Wetlands of the Bitterroot Valley: Change and Ecological Functions

Prepared for:

The Montana Department of Environmental Quality

Prepared by:

Gregory M. Kudray and Tom Schemm

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Executive Summary

The objective of this project was to evaluate wetland diversity and analyze wetland change in the Bitterroot River watershed of western Montana. This watershed is typical of many large river valleys in the West that have a rapidly increasing affluent population expanding into rural areas. We characterized the spectrum of wetland types and analyzed wetland change by comparing the original National Wetland Inventory (NWI) baseline in the early 1980's to our new NWI mapping based on year 2005 imagery. We also developed a system for labeling mapped wetland polygons using a combined NWI – HGM (Hydrogeomorphic) code. Codes have been associated with three performance levels of 10 ecological functions. This enabled us to represent hydrology, biogeochemical, and habitat wetland functions on wetland maps, and represents the most detailed mapping information system for wetlands that has ever been implemented on a statewide or regional basis. This information will help decision-makers prioritize wetlands for restoration or protection, guide mitigation requirements, support regional or local wetland policy and management, and will contribute to a broader understanding of the wetland ecological services that society values.

We found that wetlands and wetland associated ecological functions are concentrated in the valley bottom and along riparian areas. Most of the 442 Clean Water Section 404 Program permits that have been issued within the study area are concentrated in the wetland-rich riparian floodplain. Some of the permitted activities, like armoring banks with rip-rap, may limit the ability of the river to maintain the same amount of wetlands on the floodplain because high flow events are essential in creating and renewing wetlands.

Wetland change was analyzed in two ways. A random sampling indicated no net estimated change in total wetland acreage, using confidence limits that were relatively large due to high sampling variability. However, we did find that ponds increased in estimated acreage, whereas the estimated acreage of emergent wetlands, which were often converted into ponds, decreased. We additionally completed a total study area review of ponds created by humans and beavers, and found an 80% decrease in beaver pond numbers and acreage during the approximately 20 year study time frame. Only about 5 acres of beaver ponds remain in this 1.4 million acre area despite the large amount of suitable beaver habitat. Beavers are a keystone species with a disproportionate effect on ecological functions compared to their numbers. Beaver activity improves water quality through sediment retention, influences on nutrient cycling and decomposition, and hydrologic modifications. Beavers create wetlands that would otherwise be rare in mountainous terrain, thus providing important habitat for many other wetland–dependent species.

The other major wetland change in our 100% review was a 75% increase in human created Palustrine wetland acreage. The 921 new created wetlands in the study area since the early 1980's are virtually all small ponds with standing water that were primarily constructed for their recreational amenities. Fish stocking is a major use, 252 fish stocking permits were recorded since they were first required in 1998. Over 90% of the permits indicated an intention to stock non-native fish species. The presence of fish in a pond has also been strongly and negatively associated with the populations of some amphibian species in Montana. Only about 30% of these ponds had the required water use permit for pond construction. We estimated ecological functions for created ponds as generally lower than natural ponds, but there is considerable uncertainty about actual functional levels due to a lack of research and potentially large ecological impacts associated with the spread of the non-native bullfrog, a problem species in the area, and a general decline of native amphibians across Montana. If constructed wetlands do not function like natural wetlands, then landscape wetland functions may still be lost even with a gain in wetland acreage.

Wetlands and deepwater types comprise 1.1% (16,304 acres) of the total study area. Over 1,806 acres, 11% of the total wetland acreage, are isolated wetlands, which may not be regulated. The flooded

beds and shores of rivers are the most common wetland type (34%), followed by wetlands with emergent vegetation (26%), deepwater habitats (13%), and wetlands with shrub vegetation (12%). Forested wetlands are very uncommon, only 15.1 acres were mapped. The location of most wetlands in riparian corridors and on the valley floor near human developments has often resulted in a degraded ecological condition with many emergent wetlands converted to pastures with introduced grasses. Nonnative species and noxious weeds are common, especially in the riparian zone of the Bitterroot River. Higher elevation wetlands are more ecologically intact; wetlands with a saturated water regime are more common there than in most of Montana. These types are often peatlands that may provide habitat for Montana plant Species of Concern and the Northern Bog Lemming, an animal Species of Concern. About 38 acres of slope wetlands were mapped; these also have the potential for high conservation value. Our new map data provides a valuable tool for field botanists to explore these areas.

The considerable change in wetlands of the Bitterroot Valley after only 20 years underscores concern about a changing profile of wetland values and services. More effort is needed to understand the impacts of large increases in created recreational ponds. The large decrease in beaver ponds, and presumably beaver numbers, is also worthy of additional focus. Beavers and humans often share riparian areas and it is likely that beavers are diminishing due to this relationship.

Acknowledgements

We would like to first thank Lynda Saul, MT DEQ wetland coordinator, for her help in securing funding for this project and her leadership in Montana wetland issues. We gratefully acknowledge the funding support from the EPA for this project and planned similar projects in the next two years. Thanks to Tony Olsen of the EPA for his statistical help. Ralph Tiner and Kevin Bon of the USFWS National Wetland Inventory program reviewed the functional attribution rationale; Kevin also reviewed our new NWI mapping and had many useful suggestions – we are very grateful to both. Tom Parker and his staff at Geum Consulting in Hamilton helped with data and field checking. We would also like to thank Brian Giddings of Montana Fish, Wildlife and Parks for providing beaver data. Coburn Currier provided his usual high level of expertise in formatting and printing this report.

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Introduction

Concern over wetland loss in the United States reached the level of a presidential initiative when President George H. Bush established a federal policy to increase the quality and quantity of wetlands. Bush also directed the United States Fish and Wildlife Service (USFWS) to complete another update on wetland trends, which was another installment in more than 50 years of USFWS wetland trend analysis (Frayer et al. 1983, Dahl and Johnson 1991, Dahl 2000, Dahl 2006). This series of national studies reported the nation's wetlands considerable initial wetland losses in the 1950's to 1970's, slower losses from the 1970's to the 1990's, and gains during the 1998 to 2004. There has been a cumulative loss of more than 50% of wetland acreage in the continental U.S. (Dahl 1990). However, wetlands are valued not for the acreage covered but for the ecological functions provided; the USFWS national wetland status and trends analyses do not provide an assessment of changes in wetland function (Dahl 2006).

The hydrogeomorphic classification (HGM) for wetlands (Brinson 1993) is the most accepted and well-developed methodology for assessing wetland functions in the United States. The HGM classification was developed to assess the effect of projects on wetland functions in the Corp of Engineers 404 regulatory program (Brinson 1993). HGM emphasizes the hydrologic and geomorphic controls that are believed to be responsible for maintaining the functional aspects of wetlands (Brinson 1993). In the HGM system, a wetland is classified as to its geomorphic position, water source, and hydrodynamics (Brinson 1993). Since there could be considerable variability in wetland functions in a specific HGM class across the country, a series of regional guidebooks (e.g. Hauer et al. 2002) were developed to assess the wetland functions of HGM types in areas with similar environmental characteristics.

HGM applications are largely site-based and regulatory in nature but there has been increasing application of HGM as a tool in understanding cumulative effects on wetland functions through GIS landscape analyses. Johnson (2005) characterized wetland functions in reference and impacted watersheds in similar Colorado environments to develop a method that could infer likely cumulative effects in the impacted watershed. The National Wetland Inventory (NWI) has often been used in cumulative effects analyses since it is the most widely available and consistent wetland mapping product in the U.S. Kentula et al. (2004) assigned a modified HGM type to wetlands in the Portland, Oregon area and summarized HGM type changes from the original NWI in 1992, but did not extend the analysis to estimate wetland functional changes.

Linking NWI mapping to cumulative functional loss has been accomplished in the Northeastern United States by adding hydrogeomorphic descriptors for landscape position, landform, water flow path, and waterbody type to the NWI digital database and applying correlations to land characteristics and functions to identify wetlands of potential significance for various functions (Tiner 2005). This study used ancillary data to estimate pre-settlement wetlands and determined that the study watershed had lost 60% of its capacity for streamflow maintenance and over 35% of its capacity for four other functions (Tiner 2005).

Understanding how wetlands function spatially and temporally in a watershed has several management and planning applications. Implicit is the establishment of a functional baseline; while determining pre-settlement conditions is often not accurately possible, other approaches like Johnson's (2005) method of identifying a reference watershed can also be applied in some cases. However, the original NWI offers the most widespread and cost effective baseline data source, even with the caveat of pre-NWI wetland losses. Additionally, progress in linking wetland functions to NWI types helps to standardize the assessment methodology. Once a baseline is established a watershed wetland functional profile (sensu Johnson 2005) can be created. This may take the form of an acreage or percentage summary of HGM types, or may be extended further with a region-specific association of the

magnitude of specific ecological functions with mapped types, allowing an estimate of baseline wetland functionality within a watershed (Tiner 2005). When the baseline is compared with current conditions, knowledge about the status and trend of wetland functions in a watershed can help prioritize wetlands for restoration or protection, guide mitigation requirements, further regional or local wetland policy or regulations, and contributes to a broader understanding of how wetland change affects the ecological services that society values. Inferences about likely wetland functional changes in watersheds with similar ecological and social characteristics may also be useful.

The HGM classification creates wetland types that have similar functions, but does not quantify the kind and magnitude of specific functions. Regional guidebooks elaborate on the specific functions performed by a HGM type within the region and serve as an important resource in associating functions to wetlands, although there is not a comparative analysis of the importance of a function that may be performed by a variety of wetland HGM types. The most useful, but also most subjective, attribution of functions to wetland types require an estimate of the magnitude of how each function is performed by a type within a region. Additionally, there is considerable variability beyond easily measured characteristics like acreage as to the importance of a function across the variety of sites that will constitute a similarly coded class. Thus, it is important to base functions and their relative magnitude within a specific type on good information and to keep any importance attributions relatively general. A strength of the approach in a GIS cumulative assessment analysis is that the functions and/or their magnitude can be reassessed if more information becomes available, like a better function – type linkage or widespread wetland assessments that can link condition to function.

Rapid development in the large river valleys of Montana has generated concern about changes to the wetlands and their associated functions. In Montana and the Intermountain West, wetlands are concentrated in broad river valleys and riparian areas, which also form some of the most attractive sites for residential development. Population pressures drive this potential threat: the West is the fastest growing region by population in the United States with Intermountain states leading the list of fastest growing states. Wetlands are also proportionality more important in the arid West.

Our study area in the Bitterroot River watershed of Montana is typical of rapidly growing Western regions with increasing land subdivision and housing development occurring in areas previously dominated by agricultural activities. One of our objectives is to quantify wetland change in our Bitterroot Valley study area from the early 1980's original NWI baseline to our new NWI mapping based on 2005 imagery. The need for state, regional, and local scale wetland status and trends assessments is part of the USFWS National Wetland Inventory (NWI) strategic plan for the 21st century (U.S. Fish and Wildlife Service no date). Our new NWI mapping for Montana includes routine attribution with HGM modifiers; another objective is to develop a system that enables a spatial quantification of wetland functions using this mapping.

Study Area

The study area includes most of the Bitterroot River watershed in western Montana (Figure 1). Valley land use is primarily mixed residential and agricultural, the surrounding mountains are largely under Forest Service management with forestry and recreational uses dominating. The Bitterroot Valley has a north – south axis with the Bitterroot Range to the west and the Sapphire Mountains to the east.

Climate

The climate varies considerably within the study area because elevation ranges from 3,600 feet at the mid-valley city of Hamilton to over 10,000 feet in the Bitterroot Range. Most wetlands are in the valley bottom with weather similar to Hamilton. The following summary is for Hamilton and is primarily from the Western Regional Climate Center (2007). The average yearly maximum temperature is 58.9°F with an average minimum temperature of 33.3°F. July and August are the hottest months, with average maxima of 84.7°F and 83.1°F, respectively. Average annual precipitation is 12.2 inches, most months average slightly less than 1 inch; May and June are the wettest months, 1.6 and 1.7 inches, respectively. An average of 25.7 inches of snow falls annually. Detailed climatic summaries are not available for the surrounding mountain ranges, but relatively cool and wet conditions create important surface and subsurface water discharges that maintain valley wetlands. Some areas of the Bitterroot Range average over 80 inches of precipitation annually (Briar and Dutton 2000).

Geology, Landform, Soils, and Hydrology

The study area consists of two major regions: the Bitterroot River valley, which is about 50 miles long and up to 10 miles wide, and the surrounding mountain ranges. The north-south valley is composed primarily of surface alluvium over Tertiary deposits up to 2400 feet deep (Briar and Dutton 2000). Most wetlands are found on the 1 to 2 mile wide Bitterroot River floodplain and the adjacent benches. Floodplain soils are mostly derived from sand and gravel while the benches have finer textured soils over coarser alluvial deposits (Bourne 1951). The mountains are of sedimentary, metamorphic, volcanic and plutonic rocks (Briar and Dutton 2000, Lonn and Sears 2001). Mountain soils are often thin and coarse with bedrock exposure common, but there are also some areas of deeper soils (Bourne 1951). The Bitterroot Mountains rise to over 10,000 feet and extend along the entire western boundary of the valley. The Sapphire Mountains are lower and run along the east side.

Basin-fill aquifers in the valley are recharged by streamflow infiltration, irrigation water, subsurface inflow from surrounding bedrock (primarily from melting snowpack), and direct precipitation and snowmelt (Briar and Dutton 2000). The wetter Bitterroot Range contributes considerably more recharge water than the Sapphire Range to the east (Briar and Dutton 2000). The Bitterroot River peaks in the late spring, declines during the summer when irrigation withdrawals are significant and remains stable during the winter (Briar and Dutton 2000). Diffuse surface ground water discharge and irrigation is common in the valley, both can create wetland areas.

Vegetation

Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) forests dominate the uplands, western larch (*Larix occidentalis*) and subalpine fir (*Abies lasiocarpa*) are also common (McNab and Avers 1994). Wildfires are common and can lead to dense lodgepole pine (*Pinus contorta*) stands. Grasslands of bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and rough fescue (*Festuca campestris*) (McNab and Avers 1994) are common on drier aspects. Much of the native grassland vegetation in the valley has been replaced by agricultural species, especially non-native pasture grasses. In lower valley wetland and riparian areas, pasture grasses, smooth brome (*Bromus inermis*), and a variety of non-native weeds have often replaced native herbaceous species, although the woody vegetation is primarily composed of native species dominated

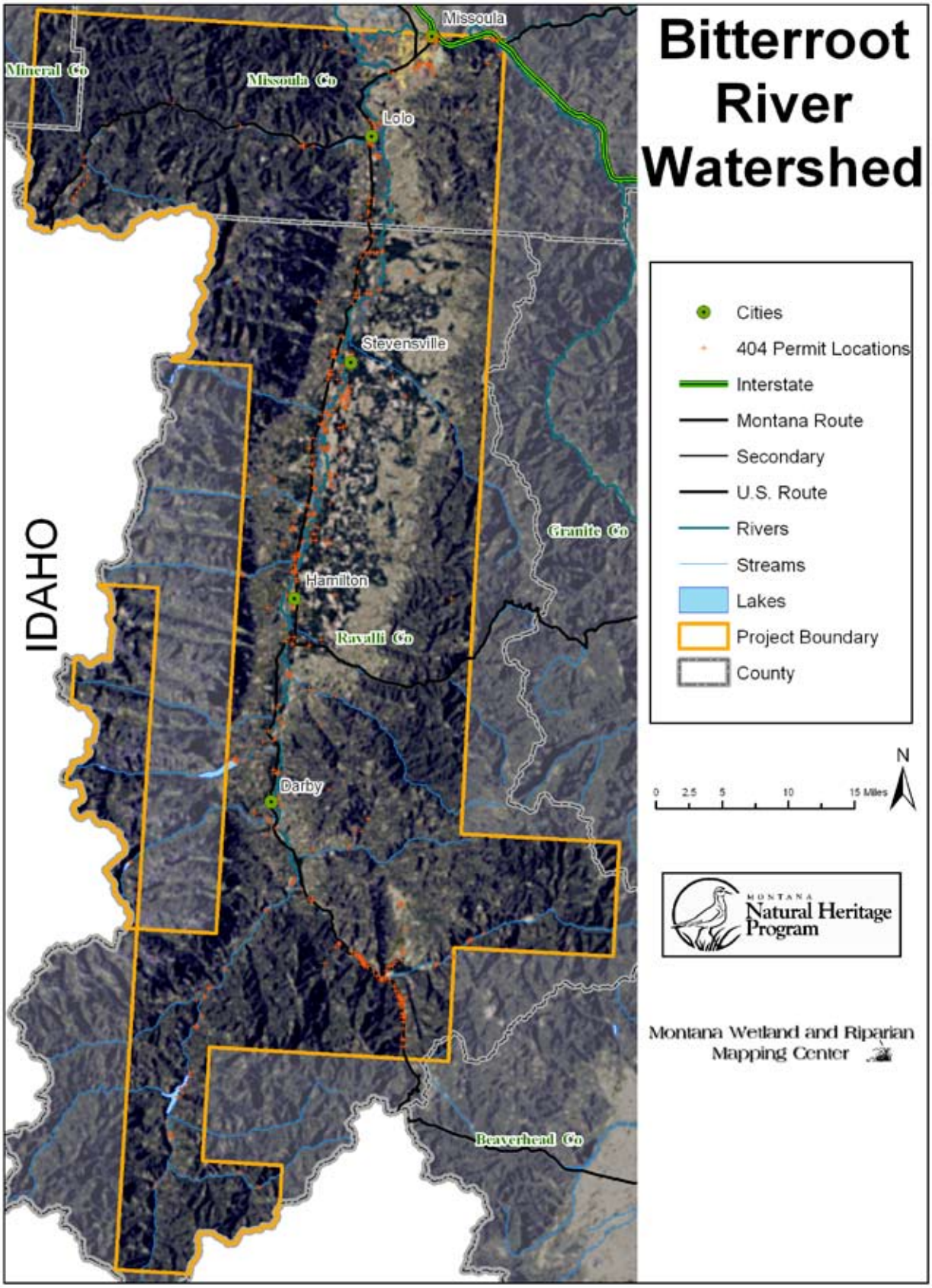

Figure 1. Map of the study area.

by cottonwoods and willows. Wetland and riparian ecosystems are generally more ecologically intact as the elevation increases because non-natives either are not adapted to climatic and soil conditions or have not dispersed to the area. Wetland types are further described later in this document.

Land Use History

In 1805 the Lewis and Clark expedition found the Bitterroot Valley occupied by the Flathead Tribe of the Salish Indian Nation (Bourne 1951), later relocated by the U.S. government following an 1850's treaty. The first European settlement occurred in 1841 near the town of Stevensville with the establishment of a Catholic mission (Bourne 1951). Livestock and crop production along with mining, logging, and the construction of the Northern Pacific railroad spurred further settlement; by the 1880's there was a thriving community (US Bureau of Reclamation 2007).

Large scale irrigation began with the construction of the Surprise Ditch in 1875 and by 1900 most of the valley was irrigated (Bourne 1951). Local irrigators completed Como Dam and its large reservoir in 1910 with subsequent improvements by the Bureau of Reclamation (US Bureau of Reclamation 2007). Painted Rocks Lake is another large irrigation reservoir. These irrigation projects have created, altered or destroyed wetlands throughout the valley; therefore, the presettlement status of wetlands in this area will always remain obscure.

The largest city is Missoula (Missoula County) at the northern end of the area. Hamilton (Ravalli County) is the next largest city and is located near the center of the valley. Missoula and Ravalli County human populations grew steadily through the 20th century (Figure 2), with much of the Ravalli County increase occurring outside of established cities and towns (Briar and Dutton 2000). There was a 44% population increase from 1990 to 2000 in predominately rural Ravalli County, which was the fastest growing county in Montana during the early 1990's (U.S. Census Bureau 2007). Most of this development has occurred in the wetland-rich Bitterroot Valley bottom where agricultural land has been subdivided into smaller acreages or residential lots.

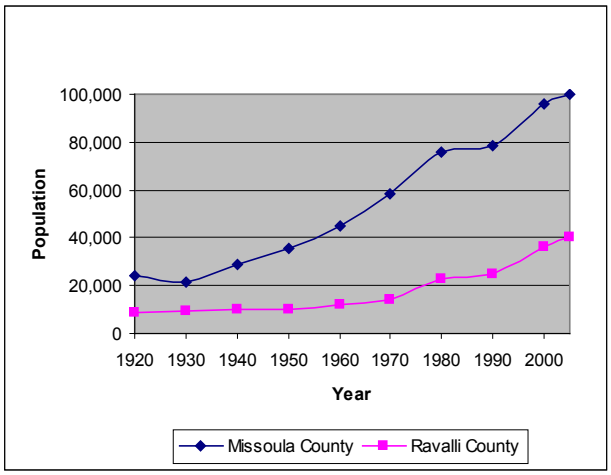

Figure 2. Annual estimates of the population for Missoula and Ravalli Counties of Montana. Source: Population Division, U.S. Census Bureau. Release date: March 16, 2006.

Methods

All new NWI wetland mapping was completed by the Montana Wetland and Riparian Mapping Center of the Montana Natural Heritage Program (MTNHP) to NWI specifications. Mapping followed the USFWS National Standards and Quality Components (2004) and the Technical Procedures for Mapping Wetland, Deepwater and Related Habitats (2004). The USFWS NWI classification system (Cowardin et al. 1979, Appendix 1) was used to code wetland polygons. Wetland areas were delineated in an ArcMap 9.X environment. We first obtained a geodatabase clip from the USFWS NWI master geodatabase and added several ancillary spatial data layers to the ArcMap project. Polygons were also coded with hydrogeomorphic modifiers adapted from Tiner (2003, Appendix 2). New NWI mapping was 100% reviewed by MTNHP personnel, approved by the NWI Regional Coordinator, and incorporated into the National NWI geodatabase.

The original NWI mapping was delineated by hand with ink on mylar overlays covering 1:58,000 scale color infrared aerial photography from the period 1982 to 1984. The original NWI mapping had enough geometric distortion that a "cookie-cutter" approach comparing the two dates of mapping, similar to the NWI status and trends approach (USFWS 2004), would not be accurate. We first randomly selected square mile sections within each 5th code HUC in the study area until at least 10% of each HUC was selected. We visually compared each original NWI polygon to the 2005 NWI mapping update and coded for change. Changes were based on the dominant 2005 type by area within each original NWI polygon. The new NWI mapping often recognized two or more wetland types within a wetland area originally attributed as one type in the original NWI. The source of change was also coded for each polygon. The majority of change was due to type interpretation differences; the new mapping benefited from multiple imagery dates with 1 meter high–resolution color infrared imagery as the base imagery and numerous ancillary data sources and spatial data layers. Interpretive differences were not considered as wetland change and were eliminated from the analysis. Tony Olsen of the EPA completed the statistical analysis with statistical programs developed for the National Wetland Status and Trends Analysis.

We also completed a 100% assessment for beaver ponds (NWI Palustrine aquatic beds and unconsolidated bottom classes) and human created wetlands, reliably identified in both sets of NWI mapping and few enough in number to be visually examined on digital imagery. The full assessment was only practicable for a subset of types that could be easily identified and where geometric displacement issues and interpretative differences could be controlled. NWI types other than ponds, like emergent or shrub wetlands, were also often given a "b" (beaver) NWI modifier because they were interpreted to have been created by beaver action, but this determination was less consistent in the two series of mapping than beaver ponds. Human created wetlands are given modifiers for excavation or impoundment, developments that are relatively easy to see on imagery. Wetlands created after the original NWI mapping were identified by applying a 20 m buffer to original NWI polygons then eliminating all intersecting new NWI wetland polygons. This buffer was applied so that geometric displacement between the two layers did not result in an incorrect identification of created wetlands created. All new human created wetlands larger than 0.2 acres were visually examined on imagery and only those that were obviously created and not due to interpreter differences were included in the analysis. Of course, all these wetlands were originally mapped, attributed, and 100% reviewed in our standard NWI mapping quality control process.

We estimated a relative level of performance for each ecological function for every mapped combination of NWI and HGM types (Appendix 3). The three performance levels we identified are relative to other types, most wetlands perform all these functions to some degree. In some cases we recognized that these functions will vary with the range of elevation in our study area and we applied the following modification for this effect.

Elevation values were established for each wetland by dividing the elevation of a site by the lowest wetland elevation within the study area (3084'). The square root of this value is then used as a multiplier for the function values of 1 (highest), 2, or 3 applied to the type. For example, a wetland type at a 4000 ft. elevation with a 2 value for a function judged to be better performed for the same type at a higher elevation will be calculated:

(4000/3084) = 1.3, square root of 1.3 = 1.14, 1.14 X 2 = 2.28

An inverse transformation is applied if the same type performs the function better at lower elevations:

(4000/3084) = 1.3, square root of 1.3 = 1.14, (1/1.14) X 2 = 1.75

Functional performance levels were modified by the elevation transformation, if appropriate, and then grouped in hydrologic, biogeochemical, and habitat categories. The habitat composite values were composed of four metrics so we multiplied these values by 0.75 to create a scale equivalent to the three metrics composing the hydrologic and biogeochemical scores. These values were multiplied by the number of acres within each wetland polygon. Total values were summed in a 500 m cell grid across the study area for map display.

Results and Discussion

Wetland and Deepwater Types

Classification Systems and Overview

Wetland and deepwater types were classified with two systems, the standard National Wetland Inventory (NWI) classification system (Cowardin et al. 1979), and a hydrogeomorphic (HGM) system (Brinson 1993) also called LLWW (for Landscape, Landform, Water Flow path, and Waterbody type). The LLWW system was adapted from Tiner (2003) and has been incorporated as a supplementary classification to the NWI in the Federal Geographic Data Committee Working Draft Wetland Mapping Standard to predict wetland functions, better characterize wetlands, and to provide salient information to policymakers (FGDC Wetland Subcommittee and Wetland Mapping Standard Workgroup 2007). We slightly modified the original Tiner (2003) system (Appendix 2) and have incorporated its use in all wetland mapping completed by the Montana Wetland and Riparian Mapping Center. Since it is fundamentally a hydrogeomorphic system (Brinson 1993) we refer to it by the HGM acronym.

An HGM approach emphasizes the abiotic setting which strongly influences wetland functions with wetland classification based on geomorphic setting, hydrodynamics, and water source (Brinson 1993). However, this classification system lacks information about significant site factors coded in the NWI classification like water regime and vegetation, which influence functions like habitat value, sediment retention, and nutrient cycling. Using both systems results in a more accurate assessment of wetland functions and gives users more insight into the value and characteristics of wetlands.

The NWI classification system (Cowardin et al. 1979) is hierarchical (Appendix 1). The first level, System, has only three categories in our study area: Riverine (wetlands within a river channel), Lacustrine (generally lakes over 20 acres), and Palustine (everything not in the two other Systems). See Cowardin et al. (1979) for full definitions. Lacustrine includes Limnetic and Littoral Subsystems. Riverine Subsystems in our area include Lower Perennial, Upper Perennial, and Intermittent. The Palustrine System lacks Subsystems. Palustrine Systems and the Lacustrine and Riverine Subsystems are further subdivided into Classes (see Appendix 1).

The HGM classification (Appendix 2) first characterizes wetlands by landscape position and differs from the NWI for some classification types that seem similar in both systems. For example, the NWI narrowly defines riverine wetland as those wetlands contained within the channel, with minor exceptions (Cowardin et al. 1979), then recognizes subsystems similar to the HGM classification (Lower Perennial, Upper Perennial, Intermittent, etc.). The HGM classification recognizes that wetlands are strongly influenced by the broader landscape setting, thus a river wetland does not have to be within the channel, only associated with a river and the dynamic ecological processes operating in that landscape setting. Further HGM classification subdivision refines landscape position and identifies water flow direction. Additional modifiers are incorporated for watercourse gradient, intermittent flows, and dams (see Appendix 2).

Wetlands and deepwater types comprise 1.1% of the total study area. The flooded beds and shores of rivers are the most common NWI wetland type (34%), followed by wetlands with emergent vegetation (26%), deepwater habitats (13%), and wetlands with shrub vegetation (12%) (Figure 3). Forested wetlands are very uncommon, only 15.1 acres were mapped.

The HGM classification more strongly emphasizes the association of most wetlands with watercourses, 74% of all wetlands are coupled to these settings (Figure 4). Terrene wetlands, surrounded by uplands and not located on floodplains (Appendix 2), comprise 12.2% of all wetlands. A large majority of all Terrene wetlands (93.3%, totaling 1,806 acres) are isolated wetlands (Figure 5), which may not be subject to wetland regulations. Slope wetlands occur where groundwater discharges,

typically at a topographic break, and may have high productivity, diverse native plant communities, and habitat for plant Species of Concern in our region (Jankovsky-Jones 1999b). Only 37.7 acres of slope wetlands were mapped in our study area (Figure 6), but, due to their potential conservation value, this wetland type is recommended for further biological review.

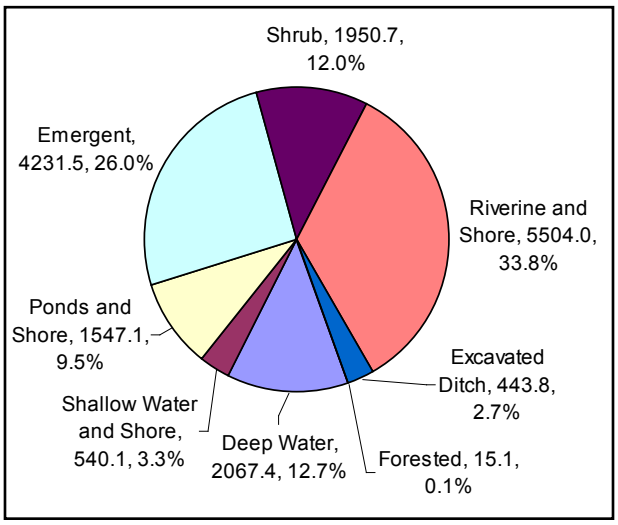

Figure 3. Distribution of National Wetland Inventory (NWI) types (to NWI System level for Riverine, Subsystem level for Lacustrine, and Class level for Palustrine) within the study area. Values are in acres followed by the type percentage of total wetland area. See Appendix 1 for a full summary of NWI type classification.

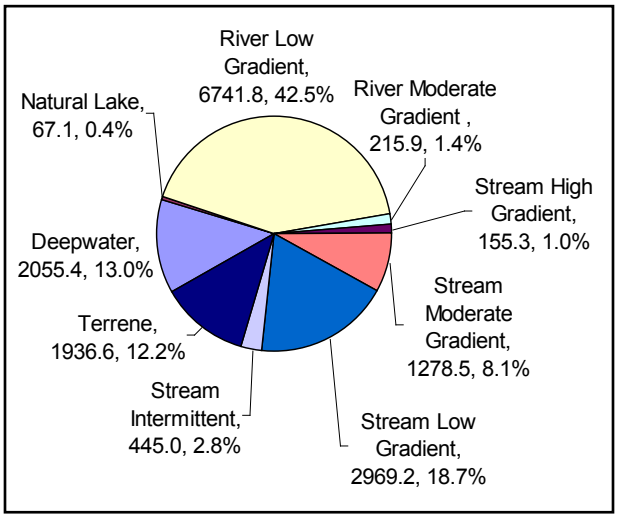

Figure 4. Distribution of hydrogeomorphic (HGM) types (see Appendix 2) within the study area. Values are in acres followed by the type percentage of total wetland area.

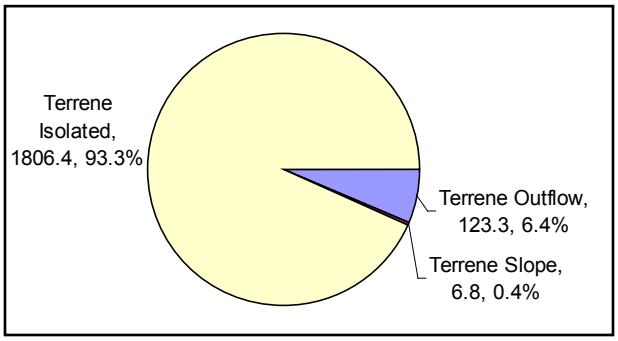

Figure 5. Distribution of terrene hydrogeomorphic (HGM) types (see Appendix 2) within the study area. Values are in acres followed by the type percentage of total terrene wetland area.

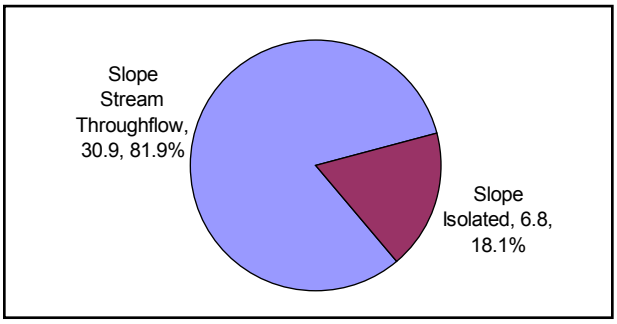

Figure 6. Distribution of slope hydrogeomorphic (HGM) types (see Appendix 2) within the study area. Values are in acres followed by the type percentage of total slope wetland area.

See Cooper et al. (1999) for a key and full description of upland and wetland vegetation associations occurring in the area. Pierce and Jensen (2002) provide a guide to aquatic plant communities.

Lacustrine and Deepwater Types

Lacustrine deep and shallow water habitats comprise 16% of all wetland and deepwater area (Figure 3). Most of that area is deepwater (Figure 7), including a few large reservoirs (Figure 8). The vegetated aquatic plant communities have been classified for this area by Pierce and Jensen (2002) and include a variety of submerged, floating, and emergent plant species. Considerable annual and seasonal water fluctuations occur in these reservoirs resulting in a variable percentage of types at any given time.

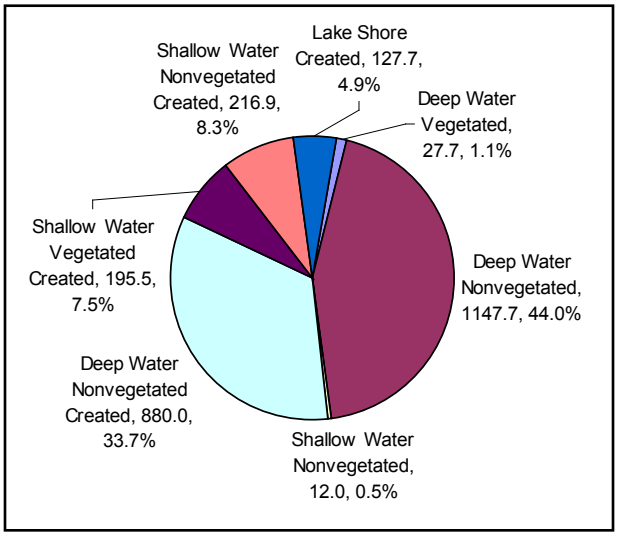

Figure 7. Distribution of Lacustrine National Wetland Inventory (NWI) types within the study area. Values are in acres followed by the type percentage of total Lacustrine wetland area. See Appendix 1 for a full summary of NWI type classification.

Figure 8. Lake Como reservoir.

Riverine Wetlands

Most of the NWI riverine type (defined as within the channel) acreage is the Lower Perennial flooded beds and their shores (Figure 9). The percentage of these two acreages will fluctuate considerably seasonally and annually due to the size of flows in the Bitterroot River, the only Lower Perennial river classified in our study area other than a few miles of the Clark Fork River. The Bitterroot River shores and bottom are mostly coarse textured with sands and gravels predominating (Figure 10). Water velocities are relatively high and aquatic vegetation is not common. The shores may be sparely colonized by vegetation during the dry season but seasonal high water flows prevent permanent vegetation from establishing. Flooded beds and shores of tributaries of the Bitterroot River like the Lolo Creek or the West and East Forks of the Bitterroot River comprise the Upper Perennial types. These fast moving rocky rivers also have considerable seasonally and annual water level fluctuations with a changing percentage of aquatic beds and shores. Excavated irrigation ditches are common in the lower valley and total 443.8 acres. Intermittent streambeds are often too small to map but occur regularly in the higher elevations.

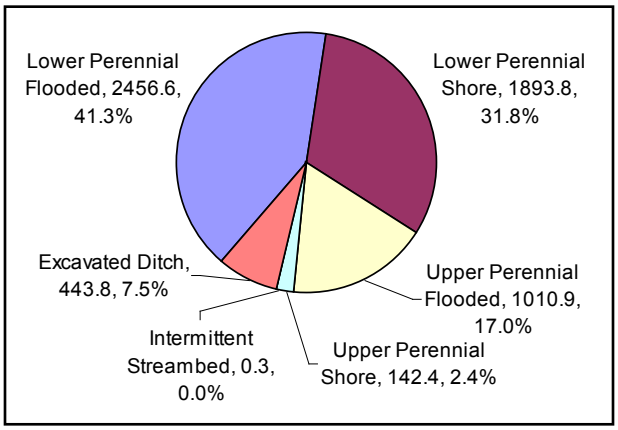

Figure 9. Distribution of Riverine National Wetland Inventory (NWI) types within the study area. Values are in acres followed by the type percentage of total Riverine wetland area. See Appendix 1 for a full summary of NWI type classification.

Figure 10. Bitterroot River with typical extensive gravel bars.

Palustrine Emergent Wetlands

Most emergent wetlands are found on the valley bottom (Figure 11). Many occur due to groundwater discharge from the surrounding mountains, but emergent wetlands are also common in the riparian corridor of the Bitterroot River. About 20% and 830 acres of emergent wetlands have been created by humans; less than 5 acres have been created by beavers (Figure 12). These wetlands have been developed by excavation, impoundment or ditching - primarily for agricultural purposes like flood irrigation for greater forage production, but these wetlands are also commonly associated with created ponds. Most emergent wetlands are drier (Figure 12), and classified as temporarily or seasonally flooded. The water table is typically only near the surface during the spring and early summer. These drier valley bottom wetlands are typically managed as pastures; many have been seeded, fertilized or otherwise disturbed. The resultant vegetation is typically dominated by a mix of native sedges and nonnative pasture grasses. Nebraska sedge (*Carex nebrascensis*) is the most common native sedge on these drier sites. These types are often borderline wetlands and represent the most problematic type to accurately map.

Figure 11. Palustrine emergent wetland on the Bitterroot River Valley floor.

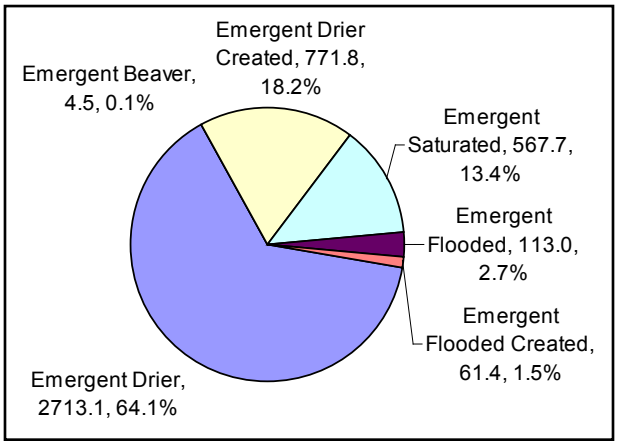

Figure 12. Distribution of Palustrine emergent National Wetland Inventory (NWI) types within the study area. Values are in acres followed by the type percentage of total Palustrine emergent wetland area. Drier wetlands are classified as temporary or seasonally flooded. See Appendix 1 for a full summary of NWI type classification.

Emergent saturated wetlands are more common in higher elevations where water levels near the surface are maintained by groundwater discharge or stable lake water levels most of the year. Organic soils often develop and form peatlands (Figure 13). These types are not common in Montana (Chadde et al. 1998). Additionally, peatlands support a large number of rare taxa and are consequently of great conservation value (Jones 2003). Forty plant Species of Concern, constituting 9% of the Montana's rare flora, are associated with peatlands, as is one animal, the Northern Bog Lemming (*Synaptomys borealis*) (Jones 2003). While not all of the 568 acres of saturated emergent wetlands are peatlands, this mapping represents a valuable resource for botanists to better survey these habitats. Large sedges like beaked sedge (*Carex utriculata*) and inflated sedge (*Carex vesicaria*) will dominate saturated wetlands with greater water table fluctuations. Wetlands with more constant high water tables are less common and are more likely to provide habitat for Montana plant Species of Concern. These sites often are dominated by Sphagnum moss species with intermixed sedge species like slender sedge (*Carex lasiocarpa*).

Figure 13. Palustrine saturated emergent wetland (peatland) in upper Lolo Creek watershed.

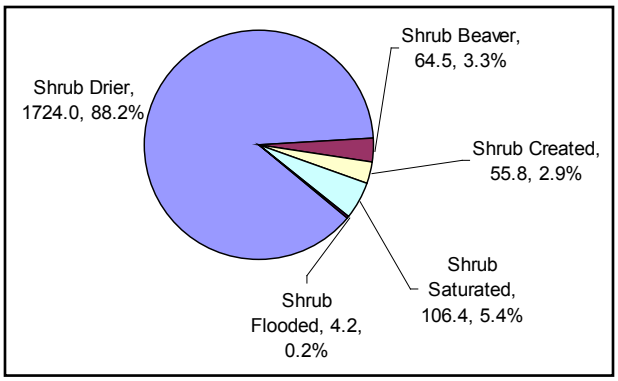

Figure 14. Distribution of Palustrine shrub National Wetland Inventory (NWI) types within the study area. Values are in acres followed by the type percentage of total Palustrine shrub wetland area. Drier wetlands are classified as temporary or seasonally flooded. See Appendix 1 for a full summary of NWI type classification.

Flooded emergent wetlands are less common. Beaked sedge and inflated sedge occur in these habitats but cattails (*Typha* spp.) and/or reed canary grass (*Phalaris arundinacea*) often dominate, especially in disturbed areas or sites with high nutrient loading.

Palustrine Shrub and Forested Wetlands

Most shrub dominated wetlands have a drier water regime, classified as temporarily or seasonally flooded (88%, Figure 14). A variety of willows species (*Salix* spp.) typically dominate these types with common mountain alder (*Alnus incana*) and red-osier dogwood (*Cornus stolonifera*). Shrub wetlands with saturated water regimes can accumulate organic soil and become peatlands with a characteristic peatland vegetation community. Beaver activity creates some shrubby wetlands; these often form at the upstream area of a beaver pond or between ponds in a complex of ponds (Figure 15). While riparian forests are common, few forested wetlands were mapped; quaking aspen (*Populus tremuloides*) was the typical dominant tree.

Figure 15. Palustrine shrub wetland associated with a beaver pond in the upper Lolo Creek watershed.

Palustrine Ponds

Ponds and their associated shores (NWI aquatic bed, unconsolidated bottom and shore classes) are 9% of the total wetland area (Figure 3). Human created ponds are very common, totaling about 70% of all ponds (Figure 16). Beaver ponds are not common, and comprised only 5.2 acres in the entire study area. Most ponds were classified as vegetated with aquatic plants. Pond vegetation is variable and often strongly zoned due to the interaction of plant species and variable depths of water. In shallow areas vegetation is similar to the species occurring in flooded emergent wetlands. Deeper water areas have submerged or floating species.

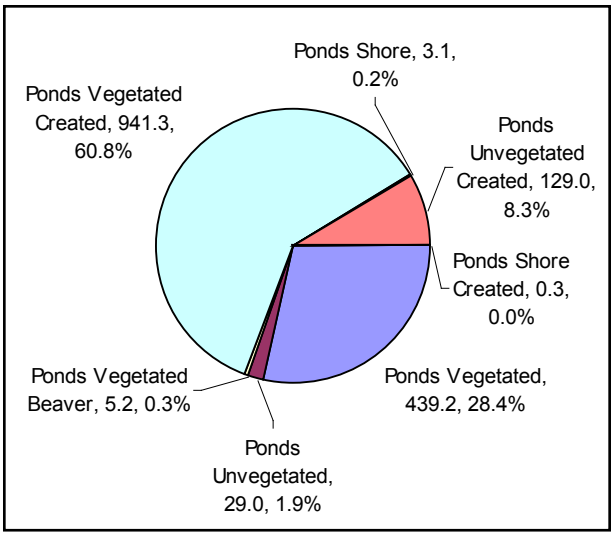

Figure 16. Distribution of Palustrine pond National Wetland Inventory (NWI) types (aquatic bed, unconsolidated bottom and shore classes) within the study area. Values are in acres followed by the type percentage of total Palustrine shrub wetland area. See Appendix 1 for a full summary of NWI type classification.

Ecological Functions

A wide variety of wetland ecological functions have been identified within various assessment methodologies (Sheldon et al. 2003). Regional characteristics and management needs often form the rationale for identifying, grouping, or subdividing functions, but most can be grouped into three main categories: hydrologic, biogeochemical, and habitat (Adamus et al. 1991). All these functions will be strongly influenced by environmental factors at the wetland site or landscape scale. An emphasis on the primacy of the abiotic setting led to the development of the HGM classification where wetlands are classified by their geomorphic setting, hydrodynamics, and water source (Brinson 1993). However, this classification system lacks information about significant site factors coded in the NWI classification like water regime and vegetation, which influence functions like habitat value, sediment retention, and nutrient cycling. Incorporating the information inherent in both systems will result in a more accurate assessment of wetland functions.

Our landscape approach to a functional analysis benefits from an emphasis on fine-scale mapping that integrates the information inherent in both the HGM and the NWI classification systems. However, we lack the site-specific assessment inherent in the HGM approach where the condition of an assessed wetland is evaluated to reference wetland functions (Brinson 1993). Condition can significantly affect wetland functions; we have no way of assessing condition across our landscape of wetlands. Many functions also depend on landscape context. The juxtaposition of surrounding wetlands, water bodies, upland types, and land use will all affect how wetlands function. We have established elevation values for individual wetland polygons as a way to integrate the elevation gradient, which is probably the most important ecological gradient in our area, but we have not attempted the complex task of characterizing and evaluating the impact of the local mosaic of land uses and vegetation types on wetland function. Not all functions will vary with elevation; we selectively applied an elevation weighting to a subset of functions.

We identified 10 ecological functions: 1) water storage and flood peak modification, 2) stream flow maintenance, 3) ground water recharge, 4) nutrient cycling, 5) sediment retention, 6) shoreline stabilization, 7) native plant community maintenance, 8) terrestrial habitat, 9) aquatic habitat, and 10) conservation of wetland biodiversity.

The NWI classification (Cowardin et al. 1979, Appendix 1) has several water regime modifiers. For the purpose of this functional assessment, we grouped these modifiers into two groups, “wetter” and “drier”. The wetter group has surface water present throughout most of the year and includes semi-permanently flooded, permanently flooded and saturated water regimes. The drier group usually does not have surface water during the drier seasons and includes seasonally flooded and temporarily flooded water regimes.

Functions Related to Hydrology

Hydrologic issues are of great concern in our study area and across the West. We identified three hydrology wetland functions that modify peak flood flows, maintain watercourse flows, and provide groundwater recharge. Figure 17 displays performance levels for this group of hydrologic

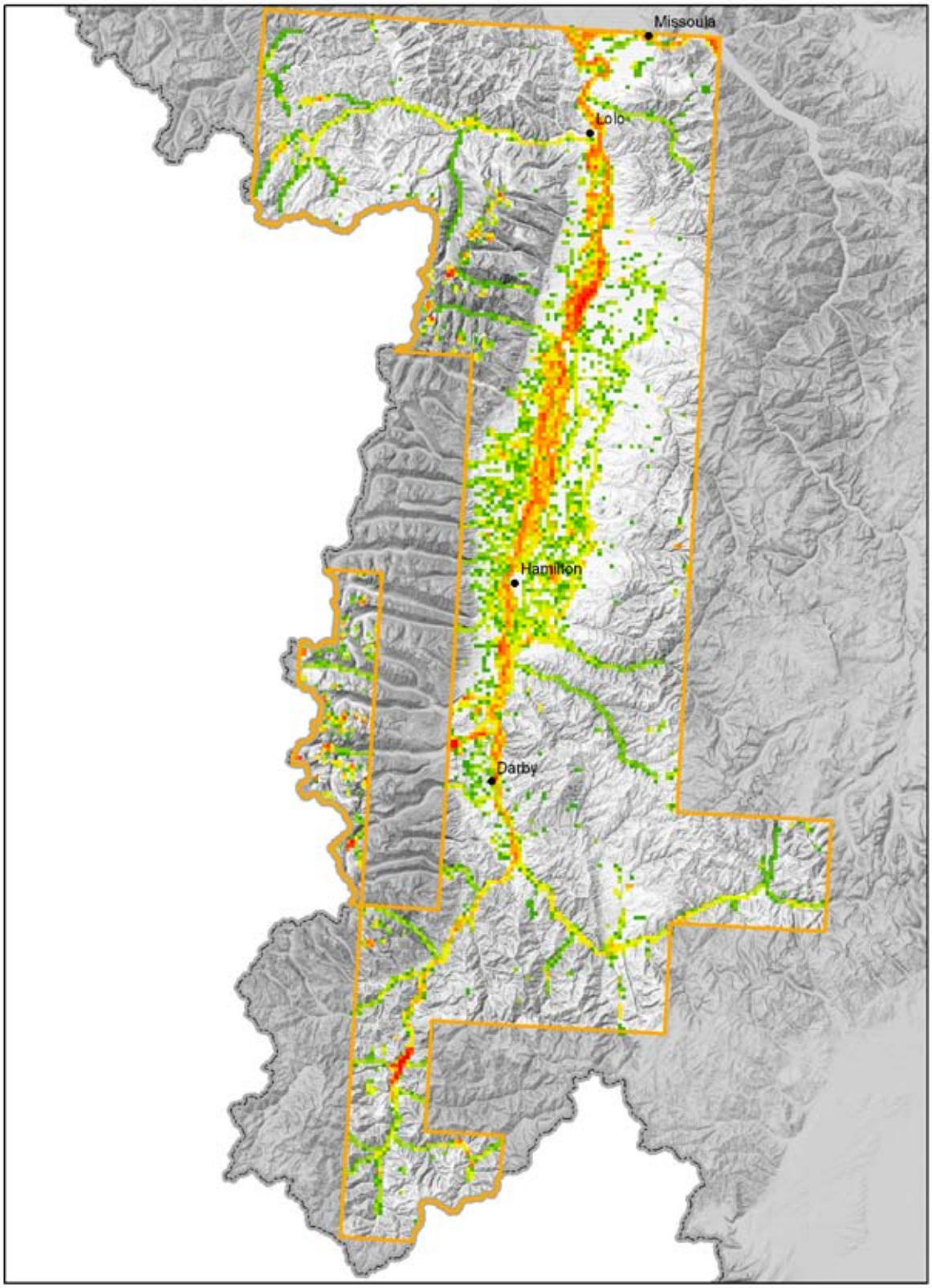

Figure 17. Study area map of wetland combined hydrologic functions. 500 m grid cells reflect wetland types coded for 3 hydrology functional performance levels multiplied by cell wetland type acreage. Red is highest performance level, followed by yellow and green.

functions. Uplands also provide these hydrologic functions, no attempt was made to estimate upland functions. Functional performance levels for hydrology follow the concentration of wetlands in riparian and valley floor locations.

Water Storage and Flood Peak Modification
Wetlands intercept and store runoff by spreading flows over a large flat area, resulting in reduced water velocities and slower discharges over long periods of time (Mitsch and Gosselink 2000). The result can be cost-effective flood control, and in some instances their protection has been recognized as less costly than flood-control measures such as reservoirs or dikes (Carter et al. 1979). A strong correlation exists between the size of flood peaks and basin storage (lakes and wetlands) in many parts of the United States (Carter 1996). River hydrology in much of the Intermountain West including our study area is strongly influenced by snowmelt with peak flows in early summer and recurring flood events (Hubert 2004). Approximately 55% of runoff in the Bitterroot River occurs during May and June (McMurtrey et al. 1972). Lowering peak flow discharges and reducing water velocity will protect human developments near or on the floodplain.

The effectiveness of wetlands for this function relies on the available storage capacity, season, and soil permeability (Carter 1996). Storage capacity refers to the space available for water storage, the higher the water table, the less the storage capacity of a wetland (Carter 1996). Drier wetlands will generally perform this function at higher levels than wetter wetlands due to a greater storage capacity.

Landscape position is important for this function. A review of research showed that floodplain wetlands reduce or delay floods (23 of 28 studies), but headwater wetland types often do not perform this function (36 of 66 studies) (Bullock and Acreman 2003). A substantial minority of these headwater types (27 of 66 studies) increased flood peaks (Bullock and Acreman 2003). Wetland types with a connection to the river system had mixed results and the few studies about wetlands with no river system connection indicated a positive influence (Bullock and Acreman 2003). Sheldon et al. (2003) believe that lacustrine fringe, flats, and slope wetlands probably do not perform this function as well as riverine and depression types. Adamus et al. (1991) considers fringe and island wetlands less likely to alter floodflows and wetlands without outlets more likely to alter floodflows than those with outlets (Adamus et al. 1991).

Vegetation will slow water velocity, allow more overbank storage and reduce the potential for water erosion damage. In a HGM assessment for forested wetlands, Klimas et al. (2004) selected vegetation ground cover, tree density, and woody debris density as rapid assessment indicators (along with flooding frequency) for water storage and floodwater velocity reduction. Forested or scrub-shrub wetlands are more capable of altering floodflows than other types of vegetated wetlands (Adamus et al. 1991).

We identified landscape setting, water storage capacity, and wooded vegetation as the most important factors in rating effectiveness for this function. Deepwater types and all non-wooded wetland types (other than those in basins) with wetter water regimes were rated low since these types will have little storage capacity available. Drier slope wetlands were also rated low for the same reason, with the exception of wooded slope wetlands which were rated moderate. All basin outflow wetlands were rated low since these wetlands are likely sources of discharge. Drier basin inflow or terrene isolated wetlands were rated high since these wetlands will keep runoff from reaching watercourses. Basin wetlands with a wetter water regime were rated moderate because these likely have some storage capacity available due to their landform even if the water table is near the surface. All other drier wetlands were rated moderate unless wooded, which were rated high if associated with throughflow locations where these types are likely to slow floodwater velocities. Created wetlands were rated low for this function because of the minimal water storage capacity present due to typically high water levels.

Streamflow Maintenance
Streamflow is supported when wetlands discharge stored water. In our study area small watercourses often go dry during the summer and larger rivers can experience low flows and warmer water temperatures due to reduced discharge and withdrawals. While streamflow maintenance is commonly regarded as a wetland function, the importance of this function in wetlands compared to the surrounding landscape is uncertain. In a review of research, Bullock and Acreman (2003) reported that floodplain wetlands were the types most likely to support dry season flows, but a majority of these types and all other wetland types studied (47 of 71) diminished rather than sustained dry season flows (Bullock and Acreman 2003).

Floodplain aquifers can store floodwater and support streamflows later in the season (Brunet et al. 2003, Hubert 2004). In mountainous headwater streams, floodplains are often narrow with little alluvium and there is little capacity to store water (Hubert 2004). However, deeper alluvial deposits like we have in the lower valley can store water at high flows and later release water into the channel at low flows (Hubert 2004). Substrate permeability will affect bank storage; gravel floodplains may drain in days while fine-textured floodplains may hold water for years (Tiner 2003). Our floodplains mostly contain coarse textured substrates.

We rated the non-vegetated unconsolidated shores of floodplain wetlands high for this function. Other floodplain or perennial watercourse associated wetlands were rated moderate due to the potential for considerable water loss through vegetation transpiration and/or evaporation in our dry climate. Basin wetlands where streams entered but did not exit were rated low as were all other wetlands. Created wetlands were rated low because evaporation rates will be high in our climate and the net result for streamflow maintenance is likely minimal or negative.

Ground water recharge
Recharge occurs when wetlands retain precipitation and surface flows that later infiltrate into the ground water (Sheldon et al. 2003). Most wetlands are primarily areas where ground water reaches the surface and discharges, but ground water recharge can also occur (Carter 1996). Recharge also takes place through the bottoms of some streams, especially in the arid West, and when floodwater moves across the floodplain (Carter 1996). Wetlands that are not permanently flooded are more likely to recharge ground water; in precipitation-deficit regions like our study area, permanent water likely indicates ground water discharge (Adamus et al. 1991). Bullock and Acreman (2003) reviewed research on ground water recharge in wetlands and found that wetlands on floodplains or in depressions without a connection to the river system were the most likely to recharge ground water. The evidence of ground water recharge in other wetland types was mixed; recharge was measured in some studies but not in others (Bullock and Acreman 2003).

Adamus et al. (1991) concluded that ground water flow rates under the wetland, the storage capacity of the wetland, water movement within the wetland, and evapotranspiration were the most important site factors associated with this function. Ground water flow rate will depend on the elevation of the wetland relative to ground water, the mass and pressure of the water and the characteristics of the underlying sediments and substrates (Adamus et al. 1991). A review of research indicates there is strong evidence that wetlands evaporate more water than other land types (Bullock and Acreman 2003). Wetland vegetation will also transpire water, resulting in less water available for recharge compared to non-vegetated wetlands, but other factors such as the impact of vegetation on snow interception and reducing evapotranspiration by providing shade and reducing wind speed and temperature may result in little influence of vegetation on overall water loss (Adamus et al. 1991).

The ground water recharge function of wetlands is complex and can change with season and location within an individual wetland (Adamus et al. 1991). This function is difficult to accurately assess but ground water quantity is a concern in our study area and all wetland types do not perform equally for this function. Wetlands on our coarse textured and permeable floodplains may

represent the most predictable areas of ground water recharge; we rated these types high along with other wetland types associated with low gradient rivers and streams. Many of our smaller and steeper gradient watercourses do not have well developed floodplains; these wetlands were rated moderate unless coded as floodplain types (rated high), associated with an intermittent stream (rated low), or an inflow basin (rated like isolated wetlands). We rated wetlands isolated from the river system with a drier water regime as high and moderate if wetter. The pressure head created by lakes will facilitate recharge. Wetlands associated with lakes were rated high unless in fringe and island locations which are least likely to recharge ground water (Adamus et al. 1991); these were rated low. Created wetlands were rated low because evaporation rates will be high in our climate so net ground water recharge is likely minimal. Although ground water recharge may generally occur at higher elevations (and discharge at lower elevations), we considered this function elevation neutral since the valley bottom has porous alluvial soils that may better capture ground water than the bedrock-dominated mountains. Also, this function is more important in the valley bottom due to ground water demands.

Functions Related to Biogeochemical Processes

Wetland biogeochemical functions strongly influence water quality through nutrient cycling, sediment retention, and shoreline stabilization. Figure 18 represents the concentration of this group of functions on our study area landscape. These functions are strongly concentrated along riparian areas.

Nutrient Cycling

Nutrient input from anthropomorphic activities can have a major detrimental impact on water quality. A review of research reported that 80% of wetlands studied retained nutrients (Fisher and Acreman 2004). Wetlands are so efficient that they are sometimes used as wastewater treatment facilities by municipalities. Phosphorus and nitrogen are the nutrients of greatest importance (Hauer et al. 2002). Major processes that affect nutrient cycling include biological uptake, sedimentation and accumulation of organic matter, adsorption and nutrient interactions with sediments, and chemical and microbial processes (Adamus et al. 1991).

Phosphorus occurs in a sedimentary cycle and is retained in wetland living or dead organic material and inorganic sediments (Mitsch and Gosselink 2000). Since the P in living plants will eventually be released, the only long-term capture of P will depend on the accumulation of organic matter and sediments, although the capture of P by vegetation may have seasonal water quality benefits. To maximize P removal, the wetland substrate should be aerobic to minimize sediment P release and allow P binding to Fe and Al (Fisher and Acreman 2004).

Wetland removal/retention of N is dependent on organic matter accumulation as an energy source for denitrifying bacteria (denitrification) and for retaining organically bound N (nitrification) (Anderson and Mitsch 2006). Denitrification is a critical process because it results in the removal rather than retention of N (Adamus et al. 1991). Nitrification will occur in aerobic conditions while denitrification requires anaerobic bacteria (Mitsch and Gosselink 2000). Both processes can occur in wetlands with a fluctuating water table that creates aerobic and anaerobic conditions. A research review indicated N loss was maximized by fluctuating water tables or the close juxtaposition of aerobic and anaerobic zones in the sediment (Fisher and Acreman 2004). Wetlands with these variable environments are best able to recycle N and other nutrients (Tiner 2003), although wetlands with a wetter water regime generally are more effective than drier wetlands (Adamus et al. 1991). In wetlands, most N is stored in organic sediments (Keddy 2000). High organic soil content is usually associated with wetter NWI water regimes (Tiner 2003). Verhoeven et al. (2001) identifies water-table fluctuation and soil organic matter as indicators expected to predict nutrient-related process rates well.

Landscape position and vegetation will also influence nutrient cycling. Since floodplain wetlands essentially collect water from the

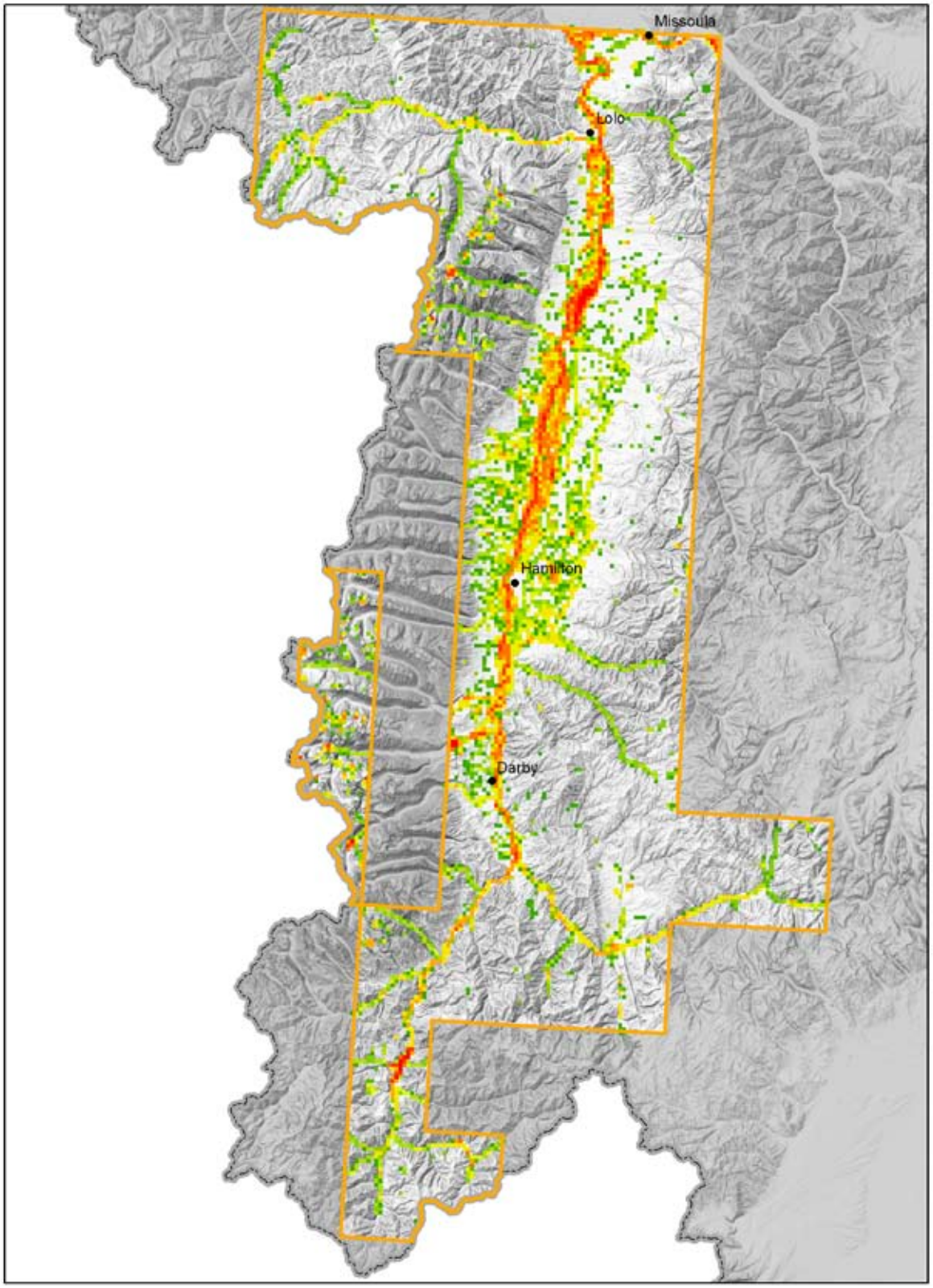

Figure 18. Study area map of wetland combined biogeochemical functions. 500 m grid cells reflect wetland types coded for 3 hydrology functional performance levels multiplied by cell wetland type acreage. Red is highest performance level, followed by yellow and green.

rest of the landscape, they will receive higher nutrient loadings per wetland area (Leibowitz 2003); loading rates and duration are key factors influencing nutrient retention (Fisher and Acreman 2004). Olde Venterink et al. (2006) found sediment deposition was a major source of N and P in floodplain communities; sites with the highest rates occurred where vegetation or surface elevation drops (like ponds) trapped sediments. Wetlands with inlets will perform this function better than those without inlets, wetlands with no outlets will also be more effective (Adamus et al. 1991). Plants will accumulate N and P which will eventually be released when the plants decay, however this process may take many decades if nutrients are incorporated into woody vegetation. Hauer et al. (2002) used herbaceous and woody vegetation cover, tree density, and soil organic factors in their model for nutrient cycling in the Northern Rocky Mountain regional HGM guidebook for assessing wetland functions of riverine floodplains.

Created wetlands may not function in the same capacity as natural wetlands for soil related functions like nutrient cycling (Stolt et al. 2000). Conservation of P by wetlands is largely regulated by geochemical processes which operate independently of succession (Craft 1997). In contrast, the conservation of N is controlled by biological processes (organic matter accumulation, denitrification) that change as succession proceeds (Craft 1997). Sediment and P retention can occur at high rates in the first few years after construction then may approximate natural wetlands over time, at least in some systems (Anderson and Mitsch 2006). Removal of N through denitrification is controlled by the build-up of organic matter over time (Anderson and Mitsch 2006) and constructed wetland can have lower organic carbon and nitrogen reserves even after 25 years (Craft et al. 1999). Clay and silt percentage may also be lower (Stolt et al. 2000), limiting P adsorption which preferentially occurs on these finer textured minerals (Mitsch and Gosselink 2000). Vegetation also improves wetland nutrient cycling (Tiner 2003), and constructed wetlands may not be well-vegetated, at least during the early years of succession.

We based this rating primarily on vegetation, water regime, human alteration, and landscape position. Vegetated wetlands with wetter water regimes were rated high and drier wetlands moderate. Non-vegetated sites were rated one class lower for types otherwise similar. Created wetlands were similarly rated one class lower than otherwise comparable wetlands due to uncertainty about site conditions and age since construction. Isolated and inflow wetlands were rated one class higher than similar types in other landscape positions since nutrients will likely be sequestered for longer periods than wetlands connected to the stream network. We applied the elevation modifier to favor lower elevation wetlands since valley bottom wetlands will receive more nutrient loading (Leibowitz 2003), and low gradient wetlands can retain or transform relatively more nutrients (Adamus et al. 1991).

Sediment Retention

Sediments deposited in wetlands are removed from surface flows, thereby improving downstream water quality (Sheldon et al. 2003). Additionally, the sediments may be bonded with nutrients or heavy metals resulting in further water quality benefits if captured (Tiner 2003). Wetlands can be very effective in removing sediment; one study reported that watersheds with only 5% of their area in wetlands trapped up to 70% of the sediment (Novitzki 1979). Our study area has considerable potential for sediment movement since forest fires, logging, and roads are common.

A review by Sheldon et al. (2003) identifies the residence time of the water, wind and wave action, sediment characteristics, and vegetation as the important factors that influence sediment deposition. Wetlands with inlets are more likely to be effective than those without inlets and wetlands with gradual gradients are more likely to retain sediments than those with steep gradients (Adamus et al. 1991). Vegetated types will trap particles better than non-vegetated types (Tiner 2003) and forested, scrub-shrub, or emergent vegetation types are more likely to stabilize sediments than unvegetated or aquatic bed wetlands (Adamus et al. 1991). However, basin morphology is probably

a better predictor of sedimentation rates than vegetation (Adamus et al. 1991). Depressions with no outlet will be effective as will lacustrine fringe wetlands (Sheldon et al. 2003). Slope wetlands may capture some sediment due to their typically dense vegetation (Sheldon et al. 2003). Riverine systems typically carry large quantities of suspended sediments and offer more opportunity for retention in associated wetlands (Adamus et al. 1991), although isolated wetlands will retain sediments indefinitely. Wetlands with longer seasonal flooding are more likely to retain sediments, as are shallow wetlands (Adamus et al. 1991).

We rated floodplain, inflow, outflow and throughflow wetlands high for this function unless they were unvegetated, these were rated moderate except for streambeds and unvegetated shores, which were rated low. Bi-directional water movement wetlands were rated moderate unless they were unvegetated and then rated low. Deepwater types were rated high if connected to the stream system. Isolated wetlands were rated moderate. Wetlands associated with intermittent streams were rated one class lower than those associated with perennial streams.

Shoreline Stabilization

Water driven by waves and currents can erode shores and increase sediment and nutrient loads to water bodies. Woody vegetation, especially deeply rooted trees, protects banks from erosion. In our area, erosion is most active along streams and rivers. Forested floodplain and throughflow locations were rated high, shrubby wetlands in the same setting were rated moderate, and all other areas were rated low.

Functions Related to Habitat

Wetlands represent important habitats for a variety of plant and animal species, especially in the arid West, where wetlands are relatively uncommon. We recognized two wetland functions primarily focused on vegetation, and two animal habitat functions. Wetland ecological integrity, also called wetland condition or health, can strongly affect ecological function, especially with habitat functions. The surrounding landscape matrix is also important in determining wetland habitat value, but is difficult to evaluate. Landscape performance levels for wetland habitat functions are summarized in Figure 19.

Maintain Native Plant Community

Maintaining a native plant community is the capacity of the wetland/riparian type to sustain a native plant community that is appropriate for the type (Hauer et al. 2002). Certain types in our study area have largely lost this capacity since non-native species are established and dominant beyond reasonable control efforts. In our region, drier types are generally more likely to be dominated by non-native species. Floodplain environments lowest in the valley are typically dominated by non-native herbaceous species due to widespread colonization sites created by the active disturbance regime and the water facilitated transport of propagules. There is a higher proportion of native vegetation if the type is shrub- or tree- dominated since most nonnative plants here are herbaceous. The floodplains of smaller streams can have a diverse mosaic of plant communities (Jankovsky-Jones 1999a) and a higher proportion of native species. Types at lower elevations are more likely to be invaded by nonnative plant species due to a more suitable habitat and more nonnative dispersion in the fragmented and well-roaded lower valley.

Although some flooded wetlands are susceptible to domination by cattail (*Typha* spp.), we ranked all natural vegetated wetlands with wetter water regimes as high for this function since they typically contain a variety of native plant species dependent on this wet environment. Drier shrub or forested types were rated moderate. All created wetlands were rated low due to the susceptibility of these sites to invasive species after disturbance and the variable management they later experience. We applied the elevation modifier to rate higher elevation wetlands higher.

Terrestrial Habitat

Intermountain West wetland areas and their associated riparian area matrix form essential habitats for a wide variety of animals (Lohman 2004, Gammonley 2004). Palustrine wetlands in the Intermountain West are used by more than 140 species of wetland-dependent and wetland-

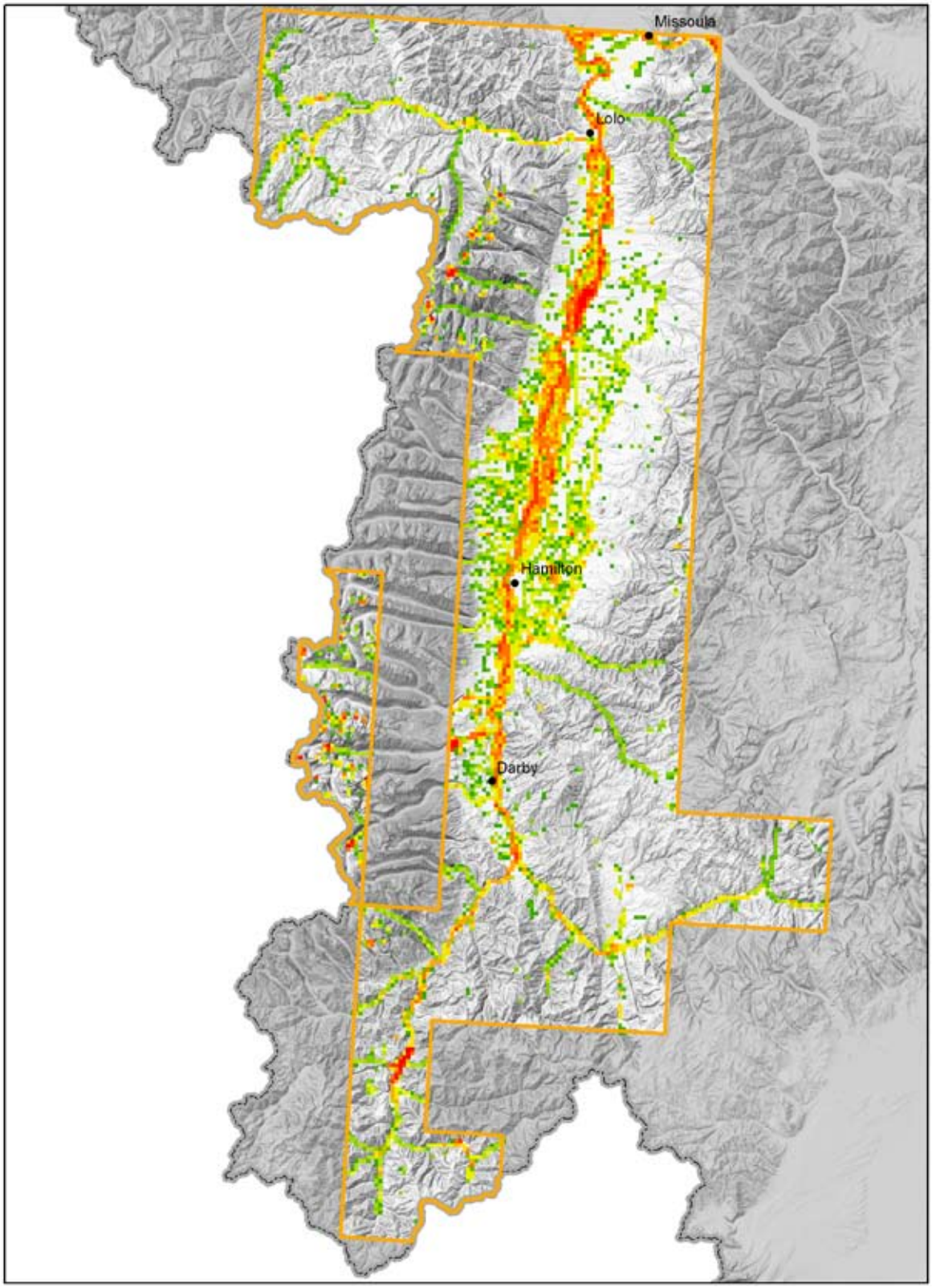

Figure 19. Study area map of wetland combined habitat functions. 500 m grid cells reflect wetland types coded for 3 hydrology functional performance levels multiplied by cell wetland type acreage. Red is highest performance level, followed by yellow and green.

associated birds, 30 species of mammals, and 30 species of reptiles (Gammonley 2004). We distinguished terrestrial from aquatic habitat based on where the animals primarily live.

Generalizations about why riparian areas are so important to wildlife can be extended to the wetlands that form much of the riparian matrix. Brinson et al. (1981) identifies woody plant communities, structural diversity, water and soil moisture, and the linear corridor shape as important habitat features of riparian areas. The wide variety of species that use wetlands will vary in their needs for specific types of wetlands but some generalizations can be made. Water depth has an important influence on wildlife use, as does vegetation, although most foraging shorebirds and some breeding amphibians prefer unvegetated or sparsely vegetated areas (Gammonley 2004). The presence of water, at least during some of the year is important or essential for many species and the structural aspects of shrub and forested types provides food and cover for birds and mammals. The greater habitat structure of woody wetlands also means they are more likely to support migrating and wintering wetland-dependent birds (Adamus et al. 1991). Many drier types in our area, especially at lower elevations, are used for cattle pasture and have low habitat value. These are typically emergent vegetation wetland types.

The value of created wetland habitat to birds is variable depending on habitat preferences. While waterfowl may benefit from the commonly constructed ponds, there will be reduced habitat value for bird species that used the original habitat, often emergent wetlands, before conversion. Large water-level fluctuations associated with artificial water control structure can also have detrimental impacts on habitats used by migrating and wintering wildlife (Adamus et al. 1991).

We primarily based this rating on vegetation and water regime. Vegetated wetlands with wetter water regimes were rated high. Woody vegetation associated with a lake or perennial stream was rated high, since water will often be nearby and adds to the overall habitat value. Woody vegetation not associated with a water sources was rated moderate. Drier wetlands lower in the landscape were rated low for terrestrial habitat. We rated island wetlands one class higher than otherwise similar wetland types since these wetlands may have less predators and a close proximity to food, water, and cover for wetland-dependent birds (Adamus et al. 1991). Created wetlands were rated one class lower than comparable natural wetlands. We applied the elevation modifier to increase the rating at higher elevations since wetlands represent a relatively uncommon and important habitat component in the forest-dominated matrix.

Aquatic Habitat

In our relatively dry climate, the presence of water throughout most or all of the summer season is the most important factor for the fish, amphibians, and invertebrates that depend on this habitat. Invertebrates convert vegetation and microorganisms into biomass that forms the food web for higher organisms (Sheldon et al. 2003) and may also be a good indicator group for water quality and other factors that influence aquatic habitat (Hauer et al. 2002). A review by Sheldon et al. (2003) identified the presence of vegetation including decaying wood, permanently flowing water, and seasonal changes in water regime as important factors influencing invertebrate habitat.

Declines of amphibian populations globally and in the Intermountain West have increased concern about this group. Site specific factors that may be important include the interspersion of open water and vegetation, stable water levels during spawning and hatching (Sheldon et al. 2003), and the absence of predatory fish. Amphibian species richness is probably related to the array of water depths and vegetation types (Keddy 2000). Rumble et al. (2004) reviews wildlife uses of created Palustrine wetlands and suggests that, although these habitats benefit some species of waterfowl and other wetland birds, they may present a threat to amphibians if fish are introduced, as is common in the recreational ponds of our areas. Additionally, created wetlands often have characteristics different from natural wetlands like steep sides and stable high water levels (Kentula et al. 2004) that limit the plant zonation and diversity found in natural wetlands. Complex

vegetation structure and shallow water are critical to maintaining the diversity of frogs within the landscape (Rumble et al. 2004). These factors, combined with the introduction of non-native fish, may lead to environments less suitable for native amphibians than for the invasive bullfrog (*Rana catesbeiana* Shaw) (Kentula et al. 2004), which is a problem species in our area. The review by Rumble et al. (2004) concludes that the relationship among herpetofauna, fish, and other wildlife in impoundments of the Intermountain West is poorly known. Unaltered wetlands are also more likely to have a greater diversity of fish and invertebrates than wetlands with drastic artificial water-level fluctuations or those affected by excavation or other alterations (Adamus et al. 1991).

Permanent flowing water is important to maintaining fish habitat. Many Intermountain West wetlands are unsuitable for fish due to intermittent water flows and other water quality reasons, although some seasonally flooded types may provide suitable habitat (Gammonley 2004). Woody vegetation enhances aquatic habitat by providing thermal shade, woody debris, terrestrial insects as a food source and nutrients through leaf fall. Aquatic bed wetlands are more important aquatic habitats than unvegetated wetlands (Adamus et al. 1991). Fringe and island wetlands are located in an interface between upland and aquatic systems with high habitat complexity and are relatively more important for fish and invertebrate habitat (Adamus et al. 1991). Most wetlands along the stream network probably benefit aquatic habitat through water quality and supply related functions, although riverine wetlands with low water velocities are more likely to have a greater diversity and/or abundance of fish and invertebrates (Adamus et al. 1991).

All natural vegetated wetlands with a water regime that indicates surface water presence during most or all of the year were rated high; similarly wet non-vegetated wetlands were rated moderate except for permanently flowing river and stream bottoms, which were rated high. Natural woody wetlands and drier fringe, shore and island wetlands associated with water bodies were rated moderate for this function. Created wetlands were rated one class lower than otherwise comparable natural wetland types.

Conservation of Wetland Biodiversity

Tiner (2003) applied this function to wetland types that contribute to preserving the natural diversity of wetlands in a given watershed. This function is important in maintaining a diversity of habitats for plant species and animals. Uncommon wetland types will be rated high for this function as will wetlands that have a diversity of different native vegetation types. In our area forested wetlands and saturated water regime wetlands are uncommon; we rated these high. Slope wetlands are rated high since they are relatively uncommon in this region and are reported to have high productivity, a diverse array of native plant communities, and habitat for plant Species of Concern (Jankovsky-Jones 1999b). Wetlands with a wet water regime are relatively common, but often have a variety of vegetation types; we rated these moderate. Emergent wetlands with drier water regimes are rated low due to their common occurrence and typically degraded condition. Created wetlands were rated low for this function because these types are unnatural and have low native plant diversity, often by design where steeply sloped sides maximize water holding capacity but limit the vegetation zonation typically present in a natural wetland.

Wetland Change

Overview

Wetland change was estimated with a random sampling analysis and through a total review of beaver pond and human created wetland change. Table 1 summarizes wetland human change estimates derived from our random sampling analysis. Appendix 4 details full statistical results including natural change estimates and confidence limits. Major changes include a 28.4% increase in pond (NWI Palustrine aquatic bed and unconsolidated bottom types) estimated acreage and a 22.0% decrease in Palustrine emergent wetland (PEM) estimated area. While there is a total estimated increase of 3.6% in wetland area, there is considerable variability in change estimates (see confidence limits, Appendix 4) and

Table 1. Summary of wetland change due to human action from old NWI (1982, 1983, 1984) to new NWI (2005).

	Estimated Area Old NWI	Estimated Area New NWI	Change (in Area)	Change (in Percent)
L1UB	1983.3	1983.3	0.0	0.0
L2UB[1]	29.4	902.1	872.7	2963.3
L2US[1]	78.5	78.5	0.0	0.0
PAB[2]	1015.0	1302.8	287.8	28.4
PEM	3411.8	2659.9	-751.9	-22.0
PFO[1]	0.5	0.5	0.0	0.0
PSS	1769.0	1753.0	-16.0	-0.9
PUS[1]	80.1	6.1	-74.0	-92.4
R2UB	2708.9	2708.9	0.0	0.0
R2US	3193.1	3422.3	229.2	7.2
R3UB	675.5	675.5	0.0	0.0
R3US	247.8	247.8	0.0	0.0
Total	15192.9	15740.6	547.7	3.6

[1] Uncommon types of low acreage. Change results are probably not representative.
[2] Includes PUB

some sampling anomalies with minor types (e.g. L2UB). Confidence limits for total wetland change (Appendix 4) indicate that the amount of variability in the sampling allow no firm conclusions about overall wetland change. The large increase in ponds is discussed below. Much of the loss in emergent wetland acreage is due to the conversion into ponds, although various agricultural activities associated with irrigation or livestock watering eliminated some emergent wetlands. A substantial amount of change occurred in the Lee Metcalf National Wildlife Refuge where emergent wetlands were converted into impoundments.

Natural change in our area was overwhelmingly due to riparian dynamics creating and destroying wetlands in wetland-rich river floodplains. While there was a net estimated loss due to these natural causes, there was also considerable variability in these estimates (Appendix 4). A shifting balance of wetland types and total acreage can be expected along these riparian areas over the decades long time scale that may be necessary for periodic large floods to create or renew wetlands. However, we noticed that there are a total of 442 Clean Water Section 404 Program permits recorded within our study area, primarily within riparian corridors (Figure 1). It is beyond the scope of our study to analyze the effects of these permitted activities, but typical actions, like armoring banks with rip-rap, may limit the ability of the river to maintain the same amount of wetlands on the floodplain.

Beaver Created Wetlands

The 105 original beaver ponds comprising 26.1 acres was reduced to only 23 ponds and 5.2 acres in our new survey (Table 2). This is an approximately 80% decrease in both acreage and the numbers of beaver ponds in approximately 20 years. The average size changed little and averages about 0.25 acres. Beavers are a keystone species with an ecological role disproportionate to their numbers (Paine 1966) and play a key role in creating wetlands in the Intermountain West where natural ponds with habitat for amphibians and aquatic reptiles are rare. Beaver activity also increases retention of sediment and organic matter, modifies nutrient cycling and decomposition, influences

Table 2. Summary of beaver pond changes in total study area based on wetland pond polygons.

Data Source	Beaver Pond Number	Beaver Pond Acreage	Beaver Pond Average Size
Old NWI	105	26.1	0.25
New NWI	23	5.2	0.23
Change (%)	-82 (-78.1%)	-20.9 (-80.1%)	-0.02 (-0.1%)

water and materials transported downstream, modifies channel geomorphology and hydrology, and changes habitat conditions (Naiman et al. 1986). Dams can remain active for periods of decades to centuries (Butler and Malanson 1995) and create backwater wetland habitats that can have a diverse mix of vegetation types and habitats. Presettlement North American beaver populations were estimated to be between 60 and 400 million (Seton 1929), but beavers were almost extinct in North America by 1900 due to trapping for their fur (Jenkins and Busher 1979). In their journey through Montana, Lewis and Clark reported that the "streams of the Missouri near and within those mountains abound in beaver" and "beaver is in every bend" of the Missouri River (University of Nebraska Press 2005). Where beavers remain unexploited, their activities may influence 20-40% of the total length of 2nd to 5th order streams (Naiman and Melillo 1984). The current North American beaver population is estimated between 6 and 12 million (Naiman et al. 1986), a fraction of the original number with a concomitant decrease in ecosystem functions attributable to beaver activity.

Beaver conflicts and complaints to the Montana Fish, Wildlife, and Parks Division have increased along with the increasing human population in the Bitterroot Valley (B. Giddings pers. comm.). Humans are attracted to the same riparian environments as beavers, but humans are often unwilling to accept the tree cutting and water damming activities of beavers. Available beaver harvest data from Ravalli County (Figure 20) and Montana (Figure 21) shows a high amount of variability. Beaver harvest numbers are compiled from trapper reports, but represent the best data available. We do not have data from Ravalli County for the statewide peak harvest period around 1980, but the three highest harvest years in the mid-1980's occurred directly after our old NWI baseline period (1982 – 1984). Statewide harvest levels generally follow the beaver pelt prices (Figure 22) due to increased trapping activity. Ravalli County harvest lows in the early- and mid- 1990's also followed low beaver pelt prices, although the late 1990's and early 2000's increased harvest does not correlate well to the price level. Since beaver ponds can remain on the landscape for very long periods (Butler and Malanson 1995), they may be a good indicator of developing long-term trends that started before the period of our available harvest data.

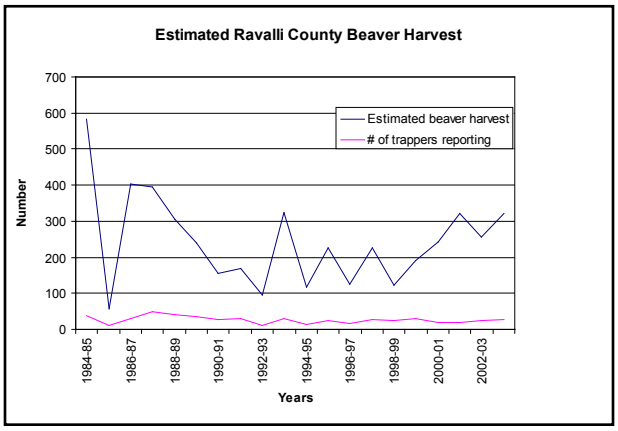

Figure 20. Estimated Ravalli County beaver harvest data based on trapper reports.

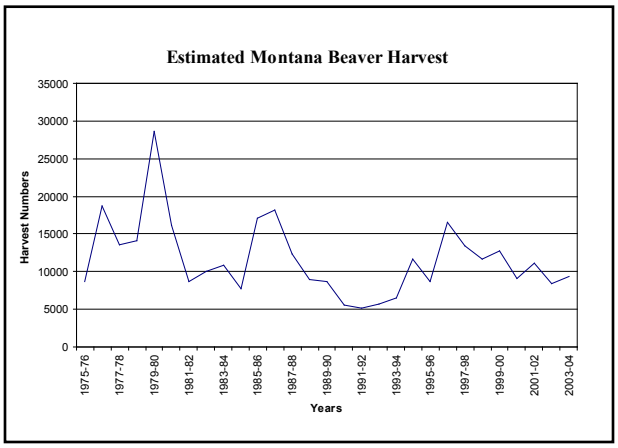

Figure 21. Estimated Montana beaver harvest data based on trapper reports.

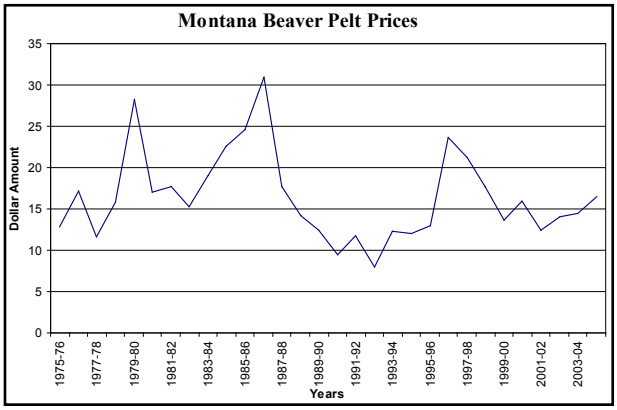

Figure 22. Montana beaver pelt prices.

Our study area includes considerable undeveloped land suitable for beaver habitat and it is surprising that beaver ponds and presumably the beaver population is so low in the Bitterroot Valley. The keystone ecological activities of beavers and their role in creating wetlands in mountainous environments are especially important to the variety of creatures that depend on these wetlands. Associated benefits to downstream water quality are also lost when beavers are removed from the landscape. Resource managers may wish to consider closer monitoring of beaver numbers and other additional actions to protect and restore beaver populations.

Figure 23. Excavated recreational pond common in the Bitterroot Valley.

Human Created Wetlands

Created wetland and deepwater acreage increased 34.8% during the 23 year study time frame (Table 3), but this figure includes Lacustrine types like deepwater reservoirs. When considering only Palustrine wetlands, there was a 74.7% increase in the number of human created wetlands with 921 new Palustrine wetlands. These are virtually all small ponds with standing water (Figure 23). These ponds have an average size of 0.9 acres and cover 636.6 acres.

Constructed wetlands are becoming more common in our study area and nationwide (Dahl 2006). There is considerable uncertainty about how well the ecological functions of these wetlands compare to natural wetlands, especially in consideration of regional variability. This question becomes fundamental in any assessment of wetland status and trends because losses in natural wetland acreage are now largely compensated by gains in constructed wetlands (Dahl 2006). Additionally, natural wetlands are often deepened or otherwise modified to create the standing water conditions favored by recreational pond owners so the natural wetland types formerly present and their ecological functions are lost. Created wetlands may also have downstream functional impacts that differ from those of pre-construction conditions. If constructed wetlands do not function like natural wetlands, then landscape wetland functions may still be lost even with a gain in wetland acreage.

Human Created Ponds: Water Rights and Fish Stocking Permits

Individuals need to apply for a water use permit to legally construct a pond in Montana. A database was obtained from the Montana Department of Natural Resources and Conservation that detailed water right permit locations in our study area. There were 260 permits in the database during the 1982 to 2005 period of our wetland change study and 921 new palustrine ponds for a compliance

Table 3. Summary of created wetland changes in total study area based on GIS analysis of wetland polygons.

Data Source	Created Wetland Number	Created Wetland Acreage	Created Wetland Number (P* only)	Created Wetland Acreage (P* only)	Created Wetland Average Size (P* only)
Old NWI	1261	2561.5	1233	1397.2	1.1
New NWI	2179	3453.8	2154	2033.8	0.9
Change (%)	+918 (+72.8%)	+892.3 (+34.8%)	+921 (+74.7%)	+636.6 (+45.6%)	-0.2 (-18.2%)

* P = Palustrine wetlands, Lacustrine wetlands, which are typically large established reservoirs, were eliminated

rate of less than 30%. The relatively low rate of compliance suggests that resource managers may have little understanding of the magnitude of pond creation and the resultant impact on water quantity and quality issues, which are increasingly problematic in Montana and other Western states. The lack of knowledge about the number of ponds being created is amplified by the lack of research quantifying the impact of created ponds on water quantity and quality issues, or other associated positive and negative ecological functions.

Our visual review of imagery indicated that most of the created ponds in our study area are designed for recreational uses. Fish are commonly stocked and a stocking permit is required from the Montana Fish, Wildlife, and Parks (MT-FWP) Division. We obtained the MT-FWP database and classified the fish to be stocked as native or non-native (Table 4). Fish stocking permits were first required in 1998. The 252 permits within our study area do not indicate actual stocking, only intent to stock as reflected by the individuals obtaining the permit. Many stocking permits listed more than one species; the non-native rainbow trout was the most popular stocking species. Only 9.1% of the permits indicated that individuals planned to only stock the native species Cutthroat trout; the actual figure will be lower because some native Cutthroat subspecies are not native to our study area and the permits did not always specify a subspecies.

Table 4. Summary of 252 fish stocking permits within study area.

Permitted Species	Number of Permits	Native to Montana?
Rainbow trout	222	No
Cutthroat trout	122	Yes
Brook trout	24	No
Brown trout	16	No
Largemouth bass	9	No
Pumpkinseed	2	No
Goldfish	1	No

Stocked predatory fish, like trout, can prey on amphibians and have been associated with landscape-scale declines of native species in some areas (Matthews et al. 2001). The presence of fish has been strongly and negatively associated with some amphibian populations in a widespread inventory of amphibians in Montana wetlands (B. Maxell pers. comm.). Created ponds and non-native fish may also lead to environments less suitable for native amphibians than for the invasive bullfrog (*Rana catesbeiana*) (Kentula et al. 2004), which is a problem species in our area. Rainbow and brown trout are established in the Bitterroot River (MT-FWP 2008) and stocked by the MT-FWP elsewhere in this region (MT-FWP 2007).

Conclusions and Management Recommendations

Summaries from our mapping detail a profile of the 16,304 acres of wetland vegetation and hydrogeomorphic types in our study area. Riverine types are the most common followed by wetlands with emergent vegetation. Most emergent wetlands are drier wetlands on the valley floor or in riparian settings, and are not in good ecological condition due to non-native vegetation and land use practices. We mapped about 670 acres of wetlands with a saturated water regime, many of these may be peatlands, an uncommon type in Montana that represents habitat for many plant Species of Concern and the Northern Bog Lemming, an animal Species of Concern. Slope wetlands were also mapped; these represent another type that may have high conservation value. Over 1,806 acres, 11% of the total wetland acreage, are isolated wetlands, which may not be regulated.

We developed a method to quantify and display the ecological functions of wetlands on maps. The concentration of wetlands and associated functions on the Bitterroot Valley bottom and especially along the riparian areas of the Bitterroot River and its larger tributaries emphasizes the importance of conserving these areas to preserve habitat and protect water quality and quantity. Our mapping combined hydrogeomorphic and National Wetland Inventory classifications systems and linked associated functions to wetland types. It represents the most detailed mapping information system for wetlands that has ever been implemented on a statewide or regional basis. Conservation practitioners can focus on types that are rare or have potential habitat for species of concern, like slope wetlands, and peatlands. Wetland mitigation and policy formulation can occur with detailed knowledge of the distribution of wetland types and associated functions in the watershed.

We documented an 80% reduction in beaver pond acreage and numbers during the last 20 years. Only 23 ponds totaling about 5 acres remain in this 1.4 million acre area despite the large amount of suitable beaver habitat. Beavers are a keystone species with important ecological functions, these functions are being lost in this area. Managers may want to focus on why beaver activity is rapidly declining and consider options to protect and restore beaver populations. The increasing human population of the Bitterroot Valley has constructed over 900 new ponds; less than 30% had the legally required water right permit and many intended to stock the ponds with non-native fish. While created ponds perform some wetland functions, there is a general lack of relevant research and some potentially negative ecological impacts, especially with native amphibians. If constructed wetlands do not function like natural wetlands, then landscape wetland functions may still be lost even with a gain in wetland acreage.

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Appendix A. Classification of wetlands and deepwater habitats of the United States (Cowardin et al. 1979), as modified for National Wetland Inventory mapping convention

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM — **M - MARINE**

SUBSYSTEM — **1 - SUBTIDAL**

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RF - REEF	OW - *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular 5 *Unknown Submergent*	1 Coral 3 Worm	

SUBSYSTEM — **2 - INTERTIDAL**

CLASS	AB – AQUATIC BED	RF– REEF	RS – ROCKY SHORE	US - UNCONSOLIDATED SHORE
Subclass	1 Algal 3 Rooted Vascular 5 *Unknown Submergent*	1 Coral 3 Worm	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic

SYSTEM — **E - ESTUARINE**

SUBSYSTEM — **1 - SUBTIDAL**

CLASS	RB - ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RF – REEF	OW - *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Mollusc 2 Worm	

SUBSYSTEM — **2 - INTERTIDAL**

CLASS	AB – AQUATIC BED	RF– REEF	SB – STREAMBED	RS - ROCKY SHORE	US – UNCONSOLIDATED SHORE	EM -EMERGENT	SS – SCRUB-SHRUB	FO – FORESTED
Subclass	1 Algal 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Mollusc 2 Worm	1 Cobble Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Persistent 2 Nonpersistent	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*

SYSTEM — **R - RIVERINE**

SUBSYSTEM	1 – TIDAL	2 – LOWER PERENNIAL	3 – UPPER PERENNIAL	4 – INTERMITTENT	5 – *UNKNOWN PERENNIAL*
CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	*SB – STREAMBED	AB – AQUATIC BED	RS – ROCKY SHORE
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Bedrock 2 Rubble 3 Cobble Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Bedrock 2 Rubble

CLASS	US – UNCONSOLIDATED SHORE	**EM – EMERGENT	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

* STREAMBED is limited to TIDAL and INTERMITTENT SUBSYSTEMS, and comprises the only CLASS in the INTERMITTENT SUBSYSTEM.
** EMERGENT is limited to TIDAL and LOWER PERENNIAL SUBSYSTEMS.

Classification of Wetlands and Deepwater Habitats of the United States
Cowardin ET AL. 1979 as modified for National Wetland Inventory Mapping Convention

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

SYSTEM: **L- LACUSTRINE**

SUBSYSTEM: **1 - LIMNETIC**

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	

SUBSYSTEM: **2 - LITTORAL**

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	RS – ROCKY SHORE	US – UNCONSOLIDATED SHORE	EM – EMERGENT	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	2 Nonpersistent	

SYSTEM: **P - PALUSTRINE**

CLASS	RB – ROCK BOTTOM	UB – UNCONSOLIDATED BOTTOM	AB – AQUATIC BED	US – UNCONSOLIDATED SHORE	ML – MOSS-LICHEN	EM – EMERGENT	SS – SCRUB-SHRUB	FO – FORESTED	OW – *OPEN WATER/ Unknown Bottom*
Subclass	1 Bedrock 2. Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular 5 *Unknown Submergent* 6 *Unknown Surface*	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Moss 2 Lichen	1 Persistent 2 Nonpersistent	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 *Deciduous* 7 *Evergreen*	

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

WATER REGIME

Non-Tidal

A Temporarily Flooded
B Saturated
C Seasonally Flooded
D *Seasonally Flooded/ Well Drained*
E *Seasonally Flooded/ Saturated*
F Semipermanently Flooded
G Intermittently Exposed
H Permanently Flooded
J Intermittently Flooded
K Artificially Flooded
W Intermittently Flooded/Temporary
Y Saturated/Semipermanent/ Seasonal
Z Intermittently Exposed/Permanent
U *Unknown*

Tidal

K *Artificially Flooded*
L Subtidal
M Irregularly Exposed
N Regularly Exposed
P Irregularly Flooded
*S Temporary-Tidal
*R Seasonal-Tidal
*T Semipermanent-Tidal
*V Permanent-Tidal
U *Unknown*

*These water regimes are only used in tidally influenced, freshwater systems.

WATER CHEMISTRY

Coastal Halinity

1 Hyperhaline
2 Euthaline
3 Mixohaline *(Brackish)*
4 Polyhaline
5 Mesohaline
6 Oligohaline
0 Fresh

Inland Salinity

7 Hypersaline
8 Eusaline
9 Mixosaline
0 Fresh

pH Modifiers for all Fresh Water

a Acid
t Circumneutral
i Alkaline

SOIL

g Organic
n Mineral

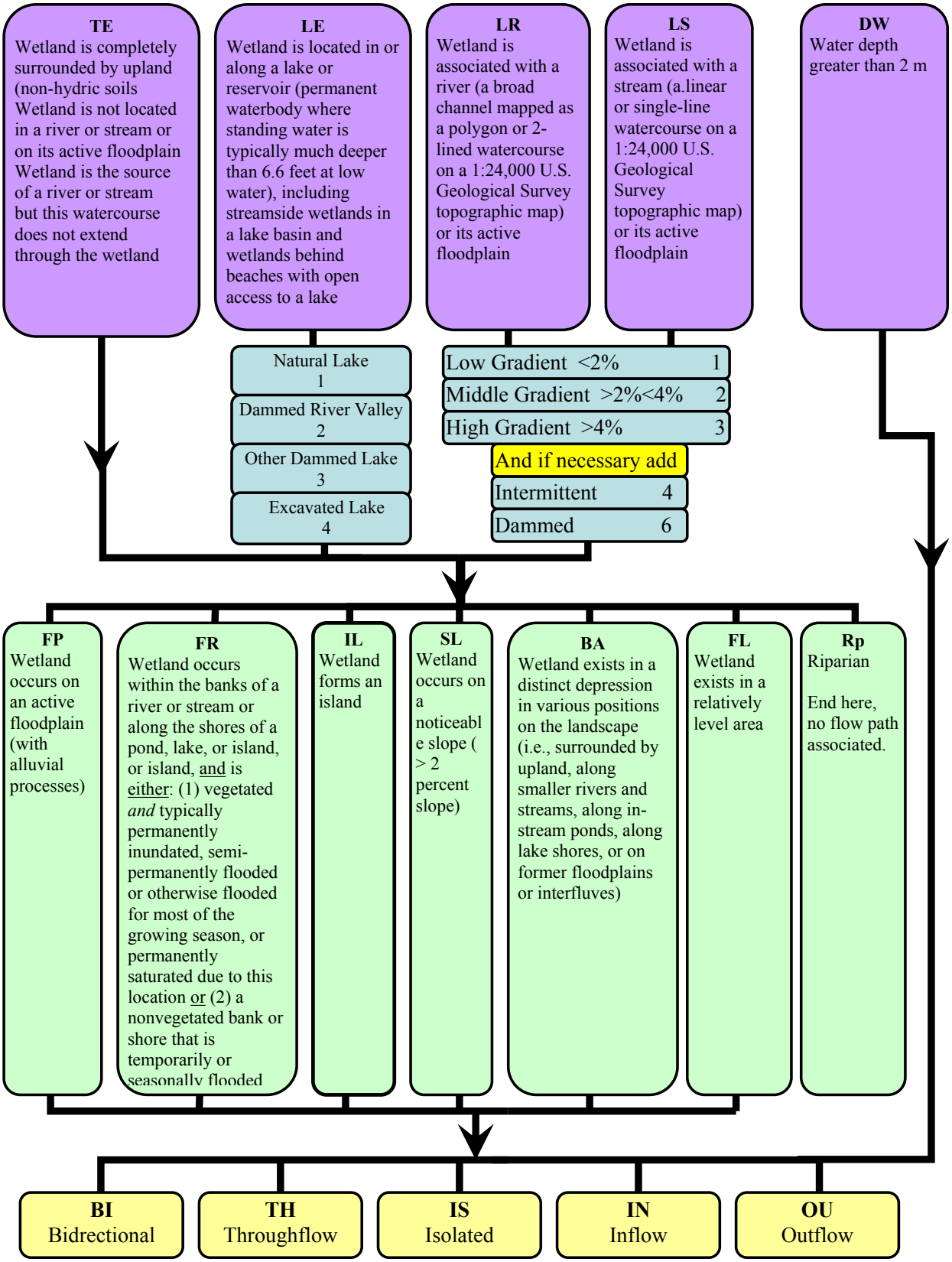
SPECIAL MODIFIERS

b *Beaver*
d *Partially Drained/Ditched*
f Farmed
h *Diked/Impounded*
r Artificial Substrate
s *Spoil*
x Excavated

NOTE: Italicized terms were added for mapping by the National Wetlands Inventory program.

Appendix B. Flowchart for and key to hydrogeomorphic coding of wetland polygons

Flowchart for hydrogeomorphic coding of wetland polygons, modified from Tiner (2003) See detailed key (Appendix B -2)



Key to hydrogeomorphic coding of wetland polygons, modified from Tiner (2003)

Key A-1: Key to Wetland Landscape Position

1. Wetland is completely surrounded by upland (non-hydric soils).....**Terrene (TE)**

1. Wetland is not surrounded by upland but is connected to a waterbody of some kind.....**2**

2. Wetland is located in or along a lake or reservoir (permanent waterbody where standing water is typically much deeper than 6.6 feet at low water), including streamside wetlands in a lake basin and wetlands behind beaches with open access to a lake.....……...**Lentic (LE)**

   Go to Key C-2 for Lake Type

   Then *Go to Key B-1 for inland landform*

   Note: Lentic wetlands consist of all wetlands in a lake basin (i.e., the depression containing the lake), including lakeside wetlands intersected by streams emptying into the lake. The upstream limit of lentic wetlands is defined by the upstream influence of the lake which is usually approximated by the limits of the basin within which the lake occurs. The streamside lentic wetlands are designated as Throughflow, thereby emphasizing the stream flow through these wetlands. Other lentic wetlands are typically classified as Bi-directional-nontidal since water tables rise and fall with lake levels during the year.

2. Wetland does not occur along this type of waterbody.....**3**

3. Wetland is located in a river or stream (including in-stream ponds), within its banks, or on its active floodplain and is periodically flooded by the river or stream.....**4**

3. Wetland is not located in a river or stream or on its active floodplain.....**Terrene**

   Note: These wetlands may occur: (1) on a slope or flat, or in a depression (including ponds, potholes, and playas) lacking a stream but contiguous to a river or stream, (2) on a historic (inactive) floodplain, or (3) in a landscape position crossed by a stream (e.g., an entrenched stream), but where the stream does not periodically inundate the wetland.

   Go to Key B-1 for inland landform

4. Wetland is the source of a river or stream but this watercourse does not extend through the wetland.....**Terrene**

   Modifiers: May include Headwater for wetlands that are sources of streams.

4. Wetland is located in a river or stream, within its banks, or on its active floodplain.....**5**

5. Wetland is associated with a river (a broad channel mapped as a polygon or 2-lined water course on a 1:24,000 U.S. Geological Survey topographic map) or its active floodplain.....**Lotic River (LR)**

Go to Couplet "a" below

(Also see note under first couplet #3 - Lentic re: streamside wetlands in lake basins)

5. Wetland is associated with a stream (a linear or single-line watercourse on a 1:24,000 U.S. Geological Survey topographic map) or its active floodplain.....**Lotic Stream (LS)**

Go to Couplet "a" below

(Also see note under first couplet #3 - Lentic re: streamside wetlands in lake basins)

Note: Artificial drainageways (i.e., ditches) are not considered part of the Lotic classification, whereas channelized streams are part of the Lotic landscape position.

a. Water flow is dammed, yet still flowing downstream, at least seasonally.....**Dammed Reach (6)**

Go to Key B-1 for inland landform

a. Water flow is unrestricted.....,.....**b**

b. Water flow is intermittent during the year..…….....**Intermittent Gradient (4)**

Go to Key B-1 for inland landform

b. Water flow is perennial (year-round).....,.....**c**

c. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first- and second-order "streams" in hilly to mountainous terrain; part of Cowardin's Upper Perennial Subsystem.....**High Gradient (3)**

Go to Key B-1 for inland landform

c. Watercourse characteristics are not so; "stream" order greater than 2 in hilly to mountainous terrain.....**d**

d. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes ditches; the lower order streams may lack significant floodplain development); Cowardin's Lower Perennial subsystem .....**Low Gradient (1)**

Go to Key B-1 for inland landform

d. Water flow is fast to moderate; with little to some floodplain; usually third-, fourth- and higher order "streams" associated with hilly to mountainous terrain; part of Cowardin's Upper Perennial Subsystem.....**Middle Gradient (2)**

Key B-1: Key to Inland Landforms

1. Wetland occurs on a noticeable slope (> 2 percent slope)……..…….**Slope Wetland (SL)**
Go to Key D-1 for water flow path

1. Wetland does not occur on a distinct slope.....**2**

2. Wetland forms an island.....**Island Wetland (IL)***
(Go to Key D-1 for water flow path)

2. Wetland does not form an island.....**3**

3. Wetland occurs within the banks of a river or stream or along the shores of a pond, lake, or island, or island, and is either: (1) vegetated *and* typically permanently inundated, semi-permanently flooded or otherwise flooded for most of the growing season, or permanently saturated due to this location or (2) a nonvegetated bank or shore that is temporarily or seasonally flooded ……..…….....**Fringe Wetland (FR)***
Go to Key D-1 for water flow path

Attention: *Seasonally to temporarily flooded vegetated wetlands along rivers and streams are classified as either Floodplain, Basin, or Flat landforms - see applicable categories.*

3. Wetland does not exist along these shores.....**4**

4. Wetland occurs on an active floodplain (with alluvial processes)…..**Floodplain Wetland (FP)**
Go to Key D-1 for water flow path

4. Wetland does not occur on an active floodplain.....**5**

5. Wetland occurs on an interstream divide (interfluve).....**Interfluve Wetland (IF)**
Go to Key D-1 for water flow path

5. Wetland does not occur on an interfluve.....**6**

6. Wetland exists in a distinct depression in various positions on the landscape (i.e., surrounded by upland, along smaller rivers and streams, along in-stream ponds, along lake shores, or on former floodplains or interfluves).....**Basin Wetland (BA)**
Go to Key D-1 for water flow path

6. Wetland exists in a relatively level area.....**Flat Wetland (FL)**
Go to Key D-1 for water flow path

*Note: Inland slope wetlands and island wetlands associated with rivers, streams, and lakes are designated as such by the landscape position classification (e.g., lotic river, lotic stream, or lentic), therefore no additional terms are needed to convey this association.

Key C-2. Key to Lakes.

The lake designation is for permanently flooded deep waters (>6.6 feet). The Cowardin et al. system considers standing waterbodies larger than 20 acres to be part of the lacustrine system (regardless of water depth; shallow = wetlands; >6.6 feet = deepwater habitat), and smaller ones typically part of the palustrine wetlands. For our purposes, shallow lakes and seasonal or intermittent lakes are considered some type of terrene or lotic wetland depending on the presence and location of a stream. Lentic wetlands are associated with permanently flooded standing waterbodies deeper than 6.6 feet at low water.

1. Waterbody is not dammed or impounded.....**Natural Lake (1)**

1. Waterbody is dammed, impounded, or excavated **2**

2. Waterbody is dammed or impounded.....**3**

2. Waterbody is excavated.....**Excavated Lake (4)**

3. Dammed river valley.....**Dammed River Valley Lake (2)**

   Note: When the dam inundates former floodplains and other low-lying areas, the waterbody is considered a Dammed River Valley Lake. If the dam crosses a higher gradient river and increase water depth in a channel without significant flooding of much neighboring land, the waterbody is considered the dammed reach of a river.

3. Dammed natural lake or other landscape.....**Other Dammed Lake (3)**

Key D-1: Key to Water Flow Paths

1. Water levels fluctuate due to lake influences or to variable river levels, but water does not flow through this wetland.....**Bidirectional-nontidal (BI)**

   Note: Lentic wetlands with streams running through them are classified as Throughflow to emphasize this additional water source, while lentic wetlands located in coves or fringing the high ground would typically be classified as Bidirectional-Nontidal. Similarly, many floodplain wetlands are throughflow types, while some are connected to the river through a single channel in which water rises and falls with changing river levels. The water flow path of the latter types is best classified as bidirectional-nontidal.

1. Wetland is not subject to lake influences.....**2**

2. Wetland receives surface or ground water from a stream, other waterbody or wetland (i.e., at a higher elevation) and surface or ground water passes through the subject wetland to a stream, another wetland, or other waterbody at a lower elevation; a flow-through system.……..…..**Throughflow (TH)**

2. Water does not pass through this wetland to other wetlands or waters.....**3**

3. There is no surface or groundwater inflow from a stream, other waterbody, or wetland (i.e., no documented surface or ground water inflow from a wetland or other waterbody at a higher elevation) and no observable or known outflow of surface or ground water to other wetlands or waters.....**Isolated (IS)**

3. Wetland is not hydrologically or geographically isolated.....**4**

4. Wetland receives surface or ground water inflow from a wetland or other waterbody (perennial or intermittent) at a higher elevation and there is no observable or known significant out flow of surface or ground water to a stream, wetland or waterbody at a lower elevation .....**Inflow (IN)**

4. Wetland receives no surface or ground water inflow from a wetland or permanent waterbody at a higher elevation (may receive flow from intermittent streams only) and surface or ground water is discharged from this wetland to a stream, wetland, or other waterbody at a lower elevation.....…….....**Outflow (OU)**

Waterbody Keys

These keys are designed to expand the classification of waterbodies beyond the system and subsystem levels in the Service's wetland classification system (Cowardin et al. 1979). Users are advised first to classify the waterbody in one of the five ecosystems: 1) marine (open ocean and associated coastline), 2) estuarine (mixing zone of fresh and ocean-derived salt water), 3) lacustrine (lakes, reservoirs, large impoundments, and dammed rivers), 4) riverine (undammed rivers and tributaries), and 5) palustrine (e.g., nontidal ponds) and then apply the waterbody type descriptors below.

Key A-2. Key to Major Waterbody Type

1. Waterbody is predominantly flowing water.....**2**

1. Waterbody is predominantly standing water.....**4**

2. Flow is unidirectional and waterbody is a river, stream, or similar channel.....**3**

2. Flow is bidirectional at least seasonally; waterbody is a lake or lake-influenced….....**4**

3. Waterbody is a polygonal feature on a U.S. Geological Survey map or a National Wetlands Inventory Map (1:24,000/1:25,000).....**River (RV)**

3. Waterbody is a linear feature on such maps.....**Stream (ST)**
Go to River/Stream Gradient Key - Key B-2

4. Waterbody is permanently flooded and deep (>than 6.6 ft at low water), excluding small kettle or bog ponds (i.e., usually less than 5 acres in size and surrounded by bog vegetation).....**Lake (LK)**
Go to Lake Key - Key C-2

4. Waterbody is shallow (< 6.6 ft at low water) or a small pond (with deeper water) **5**

5. Waterbody is small (< 20 acres).....**Pond (PD)**

5. Waterbody is large (≥20 acres).....**Lake**
Go to Lake Key - Key C-2

Key B-2. River/Stream Gradient and Other Modifiers Key

Please note that the river/stream gradient extends from the freshwater bi-directional flow zone through the intermittent reach. The limits of the latter are typically defined by drainageways with well-defined channels that discharge water seasonally. From a practical standpoint, the limits of the lotic system are displayed on 1:24,000 U.S. Geological Survey topographic maps or similar digital data. Intermittent streams, certain dammed portions of rivers plus lock and dammed canal systems may be classified as rivers using the descriptors presented in these keys. In the Cowardin et al. system, they may be classified as Riverine Intermittent Streambed or Lacustrine Unconsolidated Bottom, respectively.

1. Water flow is dammed, yet still flowing downstream at least seasonally.....**Dammed Reach (6)**

1. Water flow is unrestricted.....**2**

2. Water flow is perennial (year-round); perennial rivers and streams.....**3**

2. Water flow is seasonal or periodic (intermittent).
Cowardin's Intermittent Subsystem .....**Intermittent Gradient (4)**

3. Water flow is generally rapid due to steep gradient; typically little or no floodplain development; watercourse is generally shallow with rock, cobbles, or gravel bottoms; first and second order "streams"; part of Cowardin's Upper Perennial subsystem.....**High Gradient (3)**

3. Water flow is not so; some to much floodplain development.....**4**

4. Water flow is generally slow; typically with extensive floodplain; water course shallow or deep with mud or sand bottoms; typically fifth and higher order "streams", but includes lower order streams in nearly level landscapes.
   Cowardin's Lower Perennial subsystem .....**Low Gradient (1)**

4. Water flow is fast to moderate; with little to some floodplain; usually third and fourth order "streams"; part of Cowardin's Upper Perennial subsystem.....**Middle Gradient (2)**

Key C-2. Key to Lakes.

The lake designation is for permanently flooded deep waters (>6.6 feet). Some classification systems include shallow waterbodies or periodically exposed areas. The Cowardin et al. system considers standing waterbodies larger than 20 acres to be part of the lacustrine system (regardless of water depth; shallow = wetlands; >6.6 feet = deepwater habitat), and smaller ones typically part of the palustrine wetlands. For our purposes, shallow lakes and seasonal or intermittent lakes are considered some type of terrene or lotic wetland depending on the presence and location of a stream. Lentic wetlands are associated with permanently flooded standing waterbodies deeper than 6.6 feet at low water.

1. Waterbody is not dammed or impounded.....**Natural Lake (1)**

1. Waterbody is dammed, impounded, or excavated **2**

2. Waterbody is dammed or impounded.....**3**

2. Waterbody is excavated.....**Excavated Lake (4)**

3. Dammed river valley.....**Dammed River Valley Lake (2)**

   Note: When the dam inundates former floodplains and other low-lying areas, the water body is considered a Dammed River Valley Lake. If the dam crosses a higher gradient river and increase water depth in a channel without significant flooding of much neighboring land, the waterbody is considered the dammed reach of a river.

3. Dammed natural lake or other landscape.....**Other Dammed Lake (3)**

Key F-2. Key to Water Flow Paths

1. Water flows out of the waterbody via a river, stream, or ditch, with little or no inflow (inflow could be from intermittent streams or ground water only) .....**Outflow (OU)**

1. Water flow is not so.....**2**

2. Water enters waterbody from river, stream, or ditch, flows through it, and continues to flow downstream.....**Throughflow (TH)** or **Throughflow-intermittent (TI)**

   Note: Throughflow intermittent is applied to intermittent streams

2. Water flow is not throughflow.....**3**

3. Water flows in and out of the waterbody through the same channel; it does not flow through the waterbody.....**Bidirectional-nontidal (BI)**

3. Water flow is not bidirectional.....**4**

4. Water flow enters via a river, stream, or ditch, but does not exit pond, lake or reservoir; water-body serves as a sink for water.....**Inflow (IN)**

4. No apparent channelized inflow, source of water either by precipitation or by underground sources.....**Isolated (IS)**

   Attention: *In most applications, isolation is interpreted as "geographically isolated" since groundwater connections are typically unknown for specific waterbodies. For practical purposes then," isolated" means no obvious surface water connection to other wetlands and waters.*

Appendix C. Relative functional performance levels for wetlands classified with National Wetland Inventory (NWI) and hydrogeomorphic (HGM) codes

("1" is estimated to be the highest relative performance followed by "2" then "3")

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
L1ABH	DWIS	1	3	1	3	1	2	3	2	1	2	2
L1UBH	DWIS	58	3	1	3	2	2	3	3	2	3	3
L1UBH	DWOU	50	3	1	3	2	1	3	3	2	3	3
L1UBH	DWTH	29	3	1	3	2	1	3	3	2	3	3
L1UBHh	DWOU	1	3	1	3	3	1	3	3	2	3	3
L1UBHh	DWTH	5	3	1	3	3	1	3	3	2	3	3
L2ABFh	LR16FPTH	1	3	1	2	2	1	3	3	2	3	3
L2ABFh	LS16BATH	3	2	1	2	2	1	3	3	2	3	3
L2UBFh	LE3FRBI	3	3	3	3	3	2	3	3	3	3	3
L2UBF	TEBAIS	25	2	1	3	1	2	3	3	2	3	3
L2UBF	TEBAOU	2	3	1	3	2	2	3	3	2	3	3
L2UBFx	LR1FPIS	1	3	3	3	3	2	3	3	3	3	3
L2UBHh	LE2FRBI	2	3	1	3	3	2	3	3	3	3	3
L2UBH	LS3BATH	1	2	2	2	2	2	3	3	2	3	3
L2UBH	TEBAIS	10	2	1	3	1	2	3	3	2	3	3
L2USCh	LE2FRBI	1	2	1	3	3	3	3	3	2	3	3
L2USCh	LE2ILBI	2	2	3	3	3	3	3	2	3	3	3
L2USCh	LE3BABI	1	2	1	3	3	3	3	3	3	3	3
L2USCh	LE3FRBI	5	2	3	3	3	3	3	3	3	3	3
PABFb	LS146BATH	2	2	3	3	1	2	3	1	1	1	2
PABFb	LS16BATH	13	2	2	2	1	1	3	1	1	1	2
PABFb	LS26BATH	5	2	2	2	1	1	3	1	1	1	2
PABFb	TEBAIS	3	2	2	3	1	2	3	1	1	1	2
PABFh	LE26FRBI	7	3	3	3	2	2	3	2	2	3	3
PABFh	LR16FPBI	2	3	1	2	2	1	3	2	2	3	3
PABFh	LR16FPIS	4	3	1	2	1	1	3	2	2	3	3
PABFh	LR16FPTH	33	3	1	2	2	1	3	2	2	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PABFh	LR2FPBI	1	3	1	2	2	1	3	2	2	3	3
PABFh	LS146BABI	2	2	3	3	2	3	3	2	2	3	3
PABFh	LS146BATH	164	2	3	3	2	2	3	2	2	3	3
PABFh	LS16BABI	7	2	2	2	2	2	3	2	2	3	3
PABFh	LS16BATH	71	2	2	2	2	1	3	2	2	3	3
PABFh	LS246BABI	1	2	3	3	2	3	3	2	2	3	3
PABFh	LS246BATH	85	2	3	3	2	2	3	2	2	3	3
PABFh	LS26BABI	1	2	2	2	2	2	3	2	2	3	3
PABFh	LS26BATH	18	2	2	2	2	1	3	2	2	3	3
PABFh	LS346BABI	3	2	3	3	2	3	3	2	2	3	3
PABFh	LS346BATH	89	2	3	3	2	2	3	2	2	3	3
PABFh	LS36BATH	38	2	2	2	2	1	3	2	2	3	3
PABFh	TEBAIS	202	2	2	3	1	2	3	2	2	3	3
PABFh	TEBAOU	12	3	2	3	2	1	3	2	2	3	3
PABF	LE1FRBI	1	3	3	3	1	2	3	1	1	1	2
PABF	LE2FRBI	1	3	1	3	1	2	3	1	1	1	2
PABF	LR1FPBI	51	3	1	2	1	1	3	1	1	1	2
PABF	LR1FPIS	49	3	1	2	1	1	3	1	1	1	2
PABF	LR1FPTH	269	3	1	2	1	1	3	1	1	1	2
PABF	LR1FRTH	1	3	1	2	1	1	3	1	1	1	2
PABF	LR2FPBI	3	3	1	2	1	1	3	1	1	1	2
PABF	LR2FPTH	4	3	1	2	1	1	3	1	1	1	2
PABF	LS14BABI	2	2	3	3	1	3	3	1	1	1	2
PABF	LS14BATH	32	2	3	3	1	2	3	1	1	1	2
PABF	LS1BABI	11	2	2	2	1	2	3	1	1	1	2
PABF	LS1BATH	54	2	1	2	1	1	3	1	1	1	2
PABF	LS1FPTH	9	3	1	2	1	1	3	1	1	1	2

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PABF	LS24BATH	2	2	3	3	1	2	3	1	1	1	2
PABF	LS2BABI	1	2	2	2	1	2	3	1	1	1	2
PABF	LS2BAIN	1	2	2	3	1	1	3	1	1	1	2
PABF	LS2BATH	2	2	2	2	1	1	3	1	1	1	2
PABF	LS34BABI	1	2	3	3	1	3	3	1	1	1	2
PABF	LS34BATH	5	2	3	3	1	2	3	1	1	1	2
PABF	LS3BATH	15	2	2	2	1	1	3	1	1	1	2
PABF	TEBAIS	239	2	2	3	1	2	3	1	1	1	2
PABF	TEBAOU	5	3	2	3	1	1	3	1	1	1	2
PABFx	LR1FPBI	1	3	1	2	2	1	3	2	2	3	3
PABFx	LR1FPIS	57	3	1	2	1	1	3	2	2	3	3
PABFx	LR1FPTH	9	3	1	2	2	1	3	2	2	3	3
PABFx	LR2FPIS	1	3	1	2	1	1	3	2	2	3	3
PABFx	LS14BABI	6	2	3	3	2	3	3	2	2	3	3
PABFx	LS14BAIN	2	2	2	3	1	2	3	2	2	3	3
PABFx	LS14BATH	37	2	3	3	2	2	3	2	2	3	3
PABFx	LS1BABI	10	2	2	2	2	2	3	2	2	3	3
PABFx	LS1BAIN	2	2	2	3	1	1	3	2	2	3	3
PABFx	LS1BAOU	1	3	3	2	2	1	3	2	2	3	3
PABFx	LS1BATH	30	2	1	2	2	1	3	2	2	3	3
PABFx	LS24BATH	10	2	3	3	2	2	3	2	2	3	3
PABFx	LS2BATH	5	2	2	2	2	1	3	2	2	3	3
PABFx	LS34BATH	3	2	3	3	2	2	3	2	2	3	3
PABFx	LS3BATH	6	2	2	2	2	1	3	2	2	3	3
PABFx	TEBAIS	742	2	2	3	1	2	3	2	2	3	3
PABFx	TEBAOU	6	3	2	3	2	1	3	2	2	3	3
PABGh	LS16BATH	1	2	2	2	2	1	3	2	2	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PABG	LR1FPBI	2	3	1	2	1	1	3	1	1	1	2
PABG	LS1BABI	3	2	2	2	1	2	3	1	1	1	2
PABG	LS1BATH	6	2	1	2	1	1	3	1	1	1	2
PABG	LS24BATH	1	2	3	3	1	2	3	1	1	1	2
PABG	LS2BATH	1	2	2	2	1	1	3	1	1	1	2
PABG	TEBAIS	17	2	2	3	1	2	3	1	1	1	2
PABG	TEBAOU	5	3	2	3	1	1	3	1	1	1	2
PABGx	LS2BATH	1	2	2	2	2	1	3	2	2	3	3
PABGx	TEBAIS	3	2	2	3	1	2	3	2	2	3	3
PABHx	LR1FPIS	2	3	1	2	1	1	3	2	2	3	3
PEMAb	LS26BATH	2	1	2	2	3	1	3	2	3	2	3
PEMAb	LS36BATH	2	1	2	2	2	1	3	2	3	2	3
PEMAh	LE2FRBI	5	2	1	3	3	2	3	3	3	3	3
PEMAh	LE3BABI	4	2	1	3	3	2	3	3	3	3	3
PEMAh	LR16FPTH	13	2	1	2	3	1	3	3	3	3	3
PEMAh	LS146BABI	2	1	3	3	3	3	3	3	3	3	3
PEMAh	LS146BATH	5	1	3	3	3	2	3	3	3	3	3
PEMAh	LS146FPTH	2	2	3	3	3	2	3	3	3	3	3
PEMAh	LS16BABI	1	1	2	2	3	2	3	3	3	3	3
PEMAh	LS16BATH	22	1	2	2	3	1	3	3	3	3	3
PEMAh	LS246BATH	6	1	3	3	3	2	3	3	3	3	3
PEMAh	LS26BATH	2	1	2	2	3	1	3	3	3	3	3
PEMAh	LS346BATH	6	1	3	3	3	2	3	3	3	3	3
PEMAh	LS36BATH	1	1	2	2	3	1	3	3	3	3	3
PEMAh	TEBAIS	5	1	1	3	2	2	3	3	3	3	3
PEMAh	TEBAOU	1	3	2	3	3	1	3	3	3	3	3
PEMA	LE2BABI	3	2	1	3	3	2	3	2	3	2	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PEMA	LE3BATH	1	2	1	3	3	1	3	2	3	2	3
PEMA	LR1FPBI	67	2	1	2	3	1	2	2	3	2	3
PEMA	LR1FPIS	91	2	1	2	2	1	3	2	3	2	3
PEMA	LR1FPTH	604	2	1	2	3	1	3	2	3	2	3
PEMA	LR1ILTH	12	2	1	2	3	1	3	1	2	2	3
PEMA	LR2FPTH	7	2	1	2	3	1	3	2	3	2	3
PEMA	LRIFPTH	3	2	1	2	3	1	3	2	3	2	3
PEMA	LS146BATH	1	1	3	3	3	2	3	2	3	2	3
PEMA	LS14BABI	20	1	3	3	3	3	3	2	3	2	3
PEMA	LS14BAIN	6	1	1	3	2	2	3	2	3	2	3
PEMA	LS14BATH	183	1	3	3	3	2	3	2	3	2	3
PEMA	LS16BATH	7	1	2	2	3	1	3	2	3	2	3
PEMA	LS1BABI	24	1	2	2	3	2	3	2	3	2	3
PEMA	LS1BAOU	1	3	3	2	3	1	3	2	3	2	3
PEMA	LS1BATH	131	1	1	2	3	1	3	2	3	2	3
PEMA	LS1FPTH	14	2	1	2	3	1	3	2	3	2	3
PEMA	LS1ILTH	1	2	1	2	3	1	3	1	2	2	3
PEMA	LS24BATH	44	1	3	3	3	2	3	2	3	2	3
PEMA	LS2BABI	2	1	2	2	3	2	3	2	3	2	3
PEMA	LS2BATH	12	1	2	2	3	1	3	2	3	2	3
PEMA	LS34BATH	18	1	3	3	3	2	3	2	3	2	3
PEMA	LS34SLTH	1	3	3	3	3	2	3	2	3	2	1
PEMA	LS3BATH	12	1	2	2	3	1	3	2	3	2	3
PEMA	TEBAIS	479	1	1	3	2	2	3	2	3	2	3
PEMA	TEBAOU	11	3	2	3	3	1	3	2	3	2	3
PEMA	TESLIS	5	3	3	3	2	2	3	2	3	2	1
PEMAx	LS14BATH	1	1	3	3	3	2	3	3	3	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PEMAx	TEBAIS	3	1	1	3	2	2	3	3	3	3	3
PEMB	LE1FRBI	5	3	3	3	1	2	3	2	2	1	1
PEMB	LE1FRIS	13	3	3	3	1	2	3	2	2	1	1
PEMB	LE1FROU	10	3	3	3	1	1	3	2	2	1	1
PEMB	LE1FRTH	7	3	3	3	1	1	3	2	2	1	1
PEMB	LE3FRTH	2	3	3	3	1	1	3	2	2	1	1
PEMB	LR1FPTH	1	3	1	2	1	1	3	2	3	1	1
PEMB	LS14BATH	14	2	3	3	1	2	3	2	3	1	1
PEMB	LS1BATH	30	2	1	2	1	1	3	2	3	1	1
PEMB	LS1SLTH	1	3	1	2	1	1	3	2	3	1	1
PEMB	LS24BATH	15	2	3	3	1	2	3	2	3	1	1
PEMB	LS2BATH	27	2	2	2	1	1	3	2	3	1	1
PEMB	LS2FPTH	1	3	1	2	1	1	3	2	3	1	1
PEMB	LS34BATH	15	2	3	3	1	2	3	2	3	1	1
PEMB	LS3BATH	21	2	2	2	1	1	3	2	3	1	1
PEMB	TEBABI	3	2	2	3	1	2	3	2	3	1	1
PEMB	TEBAIS	217	2	2	3	1	2	3	2	3	1	1
PEMB	TEBAOU	18	3	2	3	1	1	3	2	3	1	1
PEMB	TEFRIS	3	3	2	3	1	2	3	2	3	1	1
PEMCh	LE2FRBI	9	2	1	3	3	2	3	3	3	3	3
PEMCh	LE3BABI	3	2	1	3	3	2	3	3	3	3	3
PEMCh	LR16FPTH	12	2	1	2	3	1	3	3	3	3	3
PEMCh	LS146BABI	1	1	3	3	3	3	3	3	3	3	3
PEMCh	LS146BATH	3	1	3	3	3	2	3	3	3	3	3
PEMCh	LS16BABI	1	1	2	2	3	2	3	3	3	3	3
PEMCh	LS16BATH	17	1	2	2	3	1	3	3	3	3	3
PEMCh	LS246BATH	1	1	3	3	3	2	3	3	3	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PEMCh	LS346BATH	3	1	3	3	3	2	3	3	3	3	3
PEMCh	TEBAIS	3	1	1	3	2	2	3	3	3	3	3
PEMC	LE1BAIS	1	1	1	3	1	2	3	2	3	2	3
PEMC	LE2BABI	1	2	1	3	3	2	3	2	3	2	3
PEMC	LR1FPBI	21	2	1	2	2	1	2	2	3	2	3
PEMC	LR1FPIS	18	2	1	2	1	1	3	2	3	2	3
PEMC	LR1FPTH	55	2	1	2	2	1	3	2	3	2	3
PEMC	LR2FPBI	2	2	1	2	2	1	3	2	3	2	3
PEMC	LR2FPTH	1	2	1	2	2	1	3	2	3	2	3
PEMC	LRIFPTH	3	2	1	2	2	1	3	2	3	2	3
PEMC	LS14BABI	2	1	3	3	2	3	3	2	3	2	3
PEMC	LS14BATH	33	1	3	3	2	2	3	2	3	2	3
PEMC	LS1BABI	2	1	2	2	2	2	3	2	3	2	3
PEMC	LS1BAIN	1	1	1	3	1	1	3	2	3	2	3
PEMC	LS1BATH	33	1	1	2	2	1	3	2	3	2	3
PEMC	LS1FPTH	3	2	1	2	2	1	3	2	3	2	3
PEMC	LS24BATH	1	1	3	3	2	2	3	2	3	2	3
PEMC	LS2BABI	1	1	2	2	2	2	3	2	3	2	3
PEMC	LS2FPTH	1	2	1	2	2	1	3	2	3	2	3
PEMC	LS34BABI	1	1	3	3	2	3	3	2	3	2	3
PEMC	LS34BATH	3	1	3	3	2	2	3	2	3	2	3
PEMC	TEBABI	1	1	1	3	1	2	3	2	3	2	3
PEMC	TEBAIS	97	1	1	3	1	2	3	2	3	2	3
PEMC	TEBAOU	2	3	2	3	2	1	3	2	3	2	3
PEMCx	LR1FPBI	1	2	1	2	2	1	3	3	3	3	3
PEMCx	LR1FPIS	1	2	1	2	2	1	3	3	3	3	3
PEMCx	LS1	1	2	1	2	3	2	3	3	3	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PEMCx	LS14BATH	1	1	3	3	3	2	3	3	3	3	3
PEMCx	LS4	1	2	3	3	3	2	3	3	3	3	3
PEMCx	TEBAIS	7	1	1	3	2	2	3	3	3	3	3
PEMFb	LS146BATH	1	2	3	3	1	2	3	1	1	1	2
PEMFb	LS16BATH	2	2	2	2	1	1	3	1	1	1	2
PEMFb	LS36BATH	2	2	2	2	1	1	3	1	1	1	2
PEMFh	LE2FRBI	2	3	1	3	2	2	3	2	2	3	3
PEMFh	LR16FPTH	11	3	1	2	2	1	3	2	2	3	3
PEMFh	LS146BABI	3	2	3	3	2	3	3	2	2	3	3
PEMFh	LS146BATH	13	2	3	3	2	2	3	2	2	3	3
PEMFh	LS16BABI	2	2	2	2	2	2	3	2	2	3	3
PEMFh	LS16BATH	11	2	2	2	2	1	3	2	2	3	3
PEMFh	LS246BABI	1	2	3	3	2	3	3	2	2	3	3
PEMFh	LS246BATH	6	2	3	3	2	2	3	2	2	3	3
PEMFh	LS26BATH	1	2	2	2	2	1	3	2	2	3	3
PEMFh	LS346BATH	6	2	3	3	2	2	3	2	2	3	3
PEMFh	LS36BATH	2	2	2	2	2	1	3	2	2	3	3
PEMFh	TEBAIS	26	2	2	3	1	2	3	2	2	3	3
PEMFh	TEBAOU	1	3	2	3	2	1	3	2	2	3	3
PEMF	LE1FRBI	2	3	3	3	1	2	3	1	1	1	2
PEMF	LE1FROU	1	3	3	3	1	1	3	1	1	1	2
PEMF	LR1FPBI	10	3	1	2	1	1	2	1	1	1	2
PEMF	LR1FPIS	17	3	1	2	1	1	3	1	1	1	2
PEMF	LR1FPTH	50	3	1	2	1	1	3	1	1	1	2
PEMF	LS14BABI	2	2	3	3	1	3	3	1	1	1	2
PEMF	LS14BATH	17	2	3	3	1	2	3	1	1	1	2
PEMF	LS14FRTH	3	2	3	3	1	2	3	1	1	1	2

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PEMF	LS1BABI	5	2	2	2	1	2	3	1	1	1	2
PEMF	LS1BATH	23	2	1	2	1	1	3	1	1	1	2
PEMF	LS1FPTH	1	3	1	2	1	1	3	1	1	1	2
PEMF	LS1FRTH	1	3	1	2	1	1	3	1	1	1	2
PEMF	LS34BATH	2	2	3	3	1	2	3	1	1	1	2
PEMF	LS3BABI	1	2	2	2	1	2	3	1	1	1	2
PEMF	LS3BATH	2	2	2	2	1	1	3	1	1	1	2
PEMF	TEBAIS	61	2	2	3	1	2	3	1	1	1	2
PEMF	TEBAOU	8	3	2	3	1	1	3	1	1	1	2
PEMFx	LS14BATH	1	2	3	3	2	2	3	2	2	3	3
PEMFx	LS1BATH	2	2	1	2	2	1	3	2	2	3	3
PEMFx	LS24BATH	1	2	3	3	2	2	3	2	2	3	3
PEMFx	TEBAIS	32	2	2	3	1	2	3	2	2	3	3
PEMFx	TEBAOU	1	3	2	3	2	1	3	2	2	3	3
PFOA	LR1FPBI	2	2	1	2	2	1	1	1	2	2	1
PFOA	LR1FPIS	1	2	1	2	1	1	1	1	2	2	1
PFOA	LR1FPTH	7	1	1	2	2	1	1	1	2	2	1
PFOA	LS1FPTH	1	1	1	2	2	1	1	1	2	2	1
PSSAb	LS16BATH	9	1	2	2	2	1	3	1	2	2	3
PSSAb	LS26BATH	6	1	2	2	2	1	2	1	2	2	3
PSSAh	LE2BABI	3	2	1	3	3	2	3	2	3	3	3
PSSAh	LE3BABI	3	2	1	3	3	2	3	2	3	3	3
PSSAh	LR16FPTH	8	1	1	2	3	1	2	2	3	3	3
PSSAh	LS146BATH	1	1	3	3	3	2	3	3	3	3	3
PSSAh	LS16BATH	6	1	2	2	3	1	3	2	3	3	3
PSSAh	LS346BATH	1	1	3	3	3	2	2	3	3	3	3
PSSAh	TEBAIS	1	1	1	3	2	2	3	3	3	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PSSA	LE2BABI	4	2	1	3	2	2	3	1	2	2	3
PSSA	LR1FPBI	39	2	1	2	2	1	1	1	2	2	3
PSSA	LR1FPIS	28	2	1	2	1	1	2	1	2	2	3
PSSA	LR1FPTH	344	1	1	2	2	1	2	1	2	2	3
PSSA	LR1FRTH	1	1	1	2	2	1	3	1	2	2	3
PSSA	LR1ILTH	41	1	1	2	2	1	3	1	2	2	3
PSSA	LR2FPBI	2	2	1	2	2	1	2	1	2	2	3
PSSA	LR2FPTH	17	1	1	2	2	1	2	1	2	2	3
PSSA	LR2ILTH	4	1	1	2	2	1	2	1	2	2	3
PSSA	LRIFPTH	7	1	1	2	2	1	2	1	2	2	3
PSSA	LS14BABI	7	1	3	3	2	3	3	2	3	2	3
PSSA	LS14BAIN	1	1	1	3	1	2	3	2	3	2	3
PSSA	LS14BATH	85	1	3	3	2	2	2	2	3	2	3
PSSA	LS14SLTH	1	2	3	3	2	2	2	2	3	2	1
PSSA	LS1BABI	12	1	2	2	2	2	3	1	2	2	3
PSSA	LS1BAOU	1	3	3	2	2	1	3	1	2	2	3
PSSA	LS1BATH	145	1	1	2	2	1	2	1	2	2	3
PSSA	LS1FPTH	25	1	1	2	2	1	2	1	2	2	3
PSSA	LS1ILTH	2	1	1	2	2	1	2	1	2	2	3
PSSA	LS24BABI	2	1	3	3	2	2	3	1	3	2	3
PSSA	LS24BATH	7	1	3	3	2	2	2	2	3	2	3
PSSA	LS24SLTH	1	2	3	3	2	2	2	2	3	2	1
PSSA	LS2BABI	2	1	2	2	2	2	3	2	2	2	3
PSSA	LS2BAIN	1	1	1	3	1	1	3	1	2	2	3
PSSA	LS2BATH	22	1	2	2	2	1	2	1	2	2	3
PSSA	LS34BATH	7	1	3	3	2	2	2	2	3	2	3
PSSA	LS34SLTH	2	2	3	3	2	2	2	2	3	2	1

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PSSA	LS3BABI	1	1	2	2	2	2	3	1	2	2	3
PSSA	LS3BATH	19	1	2	2	2	1	2	1	2	2	3
PSSA	TEBAIS	117	1	1	3	1	2	3	2	3	2	3
PSSA	TEBAOU	3	3	2	3	2	1	3	1	3	2	3
PSSB	LR1FPTH	1	1	1	2	1	1	2	1	2	1	1
PSSB	LS14BATH	4	1	3	3	1	2	2	2	3	1	1
PSSB	LS1BATH	4	1	1	2	1	1	2	1	2	1	1
PSSB	LS24BATH	2	1	3	3	1	2	2	2	3	1	1
PSSB	LS2BATH	3	1	2	2	1	1	2	1	2	1	1
PSSB	LS34BATH	5	1	3	3	1	2	2	2	3	1	1
PSSB	LS3BATH	3	1	2	2	1	1	2	1	2	1	1
PSSB	TEBAIS	16	2	1	3	1	2	3	2	3	1	1
PSSCb	LS16BATH	4	1	2	2	2	1	3	1	2	2	3
PSSCb	LS36BATH	1	1	2	2	2	1	3	1	2	2	3
PSSCh	LE2FRBI	2	2	1	3	3	2	3	2	2	3	3
PSSCh	LE3BABI	3	2	1	3	3	2	3	2	2	3	3
PSSCh	LS16BATH	3	1	2	2	3	1	3	2	3	3	3
PSSCh	TEBAIS	1	1	1	3	2	2	3	3	3	3	3
PSSC	LR1FPBI	4	2	1	2	2	1	1	1	2	2	3
PSSC	LR1FPIS	3	2	1	2	1	1	2	1	2	2	3
PSSC	LR1FPTH	15	1	1	2	2	1	2	1	2	2	3
PSSC	LR1ILTH	2	1	1	2	2	1	3	1	2	2	3
PSSC	LS14BATH	7	1	3	3	2	2	2	2	3	2	3
PSSC	LS16BATH	1	1	2	2	2	1	3	1	2	2	3
PSSC	LS1BABI	1	1	2	2	2	2	3	1	2	2	3
PSSC	LS1BATH	35	1	1	2	2	1	2	1	2	2	3
PSSC	LS1FPTH	7	1	1	2	2	1	2	1	2	2	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PSSC	LS24BABI	2	1	3	3	2	2	3	2	3	2	3
PSSC	LS24BATH	1	1	3	3	2	2	2	2	3	2	3
PSSC	LS2BAIN	2	1	1	3	1	1	3	1	2	2	3
PSSC	LS2BATH	5	1	2	2	2	1	2	1	2	2	3
PSSC	LS2FPTH	1	1	1	2	2	1	2	1	2	2	3
PSSC	LS34BATH	1	1	3	3	2	2	2	2	3	2	3
PSSC	TEBAIS	7	1	1	3	1	2	3	2	3	2	3
PSSC	TEBAOU	1	3	2	3	2	1	3	2	3	2	3
PSSCx	TEBAIS	1	1	1	3	2	2	3	3	3	3	3
PSSF	LR1FPTH	2	1	1	2	1	1	2	1	1	1	1
PSSF	LS1BABI	1	2	2	2	1	2	3	1	1	1	1
PSSF	LS1BATH	2	1	1	2	1	1	2	1	1	1	1
PUBFh	LS146BATH	1	2	3	3	3	3	3	3	3	3	3
PUBFh	LS246BATH	1	2	3	3	3	3	3	3	3	3	3
PUBFh	LS346BATH	2	2	3	3	3	3	3	3	3	3	3
PUBFh	TEBAIS	4	2	2	3	2	2	3	3	3	3	3
PUBFh	TEBAOU	1	3	2	3	3	2	3	3	3	3	3
PUBF	LR1FPIS	3	3	1	2	1	2	3	2	2	3	3
PUBF	LR1FPTH	3	3	1	2	2	2	3	2	2	3	3
PUBF	LR2FPIS	1	3	1	2	1	2	3	2	2	3	3
PUBF	LS16BATH	1	2	2	2	2	2	3	2	2	3	3
PUBF	LS1BATH	1	2	1	2	2	2	3	2	2	3	3
PUBF	LS2BATH	2	2	2	2	2	2	3	2	2	3	3
PUBF	LS34BATH	1	2	3	3	2	3	3	2	2	3	3
PUBF	LS3BATH	6	2	2	2	2	2	3	2	2	3	3
PUBF	TEBAIS	53	2	2	3	1	2	3	2	2	3	3
PUBF	TEBAOU	4	3	2	3	2	2	3	2	2	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
PUBFx	LR1FPIS	17	3	1	2	2	2	3	3	3	3	3
PUBFx	LR1FPTH	1	3	1	2	3	2	3	3	3	3	3
PUBFx	LS14BATH	4	2	3	3	3	3	3	3	3	3	3
PUBFx	LS1BABI	1	2	2	2	3	3	3	3	3	3	3
PUBFx	LS1FPTH	1	3	1	2	3	2	3	3	3	3	3
PUBFx	TEBAIS	92	2	2	3	2	2	3	3	3	3	3
PUBFx	TEBAOU	1	3	2	3	3	2	3	3	3	3	3
PUBG	LS14BATH	1	2	3	3	2	3	3	2	2	3	3
PUBG	LS2BATH	2	2	2	2	2	2	3	2	2	3	3
PUBG	LS3BATH	1	2	2	2	2	2	3	2	2	3	3
PUBG	TEBAIS	5	2	2	3	1	2	3	2	2	3	3
PUBG	TEBAOU	1	3	2	3	2	2	3	2	2	3	3
PUSAh	LR16FPTH	2	2	1	1	3	3	3	3	2	3	3
PUSA	LR1FPIS	1	2	1	2	2	3	3	2	2	3	3
PUSA	LS1BATH	1	1	1	1	3	3	3	2	2	3	3
PUSC	TEBAIS	3	1	2	3	2	2	3	2	2	3	3
PUSC	TEBAOU	1	3	2	3	3	3	3	2	2	3	3
R2UBF	LR1	14	3	1	2	3	3	3	3	1	3	3
R2UBF	LS1	15	3	1	2	3	3	3	3	1	3	3
R2UBF	LS2	9	3	1	2	3	3	3	3	1	3	3
R2UBH	LR1	5	3	1	2	3	3	3	3	1	3	3
R2UBH	LS1	1	3	1	2	3	3	3	3	1	3	3
R2UBH	LS2	1	3	1	2	3	3	3	3	1	3	3
R2USA	LR1FRTH	906	2	1	1	3	3	3	2	2	3	3
R2USA	LR1ILTH	3	2	1	1	3	3	3	1	2	3	3
R2USA	LS1FRTH	76	2	1	1	3	3	3	2	2	3	3
R2USA	LS2FRTH	4	2	2	1	3	3	3	2	2	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
R2USC	LR1FRTH	31	2	1	1	3	3	3	2	2	3	3
R2USC	LR1ILTH	3	2	1	1	3	3	3	1	2	3	3
R3UBF	LS1	2	3	1	2	3	3	3	3	1	3	3
R3UBF	LS2	30	3	1	2	3	3	3	3	1	3	3
R3UBG	LS1	1	3	1	2	3	3	3	3	1	3	3
R3UBG	LS2	10	3	1	2	3	3	3	3	1	3	3
R3UBH	LR2	1	3	1	2	3	3	3	3	1	3	3
R3UBH	LS2	15	3	1	2	3	3	3	3	1	3	3
R3USA	LR1FRTH	82	2	1	1	3	3	3	2	2	3	3
R3USA	LR1ILTH	3	2	1	1	3	3	3	1	2	3	3
R3USA	LR2FRTH	20	2	1	1	3	3	3	2	2	3	3
R3USA	LR2ILTH	1	2	1	1	3	3	3	1	2	3	3
R3USA	LS1FRTH	218	2	1	1	3	3	3	2	2	3	3
R3USA	LS2BATH	1	1	2	1	3	3	3	2	2	3	3
R3USA	LS2FRTH	35	2	2	1	3	3	3	2	2	3	3
R3USA	LS3FRTH	1	2	2	1	3	3	3	2	2	3	3
R3USC	LR1FRTH	5	2	1	1	3	3	3	2	2	3	3
R3USC	LR2FRTH	1	2	1	1	3	3	3	2	2	3	3
R3USC	LS1FRTH	1	2	1	1	3	3	3	2	2	3	3
R3USC	LS2FRTH	4	2	2	1	3	3	3	2	2	3	3
R4SBC	LR1FPBI	1	2	1	1	3	3	3	3	2	3	3
R4SBC	LS4	1	2	3	3	3	3	3	3	2	3	3
R4SBCx	LS4	26	2	3	3	3	3	3	3	3	3	3
R4SBFx	LS4	34	3	3	3	3	3	3	3	3	3	3
Rp1EM	LR1Rp	807	2	3	2	3	2	3	3	3	3	3
Rp1EM	LR2Rp	8	2	3	2	3	2	3	3	3	3	3
Rp1EM	LS14Rp	7	2	3	3	3	2	3	3	3	3	3

NWI Code	HGM Code	# of polygons	Flood Storage[1]	Groundwater Recharge[1]	Streamflow Maintenance[1]	Nutrient Cycling[1]	Sediment Retention[1]	Bank Stabilization[1]	Terrestrial Habitat[1]	Aquatic Habitat[1]	Maintain Native Vegetation[1]	Wetland Biodiversity[1]
Rp1EM	LS1Rp	140	2	3	2	3	2	3	3	3	3	3
Rp1EM	LS24Rp	4	2	3	3	3	3	3	3	3	3	3
Rp1EM	LS2Rp	22	2	3	2	3	2	3	3	3	3	3
Rp1EM	LS34Rp	12	2	3	3	3	3	3	3	3	3	3
Rp1EM	LS3Rp	33	2	3	2	3	2	3	3	3	3	3
Rp1FO	LR1Rp	1373	1	3	2	3	2	1	1	2	2	3
Rp1FO	LR2Rp	13	1	3	2	3	2	1	1	2	2	3
Rp1FO	LS14Rp	199	1	3	2	3	2	1	1	2	2	3
Rp1FO	LS1Rp	382	1	3	2	3	2	1	1	2	2	3
Rp1FO	LS24Rp	86	1	3	3	3	3	1	1	2	2	3
Rp1FO	LS2Rp	90	1	3	2	3	2	1	1	2	2	3
Rp1FO	LS34Rp	195	1	3	3	3	3	1	1	2	2	3
Rp1FO	LS3Rp	94	1	3	2	3	2	1	1	2	2	3
Rp1SS	LR1Rp	654	1	3	2	3	2	2	1	2	2	3
Rp1SS	LR2Rp	68	1	3	2	3	2	2	1	2	2	3
Rp1SS	LS14Rp	86	1	3	3	3	2	2	1	2	2	3
Rp1SS	LS1Rp	640	1	3	2	3	2	2	1	2	2	3
Rp1SS	LS24Rp	77	1	3	3	3	3	2	1	2	2	3
Rp1SS	LS2Rp	194	1	3	2	3	2	2	1	2	2	3
Rp1SS	LS34Rp	176	1	3	3	3	3	2	1	2	2	3
Rp1SS	LS3Rp	285	1	3	2	3	2	2	1	2	2	3
Rp2EM	TERp	2	2	3	3	3	3	3	3	3	3	3
Rp2FO	TERp	17	1	3	3	3	3	3	1	2	2	3
Rp2SS	TERp	13	1	3	3	3	3	3	1	2	2	3

[1]1 = high, 2 = moderate, 3 = low or N/A

Appendix D. Complete statistical results from wetland change analysis

Derived from random sampling analysis. See Appendix A for NWI code definitions. Codes without additional information (e.g. L1UB) indicate estimated area values from the old NWI (1982, 1983, 1984). Codes with "new" (e.g. L1UBnew) indicate estimated area values from the new NWI (2005). Human and natural refer to the source of change. All values are in acres.

Category	Estimated Area	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
L1UB	1983.3	1256.3	-479.0	4445.7
L1UBnew	1983.3	1256.3	-479.0	4445.7
L1UB.new.human	0.0	0.0	0.0	0.0
L1UB.new.natural	0.0	0.0	0.0	0.0
L2UB	29.4	20.0	-9.7	68.6
L2UBnew	902.1	872.9	-808.7	2612.9
L2UB.new.human	902.1	872.9	-808.7	2612.9
L2UB.new.natural	0.0	0.0	0.0	0.0
L2US	78.5	78.5	-75.4	232.4
L2USnew	78.5	78.5	-75.4	232.4
L2US.new.human	0.0	0.0	0.0	0.0
L2US.new.natural	0.0	0.0	0.0	0.0
PAB	1015.0	287.1	452.4	1577.6
PABnew	1212.1	270.9	681.2	1742.9
PAB.new.human	287.8	165.1	-35.8	611.4
PAB.new.natural	-90.7	64.1	-216.4	34.9
PEM	3411.8	1249.1	963.6	5860.0
PEMnew	2708.4	731.1	1275.6	4141.3
PEM.new.human	-751.9	806.9	-2333.5	829.6
PEM.new.natural	48.5	65.9	-80.6	177.7
PFO	0.5	0.5	-0.4	1.3
PFOnew	0.5	0.5	-0.4	1.3
PFO.new.human	0.0	0.0	0.0	0.0
PFO.new.natural	0.0	0.0	0.0	0.0
PSS	1769.0	438.8	909.0	2629.1
PSSnew	1345.7	391.2	579.0	2112.3
PSS.new.human	-16.0	12.8	-41.1	9.1
PSS.new.natural	-407.4	158.7	-718.5	-96.2
PUS	80.1	76.3	-69.5	229.7
PUSnew	4.0	3.0	-1.9	9.9
PUS.new.human	-74.0	75.0	-221.0	73.1
PUS.new.natural	0.0	0.0	0.0	0.0
R2UB	2708.9	800.2	1140.4	4277.3
R2UBnew	2197.7	773.9	680.9	3714.6
R2UB.new.human	0.0	0.0	0.0	0.0
R2UB.new.natural	-511.1	517.3	-1525.0	502.7

Category	Estimated Area	Standard Error	Lower 95% Confidence Limit	Upper 95% Confidence Limit
R2US	3193.1	1213.9	813.9	5572.3
R2USnew	2258.4	869.7	553.7	3963.0
R2US.new.human	229.2	229.2	-220.0	678.3
R2US.new.natural	-934.7	517.3	-1948.7	79.2
R3UB	675.5	229.8	225.0	1126.0
R3UBnew	463.6	187.4	96.3	830.8
R3UB.new.human	0.0	0.0	0.0	0.0
R3UB.new.natural	-211.9	119.1	-445.3	21.5
R3US	247.8	106.7	38.6	456.9
R3USnew	128.7	51.6	27.6	229.7
R3US.new.human	0.0	0.0	0.0	0.0
R3US.new.natural	-119.1	61.4	-239.4	1.2
Old.NWI.Upland	1323851.0	10025.3	1304201.8	1343500.1
Upland.new	1325761.0	9879.9	1306396.6	1345125.3
upland.new.human	-316.4	226.2	-759.7	126.9
Upland.new.natural	2219.8	743.1	763.3	3676.3
New.NWI.Sum	13282.9	3074.0	7258.0	19307.8
Old.NWI.Sum	15192.9	3361.2	8605.1	21780.7