A Geodatabase and Digital Characterization of Wetlands Mapped in the Willamette Valley

With Particular Reference to Prediction of Their Hydrogeomorphic (HGM) Class

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1.0 Background and Objectives

To achieve a goal of "no net loss" of wetland functions as well as acreage, it is important to know which functions wetlands in a specific region or watershed may individually provide, at what level. Although methods exist for assessing functions of Oregon wetlands (ORWAP; Adamus et al. 2009), site visits and hours of data collection are required to apply these to any wetland. Moreover, property access restrictions prohibit their use on many wetlands. Thus, when there is a comprehensive objective to assess all mapped wetlands in a region or watershed, time and manpower constraints require that spatial data be processed automatically using GIS, even though assessments of functions using such an approach have much lower levels of certainty.

Some states (e.g., South Carolina; SWAMPS protocol) have developed and applied GIS-based protocols for generating preliminary estimates of functions and/or values of all wetlands in a watershed or region. No such protocol has yet been developed for Oregon. A first step towards accomplishing that is to develop and apply an automated GIS protocol to estimate only the hydrogeomorphic (HGM) class of each wetland in a region. That was the main objective of this project, which covered the entire Willamette Ecoregion (Pater et al. 1998). The HGM classification was developed for national use in classifying wetlands in a functionally-relevant way (Brinson 1993) and was modified for Oregon by the Department of State Lands (Adamus 2001). HGM classes are intended primarily to reflect the different prevailing sources of water to a wetland, as estimated largely by a wetland's topographic setting.

It is commonly asserted that knowing a wetland's HGM class can tell you something about the levels of a wetland's functions relative to those of other HGM classes (Johnson 2005). The exact amount of information useful to understanding a wetland's functions, that can be provided by simply knowing a wetland's HGM class, is arguable because many other factors can overshadow the influence of HGM class (and its component variables). Nonetheless, HGM class is a useful beginning point, and has been used as a descriptor in some sample-based regional analyses of wetland trends in Oregon (Gwin et al. 1999, Morlan et al. 2010). Also, for regional sampling programs, knowing the HGM class distribution of a population of wetlands prior to visiting them can be useful for cost-effectively stratifying the sampling.

The primary object of this project was to define criteria that would allow only the use of existing spatial databases (and only those with comprehensive coverage of the ecoregion) to identify the HGM class of mapped Willamette Ecoregion wetlands, and then apply those criteria automatically and systematically to every mapped wetland in the ecoregion, resulting in an HGM label for each mapped wetland. An ancillary goal was the creation of a database that describes over 200 attributes of each mapped wetland in the Willamette ecoregion, i.e., a regional wetland "profile."

The HGM class labels assigned by this project should not be considered the sole or ultimate representation of a site's HGM class. Field inspection (preferably during both wet and dry seasons) and manual (non-automated) review of aerial images and topographic maps are necessary if a definitive determination of a wetland's HGM class (and especially, subclass) is needed. That is due both to the poor spatial resolution and unknown accuracy of many existing spatial data layers, and a lack of spatial data for several factors that define HGM class. Moreover, many wetlands contain multiple HGM classes, but boundaries are dynamic and impractical to delineate.

This project was conceived by the primary author and by John Christy and others at the Oregon State University Institute for Natural Resources (INR). The project was funded under a matching Wetland Program Development grant from Region 10 of the US Environmental Protection Agency to the INR and The Wetlands Conservancy.

2.0 Methods

2.1 Data Sources

The primary spatial data coverages or layers used to estimate HGM class were as follows:

- Wetlands
- Topography
- Hydrography
- Soils
- Floodplains
- Land Cover

Each is now briefly described. Details are explained in metadata (.xml) electronic files accompanying this report.

<u>Wetlands</u>. The October 30, 2009 version of the Wetlands coverage created by the Oregon Biodiversity Information Center (ORBIC) was used. It consists primarily of wetlands delineated by the National Wetlands Inventory (NWI), using interpretation of aerial imagery at a scale of 1:24000 or coarser. A small proportion of the mapped area is unvegetated deep water in the middle of lakes, ponds, and rivers rather than meeting a jurisdictional definition of wetland. This coverage was augmented with localized wetland maps obtained from other sources and digitized by ORBIC. These include 36 Local Wetland Inventories (LWI's), 4 local Natural Features Inventories, and 3746 wetlands mapped by Oregon Department of Transportation. Many of these additional polygons did not have attribute data, e.g., no reporting of their vegetation forms or hydroperiods. Horizontal accuracy averages about 40 ft.

IMPORTANT NOTE: It is commonly known that large but unquantified numbers of jurisdictional wetlands in the Willamette ecoregion, particularly those on agricultural lands, have not been identified or mapped in the NWI layer or other sources. Thus, the results presented herein should not be construed as demonstrating what may be true for all Willamette wetlands.

<u>Topography</u>. Topographic data with a resolution of about 50 vertical feet and 30 horizontal feet was extracted and processed from the Oregon DEM layer. Much finer-resolution topographic data from LiDAR image analyses are becoming available for parts of the region but were not available in time for this project.

Hydrography. Spatial representations of streams and other water bodies were obtained from the 2006 Pacific Northwest Hydrography Framework and the National Hydrography Dataset from the USGS. Horizontal accuracy and completeness are unknown.

Soils. Delineated soil map units and their accompanying soil attribute data were obtained from the NRCS's SSURGO soils coverage. Horizontal accuracy is probably in the hundreds of feet.

Floodplains. Boundaries of the 100-year floodplain were represented by FEMA's Q3 coverage. Horizontal accuracy is estimated at about 38 ft.

Land Cover. From an existing land cover layer for Oregon, a layer was created that consisted only of wetland types determined by ORBIC to be especially rare or threatened in the Willamette ecoregion.

Geologic Faults. A layer digitized from maps drawn at a scale of 1:500,000 by Walker et al. (2003) was used. Horizontal resolution is probably several hundred feet at best.

Springs. A layer was created from the water points feature of the Pacific Northwest Hydrography Framework. Horizontal resolution is unknown, but probably less than 100 ft.

To create a comprehensive database of wetland attributes, additional spatial data layers not directly relevant to predicting HGM class, but potentially useful for characterizing functions and values of wetlands, were also obtained and compiled. They pertain to Roads, Historical Land Cover, HUC (watershed) boundaries, Air Temperature & Precipitation, Lithographic type, and Land Ownership category.

2.2 Defining Wetland Polygon Boundaries

For many areas that most people would consider to be a single wetland (e.g., a discrete depression in the landscape), the NWI maps often show multiple contiguous polygons, with each component polygon representing a different cover class (emergent, scrub-shrub, water, etc.) and water regime (flooded permanently, seasonally, etc.). In contrast, the HGM classification distinguishes map units based on apparent distinctions in their geomorphology rather than their vegetation and hydroperiod. Thus, a first step in this project's analysis was to join together all contiguous (adjoining) NWI polygons using a GIS "dissolve" command. Riverine polygons were dissolved only into other riverine polygons. Adjoining palustrine and lacustrine wetlands were joined to one another, but not to any adjacent riverine polygons. This reduced the number of Willamette ecoregion polygons from about 80,000 to just 24,454, each with a unique identifier, and those polygons were used in this data analysis. However, all NWI attributes of these polygons were retained in a separate "one-to-many" file.

2.3 Extracting Attributes from Spatial Data

From the resulting wetlands layer, information from the layers listed in section 2.1 above was extracted using "intersect", "spatial join", or "extract values" commands. A series of shapefiles was generated, and the dbf file within each shapefile was exported for use in Access. Additional calculations were performed using Access queries, and the information was compiled into a single table with 24,255 rows (one per wetland) and 224 columns (wetland attributes), which comprises nearly the entire geodatabase. To identify the likely HGM class of each of the 24,255 wetlands, data sorts and queries were applied using criteria described below.

2.4 Criteria for Predicting Hydrogeomorphic (HGM) Class from Existing Spatial Data, and Results

Based on experience creating and applying Oregon's version of the HGM Classification, the principal investigator reviewed the available spatial data layers and identified specific variables (map unit categories) believed most likely to predict HGM class. This included a series of hydrologic variables computed from the DEM. For that, the Hydrology module of ESRI's Spatial Analyst GIS toolbox was used. The principal investigator then combined the variables in a screening approach that was believed likely to assign correctly one HGM class to each wetland. The approach was executed sequentially as follows:

1. All polygons of which any part had a hydroperiod (water regime) code of M, N, P, S, R, T, or V according to the NWI Wetlands layer were assigned an HGM class of **Tidal**. These codes all refer to tidally-influenced wetlands, even though a persistent surface connection to tidal waters may be lacking in some. Some 82 wetlands, nearly all located along the Columbia River part of the Willamette ecoregion, were so designated with the code "T" in the database. No wetlands labeled "Estuarine" were present in the Willamette ecoregion portion of the wetlands layer that was used.

2. Of the remaining polygons, all polygons in which any part had a NWI system code of L (Lacustrine) and which were larger than 20 acres were assigned an HGM class of **Lacustrine**. Some 57 wetlands were so designated and coded "L" in the database.

3. Of the remaining polygons, an HGM class of **Slope** was assigned to any in which either:
(a) the Land Cover layer had been labeled as a Bog/Fen (only 2 wetlands), or
(b) intersected Springs (57 wetlands), or
(c) located in a FEMA "AO" flood zone (flooding due to hillslope runoff, 7 wetlands).
A total of 66 wetlands were designated using the above and were coded "S" in the database. The above criteria are based on the fact that Slope wetlands are wetlands with a dominant groundwater component, and Fens and Springs are generally recognized as zones of groundwater discharge. It is likely that portions of some of the Slope wetlands fit the definition of the Riverine or other classes.

4. Of the remaining polygons, all polygons in which any part had a NWI system code of R (Riverine) were assigned an HGM class of **Riverine**. Some 2511 wetlands were so designated, and are coded "R" in the database.

5. Of the remaining polygons, any whose "Slope Potential" score was above the 75th percentile (i.e., a score >0.44) of the hitherto unlabeled polygons was assigned an HGM class of **Slope**. Some 5266 wetlands were so designated, and were coded "S2" in the database. The "Slope Potential" score was calculated as the average of the following 7 variables:

Percent Slope: If either wetland slope was >4^o according to the DEM, or weighted percent slope was >5^o according to the SSURGO data, then =1, else 0. By definition, Slope wetlands occur on or very near the base of sloping land.

NWI hydroperiod: If NWI had mapped any portion of the polygon as Saturated (B), then =1, else 0. That is because Slope wetlands are typically characterized by saturated conditions in which surface water is absent or very limited. Used alone, this is not a conclusive indicator of Slope wetlands, so it is used with other indicators to build a circumstantial case.

Open Water Index: If 4 spatial data layers concurred that no permanent and/or open water is contained within the wetland, then =1. If 3 concurred, then = 0.8. If 2 concurred, then = 0.8. If indicated only by 1, then = 0.3. If none concurred, then =0. The 4 data sources were: Land Cover (= Water), Historical Land Cover (=Water), Ownership (=Water), and NWI (hydroperiod code = G, H, K, Z, UB, or OW). Slope wetlands are less likely to contain appreciable amounts of persistent surface water.

Floodplain: If the wetland was entirely outside of the 100-yr floodplain, or that floodplain has not been mapped at the wetland's location, then =1, else 0. Slope wetlands are less likely to occur within floodplains than at higher elevations.

Inlets & Outlets: If the Hydrography layer showed only an outlet is present (no inlet), then =1, else 0. Being areas of groundwater discharge, Slope wetlands (especially springs) often lack surface water inlets but have outlets.

Faults: If the Faults layer showed intersection with a geologic fault, then =1, else 0. Groundwater commonly discharges at geologic faults.

Geomorphic Index: This is the average of 7 variables, as follows:

> *Slope Position*: If the area within 90 m of the wetland center, based on its Topographic Position Index, was classified as 2 (Toe Slope), 4 (Mid Slope), 5 (Upper Slope), or 6 (Ridge), then =1, else 0. Slope wetlands typically occur in those relative positions.
>
> *Landform*: If the area within 90 m of the wetland center, based on its Topographic Position Index, was classified as 6 (Open Slopes), 7 (Upper Slopes), 8 (Local Ridges), 9 (Midslope Ridges, Small Hills in Plains) or 10 (Mountain Tops, High Ridges), then =1, else 0. Slope wetlands typically occur in those relative positions.
>
> *Geomorphic Position*: If the SSURGO database described the site as hillslope, swale, or mountain slope, then =1. If simply hills, mountains, or benches on hills, then =0.5. If swales on floodplains or terraces, then =0.1, else 0.
>
> *Planiform Curvature*: The rate of change in slope perpendicular to the direction of slope, estimated in a 30 sq. m area centered on the wetland. Negative values indicate concave curvature (where water will tend to diverge on the landscape). This was assumed to be more indicative of Slope wetlands so was assigned a value of 1 in this Index.
>
> *Profile Curvature*: The rate of change in slope in the direction of the slope, estimated in a 30 sq. m area centered on the wetland. As above, negative values (curvature indicating water divergence) were assigned a value of 1 because water divergence rather than convergence was assumed to be more indicative of Slope wetlands.
>
> *Stream Power*: If this had a value less than 2 (the median of all mapped wetlands), then =1, else 0. It is a composite of surrounding slope and flow accumulation as estimated by ArcHydro.
>
> *Ratio of Wetland Area to Contributing Area*: Wetlands that are large but which have small contributing areas often indicate situations where groundwater discharge is

significant, thus implying a wetland classification of Slope. If this value at a site was greater than the 75th percentile of this ratio calculated for all sites (<0.000156), then =1.

Averaging was used to calculate both the Slope Potential score and the score for the Geomorphic Index, due to uncertainties associated with coarseness of the DEM and SSURGO layers that were used and choice of a spatial scale optimal for predicting HGM class.

6. Of the remaining polygons, any that the Hydrography layer showed being intersected by a stream, or having both an inlet and outlet, were assigned an HGM class of **Riverine**. This criterion was not applied earlier in the sequence because some Slope wetlands also have such features. Some 4354 wetlands were so designated and were coded “RR” in the database.

7. Of the remaining polygons, any whose NWI hydroperiod was coded G, H, K, Z, UB, or OW were assigned an HGM class of **Depressional**. Some 628 wetlands were so designated and were coded “D” in the database. Depressional wetlands typically have long hydroperiods and/or substantial areas of open water. When they have inlets and outlets, they are difficult to differentiate from Riverine wetlands (Impounding subclass).

8. Of the remaining polygons, any which met *all 3* of the following conditions were assigned an HGM class of **Flat**. The conditions were:

(a) NWI hydroperiod was NOT coded G, H, K, Z, UB, or OW in any part of the wetland, and

(b) lack both an inlet and outlet according to the Hydrography layer, and

(c) wetland slope is $<4^o$ according to the DEM, or weighted percent slope is $<5^o$ according to the SSURGO data.

Some 5740 wetlands were so designated and were coded “F” in the database.

9. *All remaining* polygons were assigned an HGM class of **Riverine** under the assumption that for many, the intermittent or small intersecting streams that would make them riverine had not been mapped. These polygons perhaps also included many non-NWI wetlands with no data on their hydroperiod. Some 5756 wetlands were so designated and were coded “RRR” in the database. This HGM assignment was the least certain of all those made.

3.0 Validation of HGM Class Assignments

3.1 Validation Process

To determine absolutely the correctness of most HGM class assignments, detailed geohydrological monitoring would be necessary in the subject wetlands. However, no such measurements have been made in any series of Willamette wetlands, so there is no “gold standard” set of reference sites with which to compare the HGM assignments produced by this project. Lacking those, an alternative approach is to compare the automated (GIS-based) assignments with ones done manually (without GIS) using best professional judgment during an individualized site-by-site review of topographic maps, aerial images, and/or onsite observations. Using that approach, the Principal Investigator examined about 1% of the assignments made in each of the larger HGM classes, and 10% of the assignments in the smaller HGM classes. Within each HGM class, half the sites were chosen based on their expected *highest* probability of being correct (i.e., degree of congruence with the criteria) and the other half were chosen based on their expected *lowest* probability of being correct (i.e., least congruence with the criteria, but still meeting them).

3.2 Validation Results

Results are presented in Tables 1 and 2. Note that it was not possible to evaluate each HGM assignment as simply correct or incorrect, because (a) many wetland polygons contain multiple HGM classes and it is impossible to draw boundaries between these, and (b) absolute verification of the correctness of a given wetland's class assignment would depend on intensive hydrological monitoring. Instead, each HGM assignment was evaluated as to whether *all, most* ("primarily"), *some* ("secondarily"), or *none* of the polygon appeared to meet the criteria for the class to which it had been assigned. For some polygons the evaluation term "primarily" instead meant that it was believed *highly likely* that the polygon was that class, and "secondarily" meant that it was somewhat *less likely* to be the assigned class. Verification was based on individualized ("manual") examination of 319 wetland polygons (1.3% of total) using topographic maps and aerial imagery and/or onsite observations. Comparisons were also made with HGM classes that had been assigned to 742 wetland polygons (3% of total) by consultants conducting Local Wetland Inventories. The accuracy of those classifications is unknown.

Overall, 81% of the automated designations appeared to be accurate based on our field determinations and/or individualized review of topographic maps and aerial imagery. This is substantially higher than the 60% accuracy rate reported from a study in central Oklahoma, which is the only known study in which classification accuracy was measured and reported. That study (Dvorett 2010) also used GIS but had different spatial data layers and models (criteria) for the HGM classes.

In our study, the accuracy rate varied by HGM class and according to which set of criteria was used for the particular HGM class. Accuracy might have been even higher if a good set of diagnostic features could been found to distinguish among polygons labeled "RRR." Those were polygons that did not clearly fit any of the other defined sets of criteria, i.e., the "leftovers". As it turned out, upon manual or field inspection more of those were found to be entirely or primarily Depressional (44%) or Flat (25%) than were found to be Riverine, which had been used as the default. Therefore, all RRR wetlands that had not been individually inspected during the validation exercise were reclassified as Depressional rather than Riverine in the final database, resulting in a higher accuracy rate overall and for Riverine wetlands in particular.

About 29% of the Depressional, 32% of the Slope wetlands, and 36% of the Flats wetlands may have been misclassified by the automated rules. Depressional wetlands were most often misclassified as Riverine (28%). Slope wetlands also were most often misclassified as Riverine (29%) and less often as Depressional (6%). Flats wetlands were most often misclassified as Depressional (28%) and less often as Riverine (6%). From this, it appears that some of the criteria that assigned wetlands to the Riverine class were too inclusive, and/or the spatial data that supported those criteria were inaccurate or incomplete. The high accuracy rate for Lacustrine and Tidal (both 100%) designations was expected.

Wetlands that were misclassified or which seemed farthest from meeting the criteria for their class were often ones that had been altered from their naturally-occurring condition by excavation or impoundment. However, keep in mind that the classes we assigned were for a wetland in its present (altered) condition, not its pre-altered condition. For example, excavated ponds connected by (or flooded at least biennially by) a stream were classified as Riverine, not Depressional. Wetlands in the Willamette River's alluvial floodplain were classified as Depressional or Flats, not Riverine, unless it was certain that, despite river regulation by upriver dams, they still are flooded by the river at least biennially.

As noted earlier, HGM labels applied to 3% of the Willamette wetlands by consultants doing Local Wetland Inventories (LWI) were also compared with our automated results. Of the 742 polygons with such a label, 378 (50%) were contrary to our results. The veracity of the LWI labels is unknown and in the author's experience, misunderstanding of HGM class definitions and criteria is not uncommon.

3.3 The Final (Reclassified) Database

After the validation had been completed, all wetlands that had been labeled RRR were reclassified as Depressional unless an individual review during the validation process had determined them to be another class. Then for the remainder of the 319 validation polygons, their HGM classes as determined by the individual reviews were substituted for those that had previously been assigned to the same polygons automatically. The corrected database was then used to create a new wetlands layer, with HGM class as an attribute for all 24,455 polygons.

Table 1. Statistical summary of the validation

Based on individualized field or aerial inspection of a sample of the polygons:
"All True" = entire polygon was this HGM class
"Primarily" = most of the polygon was this HGM class, or it is most likely this class
"Secondarily" = a lesser proportion of the polygon was this HGM class, or it is somewhat less likely to be this class
"Untrue" = none of the polygon appeared to belong to this HGM class

	Original Estimate		Validation Process		Number Validated As:				Percent Validated As:			
	WV Count	% of WV Wetlands	# checked	% checked	All True	Primarily	Secondarily	Untrue	All True	Primarily	Secondarily	Untrue
Tidal	82	0.34%	8	10%	6	2	0	0	75%	25%	0%	0%
Lacustrine	57	0.23%	6	11%	6	0	0	0	100%	0%	0%	0%
Slope - criteria 1	59	0.24%	6	10%	0	5	1	0	0%	83%	17%	0%
Slope - criteria 2	5266	21.53%	53	1%	24	11	13	5	45%	21%	25%	9%
Slope - either 1 or 2	5325	21.77%	59	11%	24	16	14	5	41%	27%	24%	8%
Riverine - criteria 1	2513	10.28%	25	1%	12	11	1	0	48%	44%	4%	0%
Riverine - criteria 2	4354	17.80%	44	1%	18	18	2	6	41%	41%	5%	14%
Riverine - criteria 3	5756	23.54%	58	1%	13	3	8	34	22%	5%	14%	59%
Riverine - 1, 2, or 3	12623	51.62%	127	3%	43	32	11	40	34%	25%	9%	31%
Depressional	628	2.57%	62	10%	31	13	15	3	50%	21%	24%	5%
Flat	5740	23.47%	58	1%	24	13	8	13	41%	22%	14%	22%

Table 2. Detailed validation results for assigned HGM classes.

Based on individualized field or aerial inspection of a sample of the polygons:

P= polygon was determined to be primarily or most likely the class in the column header
s= polygon was determined to be secondarily or somewhat likely the class in the column header
All= entire polygon was determined to be the class in the column header, with high degree of certainty

The table that preceded this one condensed the results in this table.

GIS-Modeled & Coded as:	is Tidal	is Lacustrine	is Riverine	is Slope	is Depressional	is Flat	#	% of HGM criteria class
TIDAL	s					P	1	13%
	s		P				1	**13%**
	All						6	**75%**
LACUSTRINE		All					6	**100%**
RIVERINE (Criteria R)						All	1	4%
			P				1	**4%**
			P		s		1	**4%**
			P	s			9	**36%**
			s		P		1	4%
			All				12	**48%**
RIVERINE (Criteria RR)						All	1	2%
					All		4	9%
				s	P		1	2%
			P			s	2	**5%**
			P		s		14	**32%**
			P	s			2	**5%**
			s		P		2	5%
			All				18	**41%**
RIVERINE (Criteria RRR)						All	9	16%
					P	s	2	3%
					s	P	1	2%
					All		20	34%
				P		s	1	2%
			P			s	1	2%
			P		s		2	3%
			s			P	4	7%
			s		P		4	7%
			All				13	22%
	P				s		1	2%

Table 1 (continued)

Coded as:	is Tidal	is Lacustrine	is Riverine	is Slope	is Depressional	is Flat	#	% of HGM criteria class
SLOPE (Criteria S)				P	s		2	**33%**
			P	s			1	17%
			s	P			3	**50%**
SLOPE (Criteria S2)				P		s	2	**4%**
				P	s		1	**2%**
				s	P		1	2%
				All			24	**45%**
			P	s			12	23%
			s		P		2	4%
			s	P			8	**15%**
			All				3	6%
DEPRESSIONAL					All		31	**50%**
				s	P		3	**5%**
			P			s	1	2%
			P		s		15	24%
			s			P	1	2%
			s		P		10	**16%**
			All				1	2%
FLAT						All	24	**41%**
					P	s	5	9%
					s	P	5	**9%**
					All		11	19%
				P		s	2	3%
				s		P	7	**12%**
			P			s	1	2%
			P		s		1	2%
			s			P	1	**2%**
			All				1	2%

4.0 Limitations

The criteria used in this effort, while believed to be technically sound despite the limitations of the source data to which they were applied, are only one of many formulations that might have been used to assign HGM class. In theory, a more sophisticated optimization process could be applied to adjust criteria thresholds and formulations repeatedly until the highest possible level of agreement is produced between automated vs. manual assignments of HGM class. This could be implemented through an iterative statistical analysis that would identify which particular components of a class's decision rules (criteria set) led to the most misclassifications each time, and then dropping or downweighting those components within the decision rules, while perhaps also increasing the weights of components that most reliably predicted HGM class.

Although HGM labels assigned by an automated approach such as the one demonstrated here are likely to be less accurate overall than HGM assignments based on manual site-by-site consideration of the spatial data for each wetland, the manual approach is not feasible for regionwide estimates of HGM class. Therefore the automated approach, with its imperfect but relatively high rate of accuracy using these criteria, is recommended for instances where HGM classes need to be assigned to all wetlands across a large region with only limited time and available resources. Application of these criteria to other parts of Oregon and beyond, with perhaps only slight further modification, is also recommended.

5.0 Willamette Wetlands Geodatabase

In addition to providing HGM assignments for all mapped wetland polygons in the Willamette ecoregion, this project has produced a geodatabase that is the richest organization of data currently available for all of the region's mapped wetlands. All its variables are defined and described in the Data Dictionary, an electronic version of which is appended.

Similar efforts could and should be initiated to address wetlands in other parts of Oregon. With little additional effort, statistical analyses of these organized data could identify the strongest associations among wetland size, vegetation type, soil type, climate, and dozens of other variables. For example, especially with use of refined topographic data (e.g., LiDAR), key numeric thresholds could be identified to answer questions such as, "What value for GIS-predicted flow accumulation results in wetlands of various sizes and types, given particular levels of annual precipitation and soil type?"

Even in its present form, anyone familiar with Excel spreadsheets can sort, query, or cross-tab the file comprising the Willamette wetlands geobase to answer questions such as "What proportion of the wooded wetland area in the Willamette ecoregion is on public vs. private land?" A user wanting to know the location of any wetland characterized in the geodatabase can simply go online and copy and paste its coordinates into Google Earth or the Oregon Wetland Explorer. Eventually, all or part of the geodatabase could be incorporated into the Oregon Wetland Explorer. By simply clicking on a mapped Willamette wetland, a table with over 170 attributes of that wetland could be printed or downloaded, along with supporting metadata.

6.0 Literature Cited

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6.0 Electronic Appendices

File 1. Wetlands Geodatabase and Data Dictionary for the Willamette Ecoregion
File 2. Wetlands Layer with HGM Labels (shapefiles in Arc format)