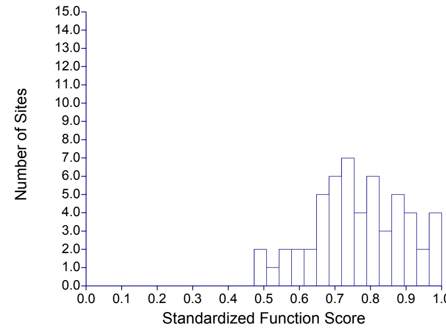
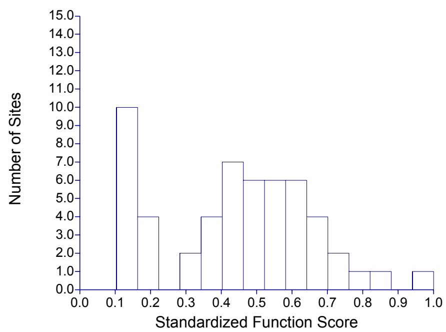
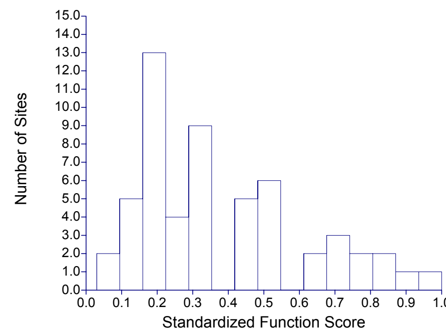
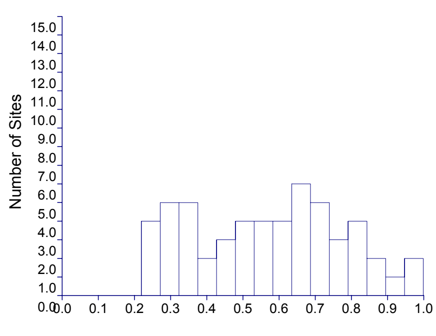
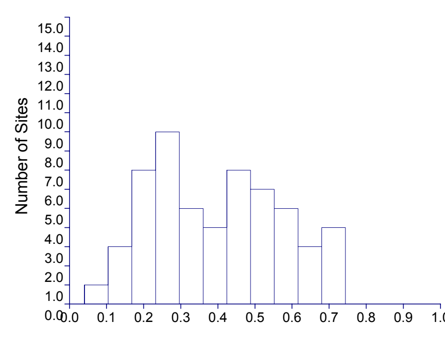
 Invertebrate Habitat Support	 Invertebrate Habitat Support
 Amphibian Habitat Support	 Amphibian Habitat Support
 Breeding Waterbird Habitat	 Breeding Waterbird Habitat
 Wintering & Migrating Waterbird Habitat	 Wintering & Migrating Waterbird Habitat

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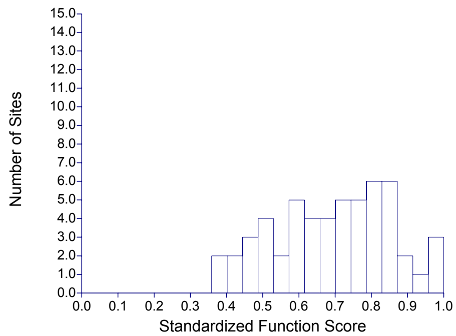
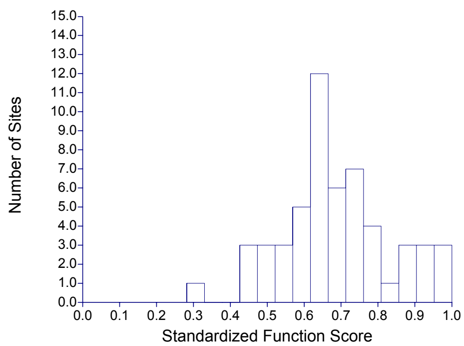
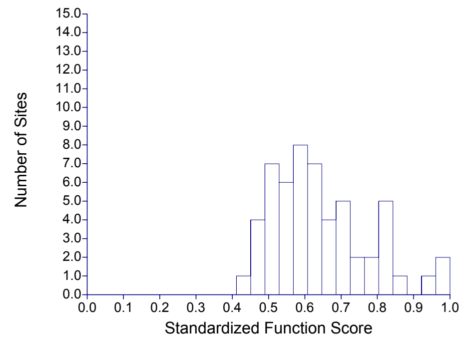


Songbird Habitat Support



Support of Characteristic Vegetation

Slope/flats subclass



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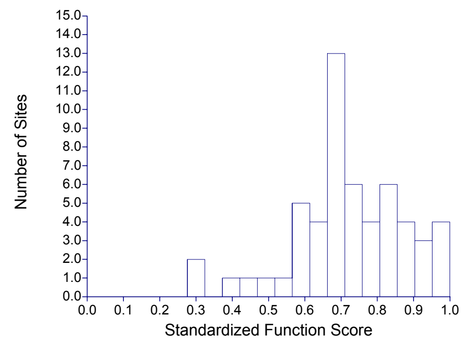

Support of Characteristic Vegetation