Wetlands of the Gallatin Valley: Change and Ecological Functions

Prepared for:

The Montana Department of Environmental Quality and
The U. S. Environmental Protection Agency

Prepared by:

Karen R. Newlon and Meghan D. Burns

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EXECUTIVE SUMMARY

Digital wetland mapping provides important information on the type, location, and extent of wetlands within a given region. Comparing historic mapping with updated mapping provides a unique opportunity to examine potential changes in wetland density and distribution due to both natural and anthropogenic causes. In addition to documenting changes in wetland area, comparing spatial datasets allows us to track change or loss of wetland functions such as flood control, nutrient retention, and wildlife habitat.

This report focuses on the Gallatin Valley and surrounding area, typical of many rapidly growing regions in the West with increasing land conversion, subdivision, and residential development. Our objectives were to quantify changes in wetland extent and function in our study area and to estimate cumulative change in wetland functions.

The project required us to produce new digital wetland maps at a 1:12,000 scale, using 2005 aerial imagery at 1-meter resolution. This was done as part of National Wetland Inventory (NWI) updating, following current federal standards.

To analyze wetland change, we compared randomly selected wetlands from the original NWI, completed in 1984 and 1988, with the new NWI mapping created for this project. We randomly selected 25% of the one-square mile Public Land Survey System sections in each subwatershed in the study area using a spatially balanced random sampling approach. Within the sampled area, we compared each wetland polygon in the old mapping to the corresponding wetland polygon in the new mapping, and we assigned a source of change to each mapped wetland. To assess the functions associated with each wetland, we analyzed the landscape position, landform, waterbody, and water flow paths for each wetland. We assigned hydrogeomorphic (HGM) modifiers to all wetland polygons in both the old and new wetland mapping. These HGM attributes were combined with the NWI classification attributes to yield a combination that could then be ranked on a performance scale of 1 (low), 2 (moderate), and 3 (high) for each of ten wetland functions (water storage, streamflow maintenance, groundwater recharge, nutrient cycling, sediment retention, shoreline stabilization, native plant community maintenance, terrestrial habitat, aquatic habitat, and conservation of wetland biodiversity). We used this performance ranking as a weighting factor and multiplied this weighting factor by wetland area to calculate functional units for each wetland function. We also completed a wetland landscape profile for each sixth code hydrologic unit that provides a broad landscape characterization of wetlands across the project area.

We digitized 56,822 acres (22,995 hectares) of wetlands and 28,210 acres (11,416 hectares) of riparian habitat within the change detection analysis area. Palustrine emergent wetlands covered the greatest area with over 28,380 acres (11,485 hectares). The majority of wetland and riparian habitats (57,358 acres; 23,212 hectares) occur on private lands within the analysis area. Overall, we observed an increase of 4,221 mapped wetland acres (1,708 hectares) between 1980's and 2005 within the study area.

Wetlands associated with lotic features comprised the largest hydrogeomorphic type in the Gallatin project area, totaling 39,454 acres (15,967 hectares). Wetlands associated with deepwater and associated lentic features covered 824 acres (333 hectares), and terrene wetlands totaled 3,256 acres (1,318 hectares). Comparison of wetland functional performance capacities throughout the Gallatin project area showed an overall 73.5% gain in hydrologic functions that include water storage, streamflow maintenance, and groundwater recharge. However, we mapped over five times more acres of lotic wetlands using higher resolution 2005 imagery, which contributed to this apparent gain in hydrologic function. Biogeochemical functions incorporating nutrient cycling, sediment retention, and shoreline stabilization showed an overall increase of 24%. Functions associated with terrestrial and native plant communities showed a combined decline of 7.3%, whereas aquatic habitat and conservation of wetland biodiversity showed a combined increase of 9.7%.

Our analysis shows an overall increase in wetland area between mapping completed in the 1980's and new mapping from 2005 aerial imagery. Many wetlands mapped as palustrine scrub shrub in the 1980's are now palustrine emergent wetlands. Examination of the aerial imagery revealed that much of this change is attributable to agricultural changes (e.g., livestock grazing, stream dewatering, and conversion to hay pasture). Additionally, some scrub shrub historically mapped as wetland was mapped as riparian scrub shrub in the new mapping.

Although our estimates indicate that few actual wetland acres were lost between the 1980's and 2005 mapping efforts across the entire project area, concentrated wetland losses occurred in a few areas. In particular, much of the wetland change in the areas immediately around Bozeman was attributable to urban and rural development. This area has seen rapid growth and much of the valley bottom locations along the East Gallatin River have been subdivided. The wetland landscape profiling also revealed that the areas around Bozeman contain wetlands with the potential for high performance of several wetland functions, including groundwater recharge, streamflow maintenance, water storage, sediment retention, and terrestrial habitat. Continued impacts to wetlands in these important areas will reduce the ability of wetlands to perform these functions, potentially resulting in ecological and economic losses in these areas.

It is also important to note that differences between the scales of the imagery used in the historic and new mapping products make accurate quantification of wetland change problematic. The historic wetland mapping was digitized at a 1:58,000 scale and exhibits considerably more spatial error than the current mapping that was digitized at a 1:12,000 scale.

Factors such as photo quality, scale, and environmental conditions at the time of photo acquisition can also affect mapping accuracy. Digital wetland maps are static and may not reflect the dynamic nature of wetlands subject to drastic annual and seasonal fluctuations in size and distribution. We also emphasize that the functional capacity ratings assigned to wetlands in this project are only potential capacities. Data on actual functional capacity would require extensive field work and assessment.

This analysis should be considered a preliminary assessment of changes in the Gallatin Valley wetlands and wetland functional capacity. Data from this analysis can provide very effective conservation tools to identify areas with the potential to perform wetland functions most effectively, allowing natural resource managers and other stakeholders to focus or prioritize conservation and restoration efforts.

ACKNOWLEDGEMENTS

This project was funded by the Environmental Protection Agency and administered by the Montana Department of Environmental Quality. We would like to thank Lynda Saul, Wetland Program Manager with Montana Department of Environmental Quality for her support and strong leadership in Montana wetland issues. Erika Colaiacomo and Robin Lium of MTNHP assisted with wetland mapping, hydrogeomorphic modifier attribution, and quality control. Patty Gude with Headwaters Economics provided data on housing density in the study area. Catherine McIntyre, Wetland Ecologist and Project Manager with MTNHP, and Linda Vance, Senior Ecologist, of MTNHP provided helpful comments that greatly improved this report. Coburn Currier of MTNHP formatted and edited the final version of this report. Any errors or omissions in the report are entirely the responsibility of the authors.

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INTRODUCTION

Digital wetland mapping provides important information on the type, location, and extent of wetlands within a given region. Comparing historic wetland mapping with updated mapping provides an opportunity to examine potential changes in wetland density and distribution due to both natural and anthropogenic causes. The National Wetland Inventory (NWI) of the U.S. Fish and Wildlife Service has completed several reports on the status and trends of the nation's wetlands (Frayer et al. 1983, Dahl and Johnson 1991, Dahl 2000, 2006), underscoring the cumulative change in wetland area on a national scale. However, documentation of wetland change at a local or regional scale is also necessary, particularly for areas undergoing rapid land use changes. In addition to documenting changes in wetland area, addressing the corresponding change or loss of wetland functions such as flood control, nutrient retention, and wildlife habitat is also important, as wetlands are valued not for the area they cover but for the ecological functions they provide.

Certain wetland functions become increasingly important in areas influenced by human development (Mitsch and Gosselink 2000a). Yet, wetland functional performance can vary both annually and seasonally. Moreover, not all wetlands perform all functions. For example, a wetland located near a headwater stream performs different functions than a wetland at the stream's mouth (Mitsch and Gosselink 2000b). Thus, each wetland is unique in both its ecology and functionality.

Although individual wetlands perform unique functions, they do not act in isolation but are instead influenced by the surrounding landscape. Wetlands also influence the function and condition of entire watersheds. Mapping wetland resources provides information on the density and distribution of wetlands across these large landscapes. NWI data are the most widely available, comprehensive, and standardized wetland mapping products available. The NWI classification system (Cowardin et al. 1979) also provides a means of describing wetland characteristics such as water regime, vegetation, and substrate. However, NWI descriptors provide little information on the functionality of individual wetlands. The hydrogeomorphic classification (HGM) was developed to classify wetlands according to their geomorphic position, water source, and hydrodynamics (Brinson 1993). These three factors affect how a wetland functions; and wetlands with similar characteristics typically function similarly. The addition of HGM descriptors to each wetland polygon in an NWI digital database enhances the information about each wetland. Wetland type can be linked to wetland function, providing a simple way to identify wetlands with the potential to perform various ecological functions (Tiner 2005).

In an assessment context, HGM applications are largely site specific, based on regional reference conditions, and require substantial field investigations. However, recent studies in the northeastern U.S. (Tiner 2005) and Colorado (Johnson 2005) have illustrated the application of HGM as a tool for initial, coarse-scale characterization and assessment of wetland functions through GIS-based landscape analyses. This tool can be used to establish a baseline for wetland functionality, and to create a landscape-level wetland functional profile. This baseline can be compared with current conditions to provide information on the status and trends of wetland functions, allowing for the identification of potentially ecologically significant wetlands, prioritization of restoration and protection efforts, and detection of wetlands most effective at performing particular wetland functions.

Estimating change in wetland extent and distribution as well as change in wetland function over time is particularly valuable for areas experiencing rapid land use changes. In Montana and much of the western U.S., wetlands are typically concentrated in broad river valleys and riparian areas. The attractive amenities offered by such areas often lead to increased development and land conversion. These pressures can have negative impacts on wetland functions including reduced groundwater recharge, increased sediment and nutrient inputs, increased invasion of nonnative species, and reduced wildlife habitat.

Increasing concern over the potential loss of wetlands and their associated functions due to rapid development in large river valleys has prompted examination of how wetland extent, distribution, and function have changed in these areas. This report is the final of three reports focusing on wetland change and ecological function in rapidly developing valleys of Montana (Kudray and Schemm 2008, Newlon and Burns 2009). This report focuses on the Gallatin Valley and surrounding area, which is typical of many rapidly growing regions in the West experiencing increased land conversion, subdivision, and residential development. Our objectives were to quantify changes in wetland extent and function in our study area and to estimate cumulative change in wetland functions. In conjunction with new NWI maps produced by the MTNHP, this report provides a comprehensive characterization of wetlands in the study area.

STUDY AREA

The Gallatin Valley study area includes portions of Broadwater, Jefferson, Madison, and Gallatin counties in the Middle Rockies Level III Ecoregion (Omernik 1987). Elevation ranges from 4,000 feet (1,219 meters) in the valley bottom near Logan to 9,012 feet (2,747 meters) in the Tobacco Root Mountains. The area mapped is over 967,000 acres (391,000 hectares) and includes portions of 70 subwatersheds (sixth code hydrologic units or HUCs) covering 29 U.S. Geological Survey 1:24,000 topographic quadrangles (Figure 1). Outside of urban areas, land use is predominantly wildlife habitat and recreation. Livestock grazing and farming occur in valley locations. Approximately 86% of the analysis area is privately owned (Figure 2). The largest city is Bozeman (Gallatin County).

Climate

Regional climate is influenced by continental air masses with cold, sunny, and dry winters and warm, dry summers. In the valley bottoms around Bozeman, average yearly maximum temperature is 55.2°F (12.9°C) and average yearly minimum temperature is 31.2°F (-0.4°C). The warmest months are July and August. Average annual precipitation is 18.4 inches (467 mm). A third of the yearly precipitation occurs during April, May, and June. Average total snowfall is 85 inches (2,162 mm) (Western Regional Climate Center 2009).

Geology

The area is characterized by wide intermontane valleys and several mountain ranges. Geology of the project area is complex. The majority of the project area is comprised of large river valleys primarily formed in Tertiary sediments and Quaternary alluvial deposits (Nesser et al. 1997). Mountain ranges in the area were largely formed in mixed sedimentary or metasedimentary bedrock, with the exception of the Gallatin Mountains in the southeastern portion of the project area, which were formed in Tertiary volcanic flows and associated pyroclastic deposits consisting of rhyolite, basalt, and andesite.

Hydrology

The study area encompasses portions of the following watersheds: the Jefferson River, the Madison River, the Gallatin River, and the East Gallatin River (Figure 3). Primary water uses are irrigation, livestock, and domestic wells.

Vegetation

Natural vegetation communities are the most common land cover type in the project area (Table 1). Although, pasture and cultivated cropland comprise nearly 25% of the area. Land cover and land use data for each sixth code hydrologic unit are shown in Appendix G. Montane portions of the project area are dominated by coniferous forests. Higher elevation forests are comprised of whitebark pine (*Pinus albicaulis*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and lodgepole pine (*Pinus contorta*). Middle and lower elevation forests are dominated by Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine. Limber pine (*Pinus flexilis*) and Rocky Mountain juniper (*Juniperus scopulorum*) are locally common on calcareous substrates. Quaking aspen (*Populus tremuloides*) occurs in stands throughout the project area in sites where adequate soil moisture is available.

Foothills and valleys are largely grassland and shrubland. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) is the dominant shrub, although stands of threetip sagebrush (*A. tripartita*) and basin big sagebrush (*A. tridentata* ssp.

Table 1. Land cover and land use area (in acres) for the Gallatin project area from the 2009 Montana Land Cover theme.

Open Water	Developed Area	Pasture/Cultivated Cropland	Natural Vegetation	Harvested Forest
3,190.7	49,500.2	229,771.4	681,897.9	694.8

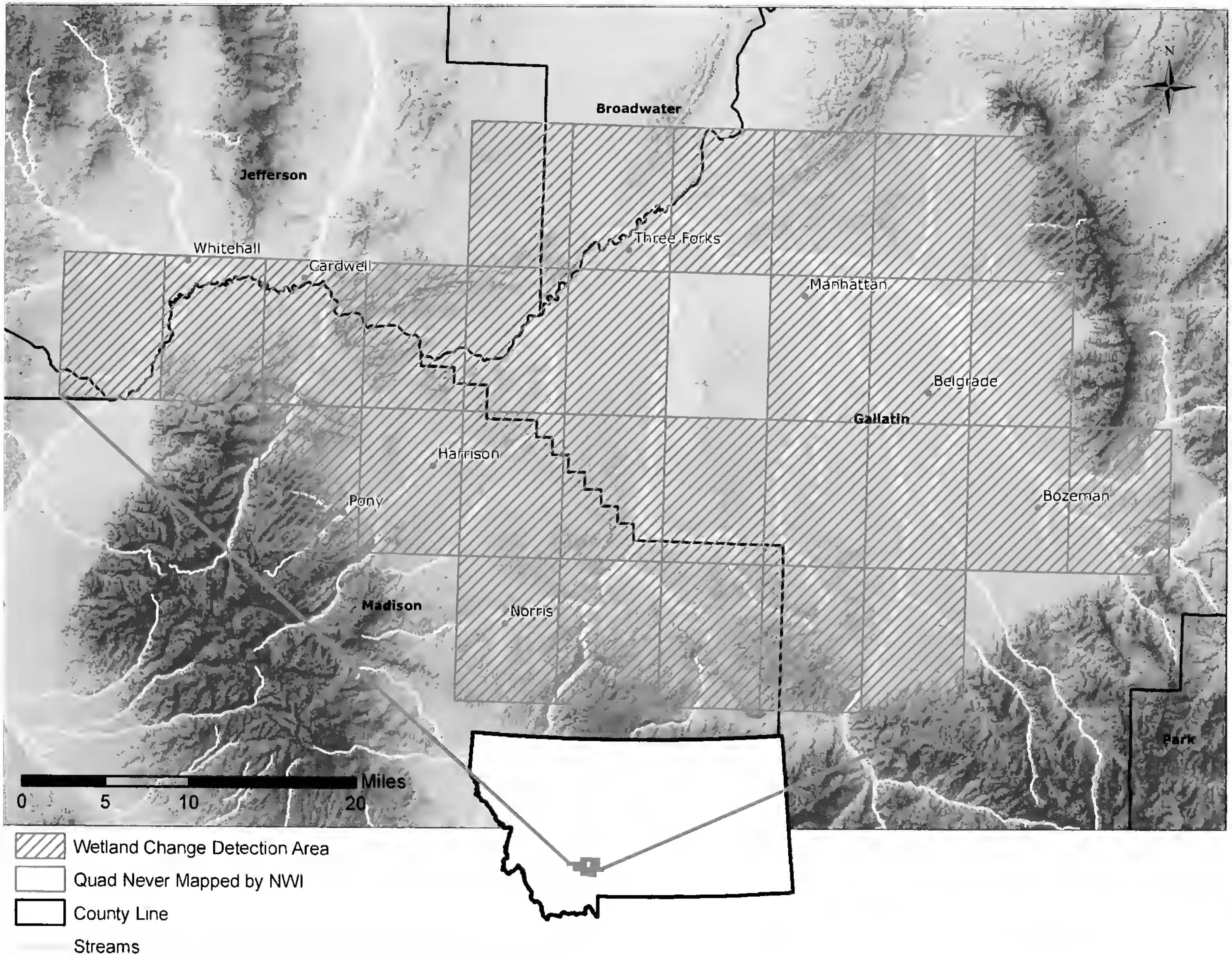

Figure 1 The change detection analysis area for the Gallatin Valley.

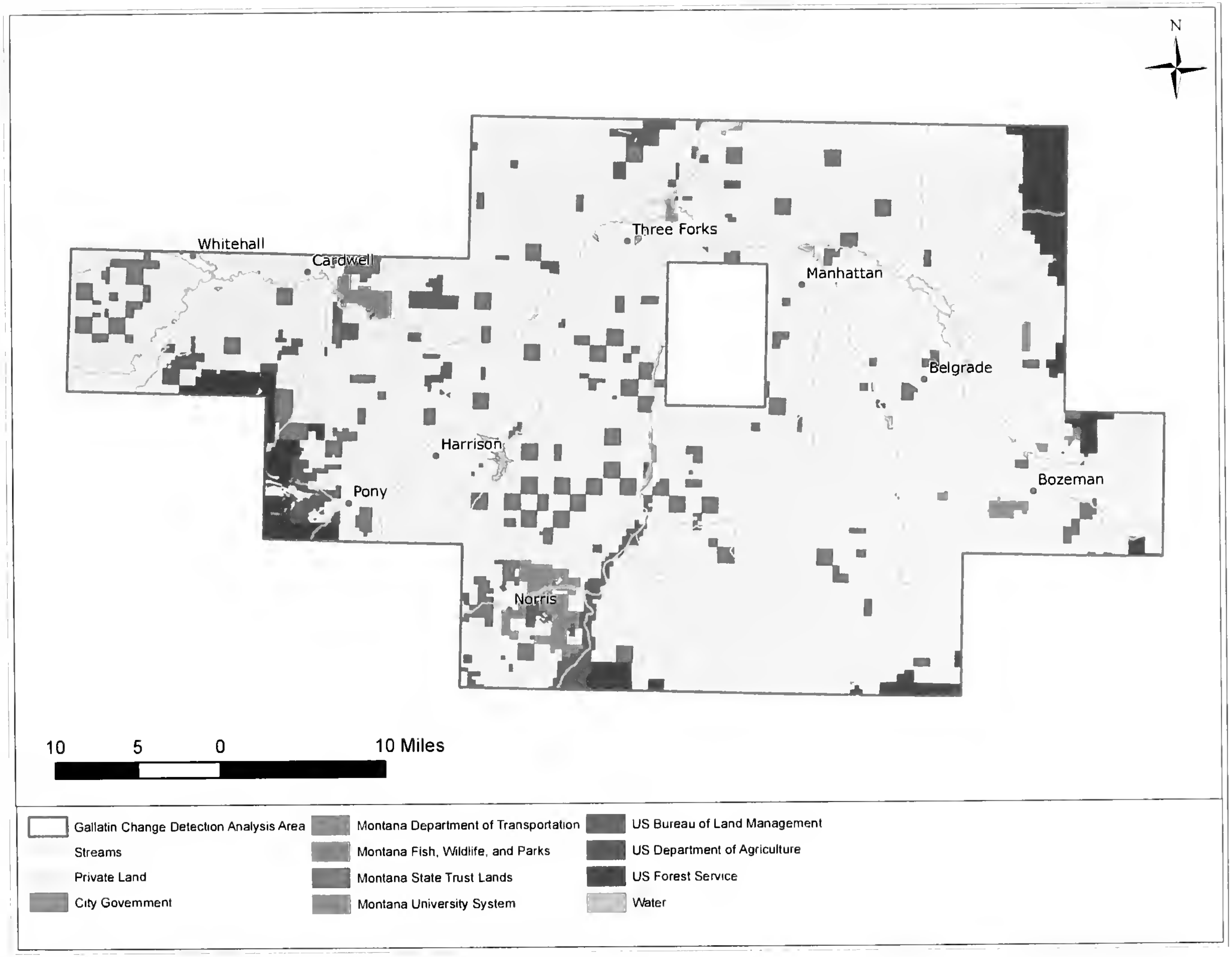

Figure 2. Land ownership within the Gallatin Valley change detection analysis area.

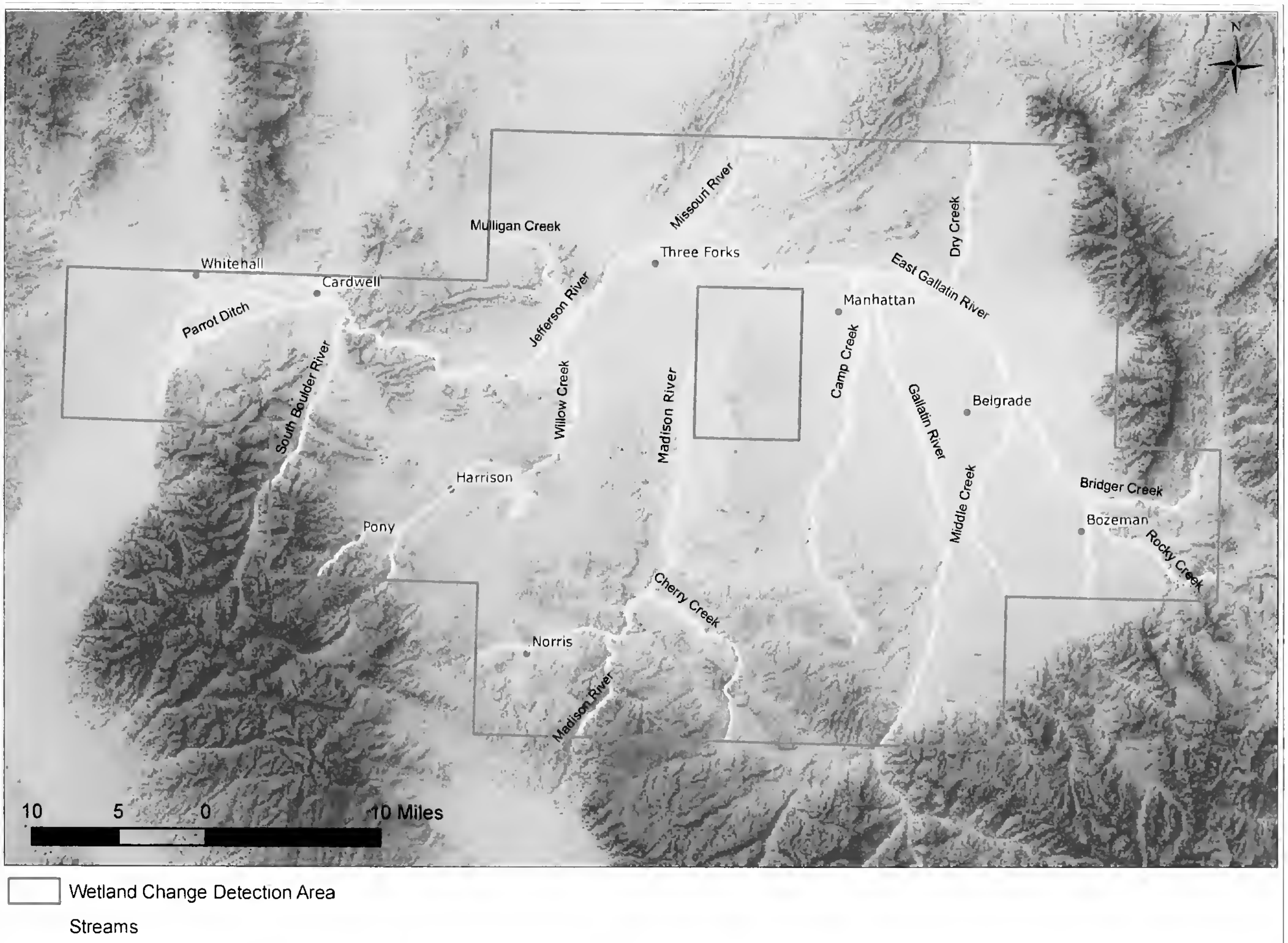

Figure 3. Major streams in the Gallatin project area.

tridentata) are locally common. Alkaline or saline sites may support stands of greasewood (*Sarcobatus vermiculatus*). Bunchgrasses dominate the herbaceous layer, including bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), needle-and-thread (*Hesperostipa comata*), Sandberg's bluegrass (*Poa secunda*), and blue grama (*Bouteloua gracilis*).

A previous study identified high quality wetlands in this area (Jones 2004). The following descriptions of wetland and riparian types in the Gallatin project area are based on observations from that report.

Riparian and Palustrine Forested Wetlands

The large river valleys consist of riparian and palustrine forests dominated by black cottonwood (*Populus balsamifera*) (Figure 4). Cottonwood stands vary from open woodlands to closed canopy forests. Some areas along the lower reaches of the Jefferson, Madison, and Gallatin Rivers still have cottonwood recruitment, although the shrub layer has been lost in many areas. On those floodplains with a well-developed shrub layer, yellow willow (*Salix lutea*), redosier dogwood (*Cornus sericea*), common chokecherry (*Prunus virginiana*), western snowberry (*Symphoricarpos occidentalis*), and Wood's rose (*Rosa woodsii*) are found. Degraded stands have little to no shrub development or a shrub layer dominated by western snowberry and Wood's rose. The herbaceous layer is largely dominated by non-native pasture grasses, particularly Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and common timothy (*Phleum pratense*). Higher elevation streams are dominated by Engelmann spruce, subalpine fir, and quaking aspen.

Figure 4. Cottonwood forest along the Gallatin River.

Riparian and Palustrine Scrub Shrub Wetlands

Riparian and wetland scrub shrub vegetation occurs on terraces along the floodplains of both low and high gradient streams and rivers (Figure 5). It can also be found around beaver ponds and on the fringes of fens and lakes. Common willow species at higher elevations include planeleaf willow (*Salix planifolia*) and Wolf's willow (*S. wolfii*). At middle elevations, Drummond's willow (*S. drummondiana*), Geyer willow (*S. geyeriana*), and Booth's willow (*S. boothii*) are common. At lower elevations, yellow willow and sandbar willow (*S. exigua*) occur along floodplains and on active gravel bars. Other common shrub species include mountain alder (*Alnus incana*), chokecherry, Wood's rose, and western snowberry.

Figure 5. Palustrine scrub shrub wetland in the Gallatin project area.

Palustrine Emergent Wetlands

Herbaceous emergent vegetation in the project area is found in a variety of settings with several sedge species dominant, including *Carex lasiocarpa*, *C. utriculata*, *C. vesicaria*, and *C. limosa* occurring on the wettest sites. Native grasses such as tufted hairgrass (*Deschampsia cespitosa*) and bluejoint reedgrass (*Calamagrostis canadensis*) are common on wet meadow sites (Figure 6). Wet meadow communities have been greatly impacted by livestock and other agricultural practices are largely dominated by non-native grasses, particularly Kentucky bluegrass, smooth brome, common timothy, redtop (*Agrostis gigantea*), and reed canarygrass (*Phalaris arundinacea*).

Figure 6. Palustrine emergent wetlands in the Gallatin project area.

Aquatic Bed

Palustrine, Lacustrine, and Riverine aquatic bed wetlands occur in littoral (< 2 meters in depth) and limnetic (> 2 meters in depth) zones of ponds and lakes (Figure 7) or on the beds of slow-moving perennial streams. Common aquatic plant species include the floating-leaved yellow pond lily (*Nuphar polysepalum*), submerged or partially submerged species such as water milfoil (*Myriophyllum* spp.), common mare's-tail (*Hippuris vulgaris*), and pondweeds (*Potamogeton* spp.).

Figure 7. Palustrine aquatic bed wetland in the Gallatin project area.

Land Use History

The following historical information is taken from Smith (1996). The Blackfeet tribe considered the Gallatin Valley to be prime hunting grounds. Later, other tribes including the Crow, Flathead, and Shoshone began to use the area, as did early European explorers, fur trappers, and settlers. The expedition led by Lewis and Clark through the area in 1805 signaled the beginning of settlement in the region. However, the discovery of gold southwest of the Gallatin Valley in the mid-1860's resulted in the establishment of the first permanent settlements in the area.

One of the first settlements occurred in the area at present day Three Forks, where agriculture became an important land use. Crops found markets in the nearby mining communities of Virginia City and Helena. Livestock operations had an important economic impact on the early history of the area as well. Settlements formed in the Gallatin Valley around 1864 at the site of present day Bozeman. The Gallatin Valley became a transportation hub with the arrival of the Northern Pacific Railroad in 1883. Livestock grazing and agriculture remain important land uses in the area.

The Gallatin area has seen rapid population growth over the past century, particularly over the last 30 years. The populations of all four counties have increased since 1980 (Figure 8). Growth has been especially rapid in Gallatin County, where the population more than doubled since 1980 (U.S. Census Bureau 2009). Population growth in all counties except Madison has outpaced that of both Montana and the nation (Headwaters Economics 2009a, 2009b, 2009c, 2009d). Similarly, density of single-family housing has increased since 1980, particularly in Gallatin County (Figure 9). A comparison of the number of water rights between 1980 and 2008 illustrates the increased demand on water resources within the Gallatin Valley, particularly around the cities of Manhattan, Belgrade, and Bozeman (Figure 10).

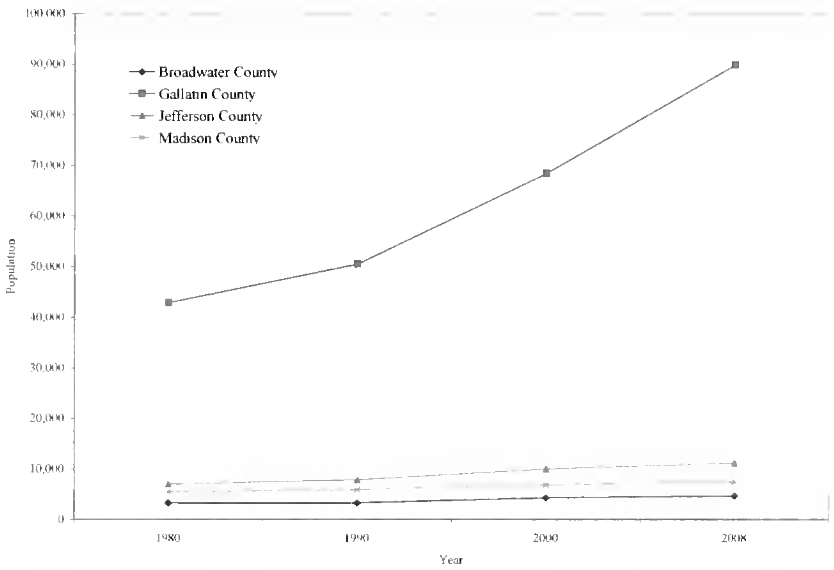

Figure 8. Population growth from 1980-2008 in Gallatin, Madison, Broadwater, and Jefferson Counties. Source: U.S. Census Bureau 2009.

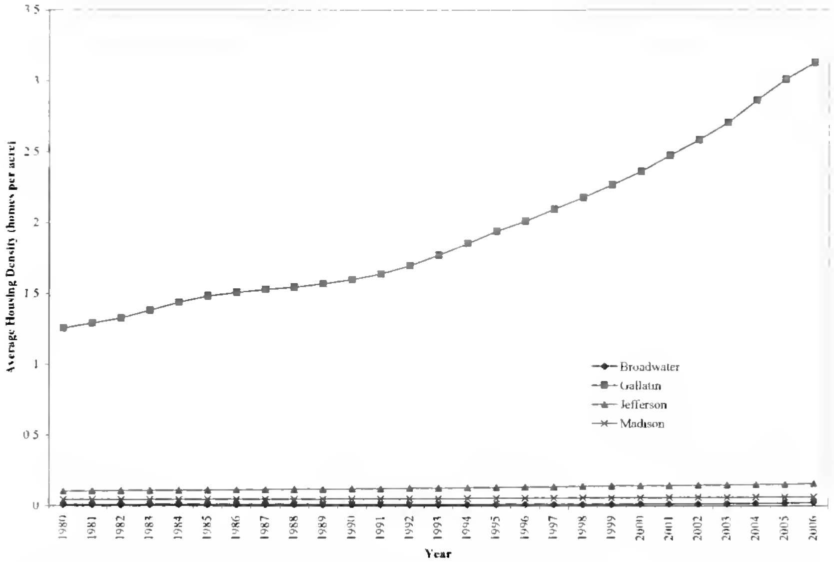

Figure 9. Growth in single-family housing density in Gallatin, Madison, Broadwater, and Jefferson Counties from 1980-2006. Source: Headwaters Economics 2009.

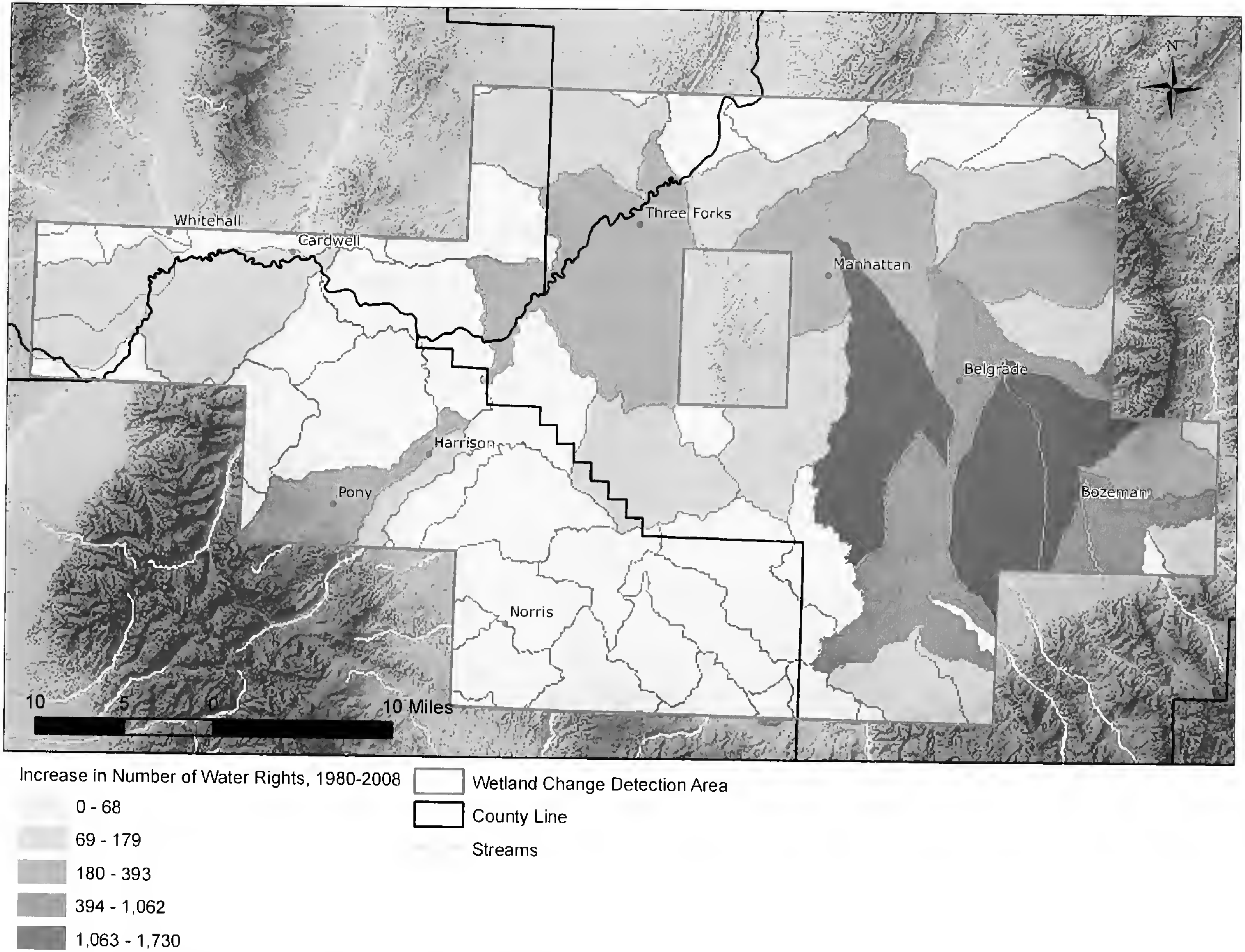

Figure 10. Increase in the number of water rights from 1980 to 2008 in the Gallatin project area.

METHODS

Wetland and Riparian Mapping

To create the new wetland and riparian mapping, we digitized wetland and riparian areas using ArcGIS 9.3 (ESRI 2008). We used 1:12,000 scale color-infrared aerial photography taken in 2005 along with several ancillary data layers (Table 2) to enhance mapping accuracy. The NWI classification system (Cowardin et al. 1979) was used to classify wetlands. Mapping procedures followed the USFWS National Standards and Quality Components (USFWS 2004a) and the Technical Procedures for Mapping Wetland, Deepwater, and Related Habitats (USFWS 2004b). Historic wetland mapping was completed for the project area by the National Wetlands Inventory using 1:58,000 scale color-infrared aerial photography in 1984 and 1988 (Figure 11).

The NWI classification system is a hierarchical approach that classifies wetlands into systems, subsystems, and classes (Appendix A). Three systems occur in Montana: Palustrine wetlands (e.g., marshes, fens, potholes, wet meadows, willow carrs, forested swamps); Lacustrine wetlands (e.g., associated with waterbodies at least 6.6 feet [2 meters] in depth and/or at least 20 acres [8 hectares] in size); and Riverine wetlands (e.g., occurring within the active channel of a stream or river). Lacustrine and Riverine systems are further classified into subsystems. Lacustrine subsystems include limnetic (> 2 meters in depth) and littoral (< 2 meters in depth) zones. Riverine subsystems that occur in Montana include Lower Perennial, Upper Perennial, and Intermittent. Classes describe the substrate for Lacustrine and Riverine systems, and the vegetation life form (e.g., emergent, scrub-shrub, forested) for Palustrine wetlands. Hydrologic modifiers are applied to each wetland to describe the water regime along a continuum from wettest (permanently flooded) to driest (temporarily flooded). Additional modifiers are added to wetlands altered by anthropogenic (e.g., excavated, impounded) and natural (e.g., beaver) influences.

Riparian habitats have not been previously mapped in Montana. We used the U.S. Fish and Wildlife Service Western Riparian Classification System (USFWS 1997: Appendix B) to classify riparian areas. Riparian areas typically lack the amount or duration of water present in wetlands, yet are more mesic and vegetation is more vigorous than adjacent uplands. Woody vegetation is the predominant type of riparian habitat mapped (e.g., riparian shrubland and riparian forest), although herbaceous riparian emergent vegetation may be mapped if the imagery allows for identification of this type. The riparian classification system is similar to the Cowardin classification system in its hierarchical approach. The riparian classification system has

Table 2. Ancillary spatial data layers used to digitize and classify wetlands and riparian areas.

Data Layer	Data Source	Year
1-meter resolution color-infrared digital orthophotography	National Agricultural Imagery Program	2005
1-meter resolution true color	National Agricultural Imagery Program	2005
1-meter black and white digital orthophoto quarter quadrangles	U.S. Geological Survey	1990
10-meter digital elevation model	U.S. Geological Survey	Various
1:24,000 topographic quadrangle digital raster graphic	U.S. Geological Survey	Various
1:24,000 high resolution National Hydrography Dataset	U.S. Geological Survey	Various
Original National Wetlands Inventory Wetland Mapping	National Wetlands Inventory, U.S. Fish and Wildlife Service	1981

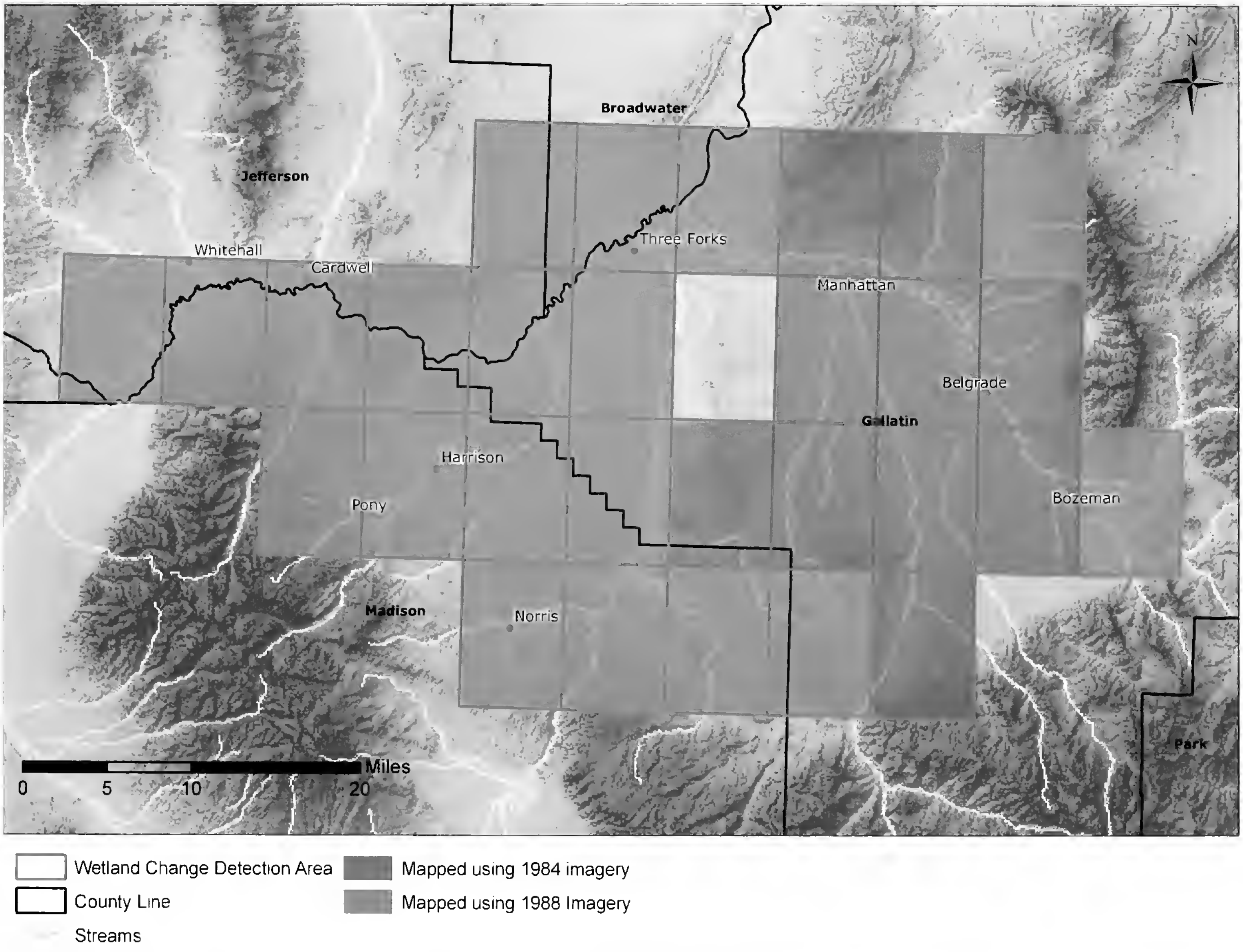

Figure 11 1984 and 1988 project areas for historic wetland mapping in the Gallatin project area.

a single system (Riparian), two subsystems (Lotic and Lentic), and three classes (Forested, Scrub-shrub, and Emergent).

Wetland Change Detection Analysis

Our sampling units were one-square mile Public Land Survey System (PLSS) sections. We randomly selected 25% of the sections in each sixth code hydrologic unit in the study area using a spatially balanced random sampling approach. We used a Generalized Random Tessellation Stratified (GRTS) sampling design to select PLSS sections (Stevens 1997, Stevens and Olsen 1999, Stevens and Olsen 2004), using the "spsurvey" package for Spatial Survey Design and Analysis (Kincaid et al. 2008) in R 2.8.1 (R Core Development Team 2008). Historic wetland mapping that occurred within these selected PLSS sections was used in the change detection analysis.

Improved image quality and resolution associated with the 2005 imagery has enhanced our ability to map wetlands more accurately by delineating wetland boundaries more precisely or detecting wetlands that may have been excluded from previous mapping efforts. We made every effort to correctly recognize and attribute the sources of wetland change by visually inspecting each wetland polygon in both the old and new wetland mapping within the sampled sections. Within the sampled area, we compared each wetland polygon in the old mapping to the corresponding wetland polygon in the new mapping, and we assigned a source of change to each polygon based on the USFWS Status and Trends Procedures (2005) with some modifications (Table 3). For example, if a wetland was mapped as palustrine emergent in the old mapping but had been excavated to create a pond, the polygon was attributed as a "New Pond." If the new wetland polygon was classified the same as the old wetland polygon, then the polygon was attributed with "No Change." We also included a "Mapped as Riparian" category because riparian areas were not previously mapped. Wetland changes attributable to interpreter differences or differences in image quality were attributed with "Interpreter Difference" and removed from the analysis. Additionally, we visually inspected all wetlands associated with beaver ponds and all created wetlands (e.g., excavated ponds).

Wetland water regimes can change annually, so we analyzed wetland change to the class level only. We estimated the difference in wetland acreage between the old and new mapping using the "spsurvey" package for Spatial Survey Design and Analysis (Kincaid et al. 2008) in R 2.8.1 (R Core Development Team 2008).

Table 3. Change categories assigned to sampled wetland polygons.

Code	Type	Description
AG	Agriculture	Land used for the production of food/fiber. Often evidenced by geometric patterns.
RD	Rural Development	Non-intensive land use and sparse building density.
UD	Urban Development	Land is predominantly covered by structures (high building density).
NC	No Change	No change in wetland attribute.
NA	Natural	Change in wetland class due to natural changes in seral stage (e.g., PEM succeeding to PSS).
RE	Resource Extraction	Oil and gas, mining, wind farm.
OT	Other	Areas in transition (filled, drained), but final land use is undetermined at date of imagery.
IN	Interpreter differences	Wetland change due to interpreter error, differences in imagery, etc.
PD	New pond	Pond created by either excavation or impoundment.
RP	Mapped as Riparian	Wetland mapped as riparian in new mapping

Wetland Functional Performance

To assess the functions associated with each wetland, we analyzed its landscape position, landform, waterbody, and water flow path. We used an HGM attribute coding approach developed by Tiner (2003, 2005) and modified by the Montana Natural Heritage Program. This approach has been demonstrated in previous wetland analyses (Vance et al. 2006, Kudray and Schemm 2008, Vance 2009) but has been further refined for this study (Appendices C and D). We assigned an HGM attribute code to all wetland polygons in both the old and new wetland mapping (Appendix E). These HGM attributes were combined with the NWI classification attributes to yield a combination that can then be ranked on a performance scale of 1 (low), 2 (moderate), and 3 (high) for each of ten wetland functions (water storage, streamflow maintenance, groundwater recharge, nutrient cycling, sediment retention, shoreline stabilization, native plant community maintenance, terrestrial habitat, aquatic habitat, and conservation of wetland biodiversity) (Appendix F). We used this performance ranking as a weighting factor and multiplied this weighting factor by wetland area to calculate functional units for each wetland function (see Tiner 2005). This method does not account for actual wetland functional performance but rather ranks potential wetland functional performance based on presumed functioning condition. Rationale for wetland functional performance rankings can be found in Vance et al. (2006) and Kudray and Schemm (2008).

Wetland Landscape Profiling

A wetland landscape profile provides a broad landscape characterization of the wetlands within a particular area at the subwatershed level. For this project, we completed analysis at the sixth code hydrologic unit level using the new mapping based on 2005 imagery. We calculated five metrics to produce the wetland profile: overall wetland acres; acres of isolated wetlands (defined as wetlands not located within a stream or on its floodplain and not connected to another wetland); acres of altered wetlands; percent of wetlands in private ownership; and percent of wetlands with high functional value for each of ten wetland ecological functions. For each function, the acres of wetland assigned a value of "3" for high function were summed and divided by the total number of acres within each subwatershed.

RESULTS

We digitized 56,822 acres (22,995 hectares) of wetlands and 28,210 acres (11,416 hectares) of riparian habitat within the change detection analysis area. Palustrine emergent wetlands covered the greatest area with over 28,380 acres (11,485 hectares) (Figure 12).

The majority of wetland and riparian habitats (57,358 acres; 23,212 hectares) occur on private lands within the analysis area. Palustrine emergent wetlands occupied the largest acreage with over 25,749 acres (10,420 hectares) (Figure 13). On public lands, over 6,126 acres (2,479 hectares) of wetlands and riparian areas were mapped, with lands owned by The Nature Conservancy having the most wetlands (Figure 14).

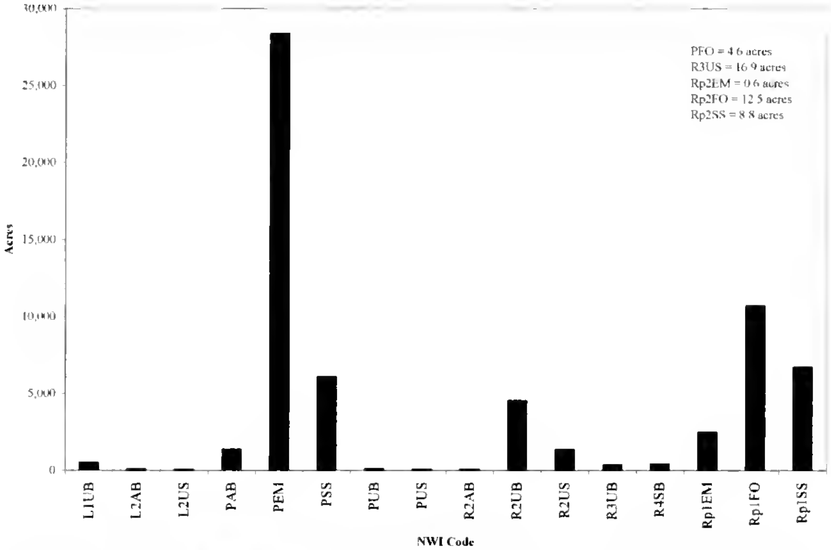

Figure 12. National Wetland Inventory (NWI) wetlands mapped using 2005 color-infrared aerial photography. NWI wetland types with acreage too low to present graphically are included in the graph inset. See Appendix A for NWI codes.

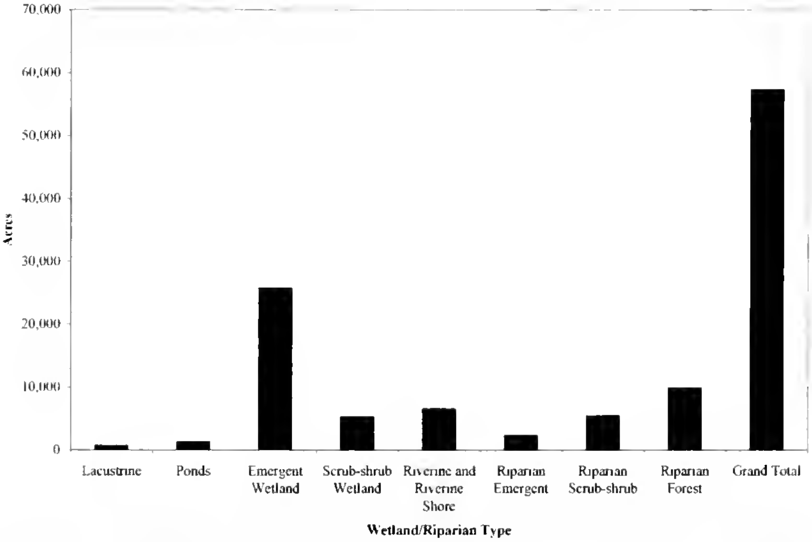

Figure 13. Acreage of wetland and riparian types mapped on private lands within the Gallatin project area.

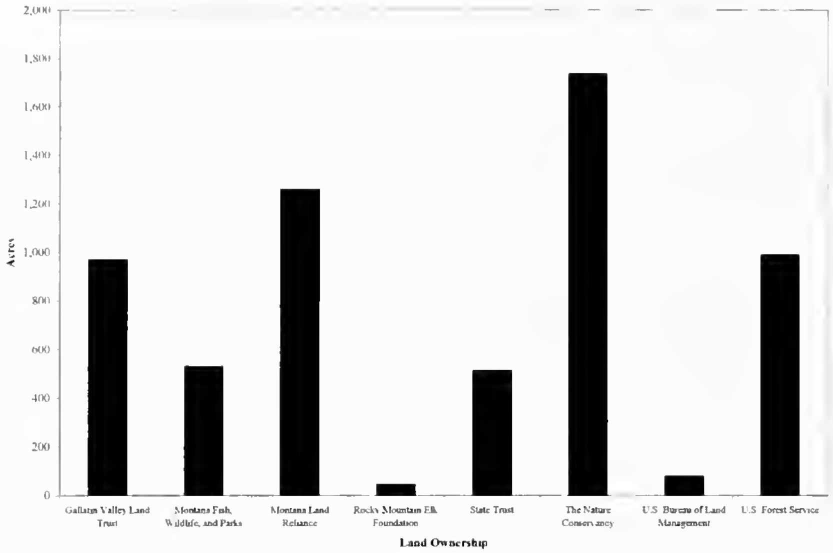

Figure 14. Acreage of all wetland and riparian types combined mapped on public lands within the Gallatin project area.

Wetland Change Detection Analysis

We observed an increase of 4,221 wetland acres (1,708 hectares) between the old and new mapping, although estimates were highly imprecise for some wetland types with very few polygons (Table 4). Palustrine emergent wetlands showed an increase, while palustrine scrub shrub wetlands showed a decline. Many of the wetlands associated with rivers mapped in the 1980's were mapped as upper perennial, whereas riverine wetlands in the new mapping were classified as lower perennial. Additionally, using the larger scale 2005 imagery often resulted in a wetland feature increasing size. Due to small sample sizes, we could not estimate wetland change separately for each sixth code hydrologic unit.

Within the wetlands sampled, 698 acres (282 hectares) mapped as wetland in the historic mapping were mapped as riparian in the new wetland mapping (Figure 15). Approximately 10 acres (4 hectares) of beaver-created wetlands have been lost since the historic mapping was completed (Figure 16). Diked/impounded palustrine wetlands largely showed a decline across the project area; however, excavated wetlands showed an increase, particularly in the form of canals and ditches.

Wetland Functional Performance

Wetlands associated with lotic features comprised the largest hydrogeomorphic type in the Gallatin project area, totaling 39,454 acres (15,967 hectares) (Table 5). Wetlands associated with deepwater and associated lentic features covered 824 acres (333 hectares), and terrene wetlands totaled 3,256 acres (1,318 hectares).

Comparison of wetland functional performance capacities throughout the Gallatin project area showed an overall 73.5% gain in hydrologic functions that include water storage, streamflow maintenance, and groundwater recharge. However, we mapped over five times more acres of lotic wetlands using the larger scale 2005 imagery, which largely contributed to this change in hydrologic function. Biogeochemical functions incorporating nutrient cycling, sediment retention, and shoreline stabilization showed an overall increase of 24%. Functions associated with terrestrial and native plant community maintenance showed a combined decline of 7.3%, whereas aquatic habitat and conservation of wetland biodiversity showed a combined increase of 9.7% (Table 6).

Wetland Landscape Profiling

The wetland landscape profiling analysis revealed that the confluence of the Madison, Jefferson, and

Table 4. Changes in wetland area within the Gallatin project area (in acres) generalized by NWI wetland type between the 1980's and 2005.

	1980's					2005					
NWI Class	**# of mapped polygons included in analysis**	**Estimated Acres**	**Standard Error**	**95% Confidence Limits**		**# of mapped polygons included in analysis**	**Estimated Acres**	**Standard Error**	**95% Confidence Limits**		**Estimated Wetland Change**
L1UB	3	294.9	79.7	138.8	451.0	5	341.7	132.2	82.5	600.9	46.8
L2AB	none mapped					3	30.5	13.3	4.4	56.6	—
L2US	4	18.0	8.0	2.3	33.7	2	1.9	0.2	1.5	2.4	-16.1
PAB/PUB	175	631.4	87.4	460.2	802.7	126	538.1	87.6	366.3	709.8	-93.4
PEM	375	9,502.9	1,820.4	5,934.9	13,070.8	280	13,829.4	2,733.9	8,471.0	19,187.7	4,326.5
PFO	20	117.5	33.5	51.8	183.3	none mapped					—
PSS	213	3,169.9	437.2	2,313.0	4,026.8	122	1,701.9	290.9	1,131.9	2,272.0	-1,468.0
PUS	4	10.7	6.2	-1.5	23.0	15	12.0	3.7	4.7	19.2	1.2
R2UB	52	2,273.1	405.4	1,478.5	3,067.6	98	5,102.4	568.1	3,989.0	6,215.8	2,829.3
R2US	96	1,129.8	199.1	739.6	1,520.0	none mapped					—
R3UB	36	1,503.1	225.6	1,060.9	1,945.4	5	78.6	26.6	26.5	130.8	-1,424.5
R3US	53	513.1	96.8	323.3	702.9	none mapped					—
R4SB	2	1.0	0.0	0.9	1.0	4	20.2	12.9	-5.1	45.6	19.3
All Wetlands	1033	19,165.5	3,399.5	12,502.6	25,828.3	660	21,656.6	3,869.5	14,072.6	29,240.7	4,221.1

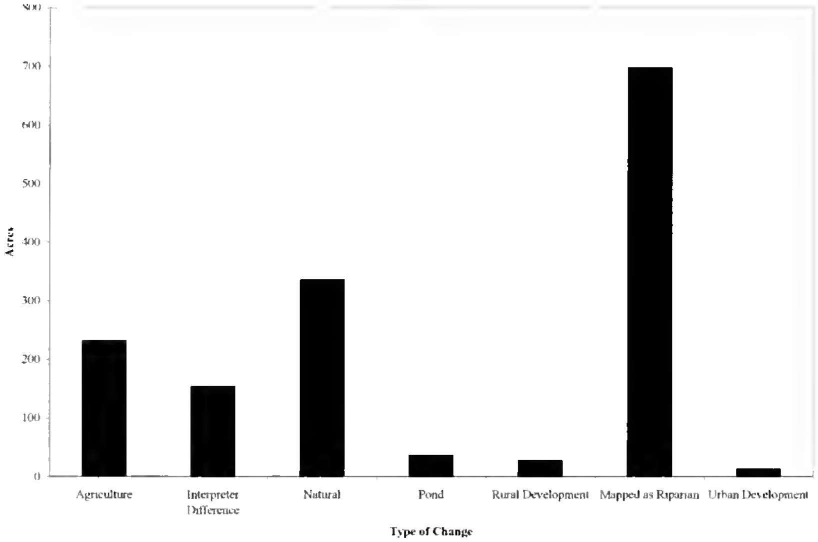

Figure 15. Types of wetland changes (in acres) between historic and new wetland mapping in the Gallatin project area.

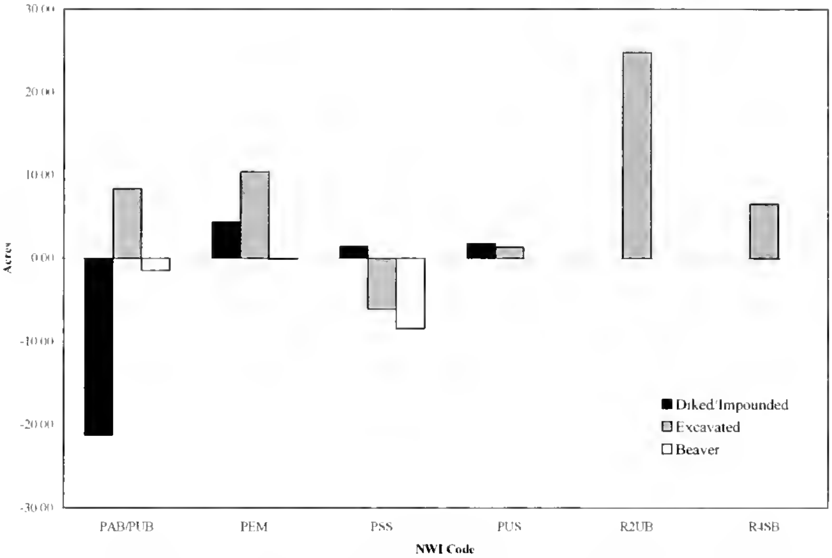

Figure 16. Changes in naturally modified (beaver) and created wetlands (in acres) between historic and new wetland mapping in the Gallatin project area.

Table 5. Hydrogeomorphic types and area (in acres) mapped within the Gallatin project area for both historic (left) and new wetland mapping (right).

Landscape Position/ Waterbody Type	**Landform**	**Water Flow Path**	**Area (Acres)**
Deepwater		Throughflow	474.4
River			3635.9
Stream			858.1
Lentic	Basin	Throughflow	37.4
	Fringe	Bidirectional	111.3
		Throughflow	2.3
	Island	Bidirectional	0.5
Lotic River	Basin	Throughflow	173.1
	Floodplain	Throughflow	3008.4
	Fringe	Throughflow	1060.9
	Island	Throughflow	473.7
Lotic Stream	Basin	Throughflow	6916.6
	Fringe	Throughflow	1614.9
	Island	Throughflow	81.8
Terrene	Basin	Isolated	472.3
		Complex	479.1
	Slope	Isolated	285.0
		Complex	101.2

Landscape Position/ Waterbody Type	**Landform**	**Water Flow Path**	**Area (Acres)**
Deepwater		Throughflow	529.1
River			4,451.5
Stream			935.7
Lentic	Basin	Throughflow	116.8
	Fringe	Bidirectional	169.9
		Throughflow	7.7
Lotic River	Basin	Throughflow	483.8
	Floodplain	Throughflow	15,516.9
	Fringe	Throughflow	1,558.6
Lotic Stream	Basin	Throughflow	16,120.5
	Fringe	Throughflow	387.5
Terrene	Basin	Isolated	613.0
		Complex	991.8
	Slope	Isolated	814.3
		Complex	836.5

Table 6. Predicted change in wetland functional capacity between historic and new wetland mapping for the Gallatin project area.

Function	1980's Functional Units	2005 Functional Units	Predicted Percent Change in Functional Capacity
Hydrology			
Water Storage	11,606.7	12,998.9	12.0
Streamflow Maintenance	11,894.7	14,577.3	22.6
Groundwater Recharge	14,144.1	19,652.1	38.9
Biogeochemical			
Nutrient Cycling	12,079.7	12,576.0	4.1
Sediment Retention	13,339.5	15,204.2	14.0
Shoreline Stabilization	7,546.9	7,995.4	5.9
Habitat			
Native Plant Community Maintenance	8,693.3	8,269.7	-4.9
Terrestrial Habitat	9,311.3	9,083.6	-2.4
Aquatic Habitat	11,837.3	12,717.3	7.4
Conservation of Wetland Biodiversity	7,621.6	7,796.0	2.3

Gallatin Rivers near Three Forks has the highest density of wetland acres followed by the area along the Gallatin River (Figure 17). The area southeast of Harrison has the largest acreage of altered wetlands, represented largely by Willow Creek Reservoir (Figure 18). Lands to the south of Belgrade and west of Bozeman have the highest acreage of isolated wetlands along with the west slope of the Bridger Mountains (Figure 19). The wetland landscape profile also indicated that the majority of wetlands mapped within the project area are located on private lands, particularly in the western portion of the project area and the areas immediately around Bozeman (Figure 20).

Wetlands with the potential for high wetland hydrologic functions, including water storage, streamflow maintenance, and groundwater recharge showed variable results across the project area. A relatively low percentage of wetlands had the potential for high functional performance of streamflow maintenance, with the majority of those wetlands occurring along the Gallatin and Jefferson Rivers (Figure 21). In contrast, the majority of hydrologic units in the project area had a moderate to high percentage of wetlands with the potential for high functional performance of groundwater recharge (Figure 22). The west slope of the Bridger Mountains had the highest percentage of wetlands with the potential for high water storage performance (Figure 23).

Two of the functions related to biogeochemical processes, shore stabilization and nutrient cycling, had a relatively low percentage of wetlands across the project area with the potential for high functional performance (Figure 24 and Figure 25). Conversely, many of the hydrologic units, particularly those along the East Gallatin and Jefferson Rivers had a moderate to high percentage of wetlands with the potential for high sediment retention performance (Figure 26).

Functions related to wildlife and plant habitat, including conservation of wetland biodiversity, plant community maintenance, terrestrial habitat, and aquatic habitat, displayed interesting patterns across the project area. The river valleys had the lowest percentage of wetlands with the potential for high conservation of wetland biodiversity, lacking ecologically significant wetland types such as fens and forested wetlands (Figure 27). In contrast, these areas had a relatively high percentage of wetlands with the potential for high plant community

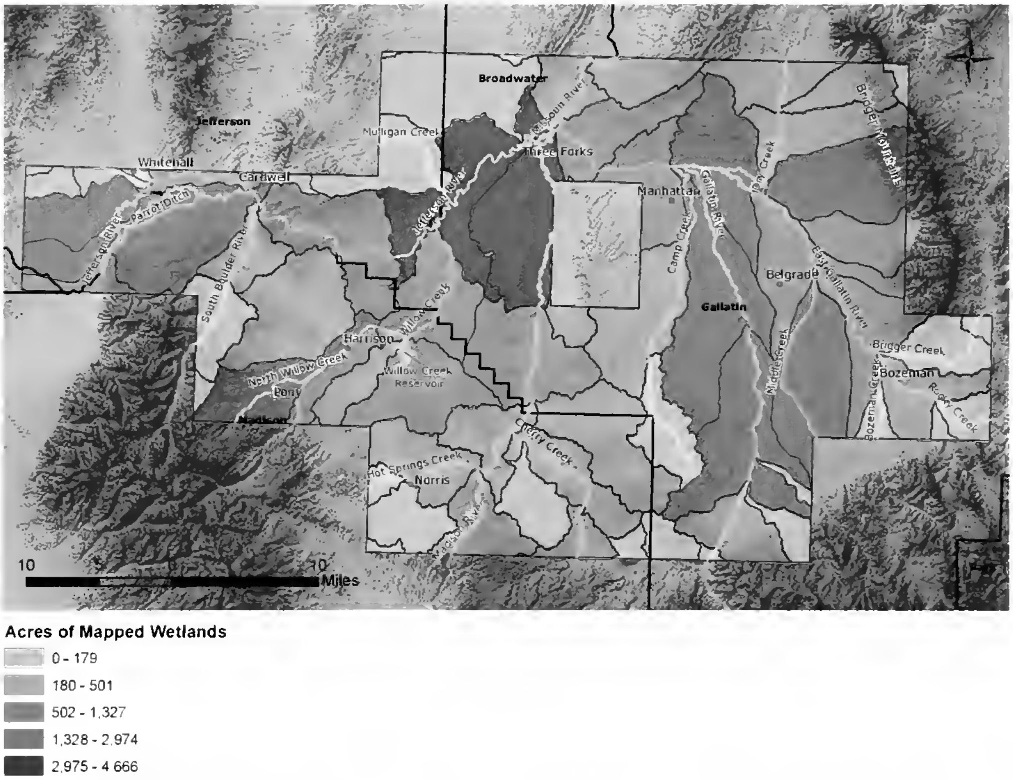

Figure 17. Wetland landscape profile for each sixth code hydrologic unit across the Gallatin project area: wetland acreage.

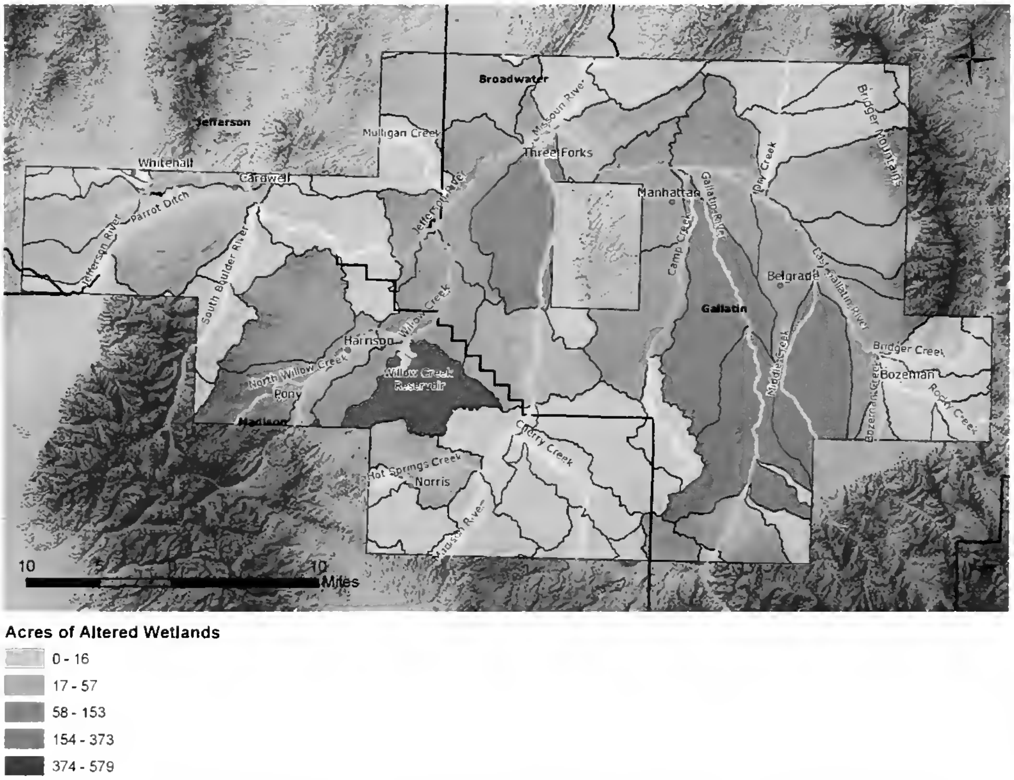

Figure 18. Wetland landscape profile for each sixth code hydrologic unit across the Gallatin project area: acreage of altered wetlands.

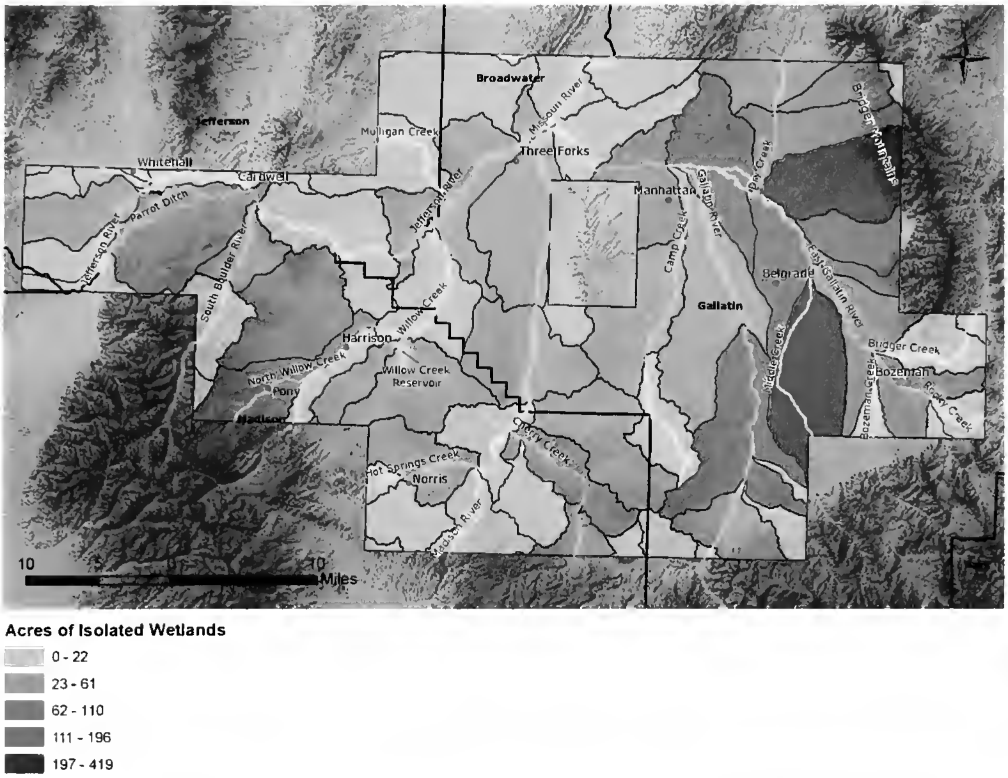

Figure 19. Wetland landscape profile for each sixth code hydrologic unit across the Gallatin project area: acreage of isolated wetlands.

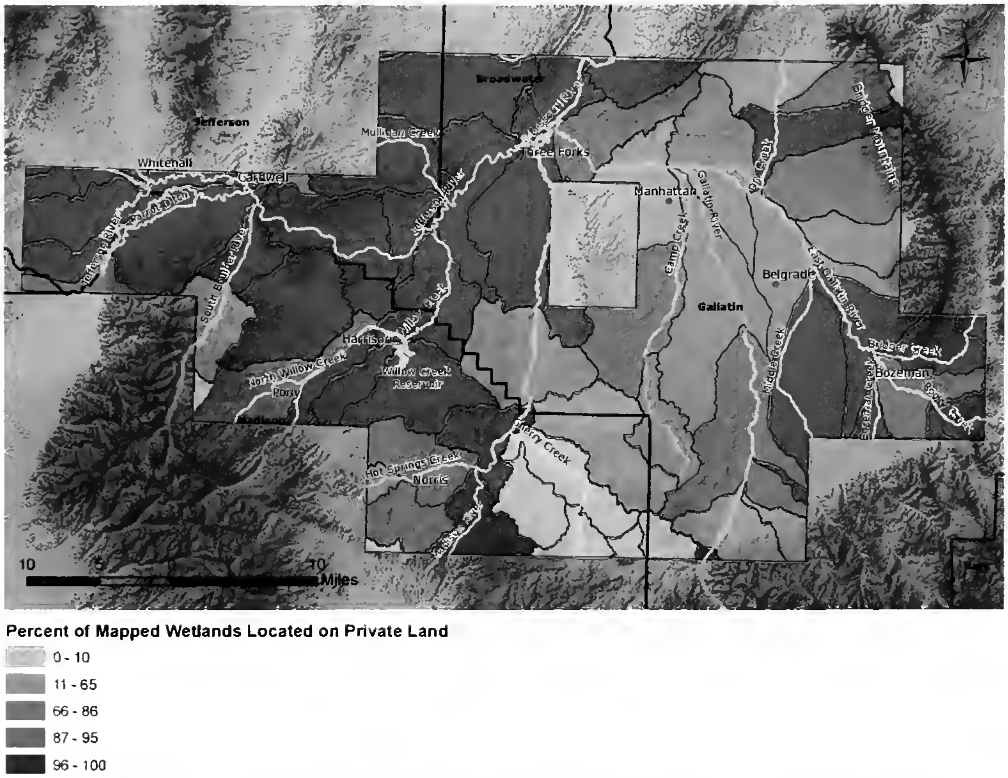

Figure 20. Wetland landscape profile for each sixth code hydrologic unit across the Gallatin project area: acreage of wetlands on privately owned lands.

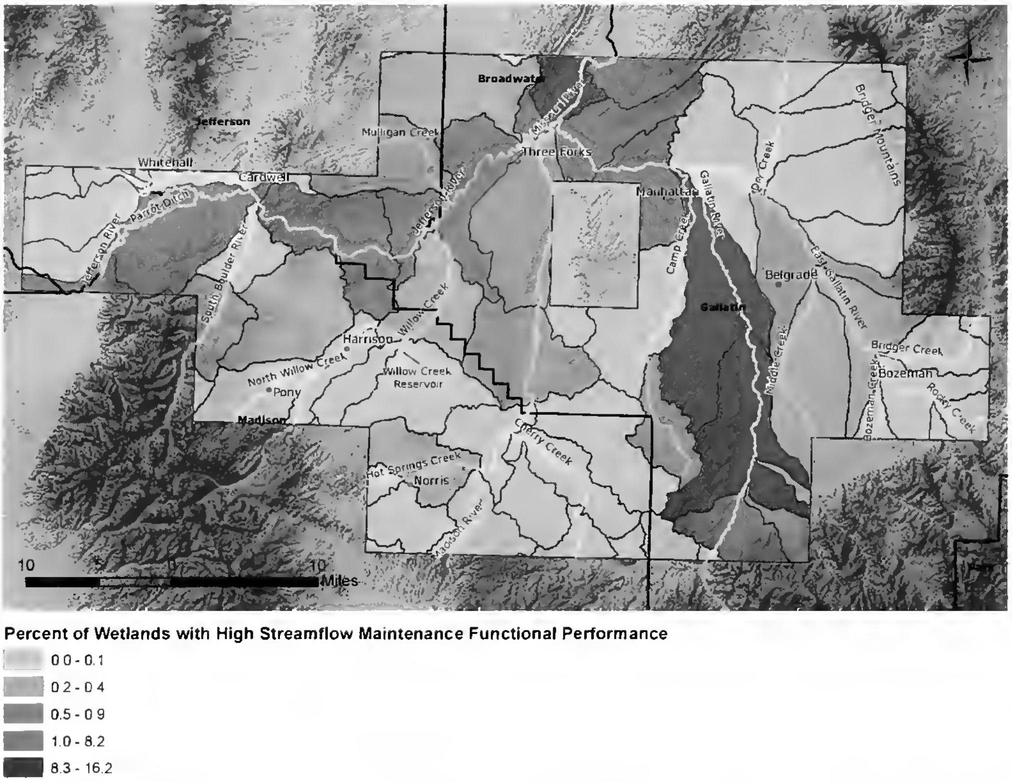

Figure 21. Wetland landscape profile of wetlands performing hydrologic functions for each sixth code hydrologic unit across the Gallatin project area: streamflow maintenance.

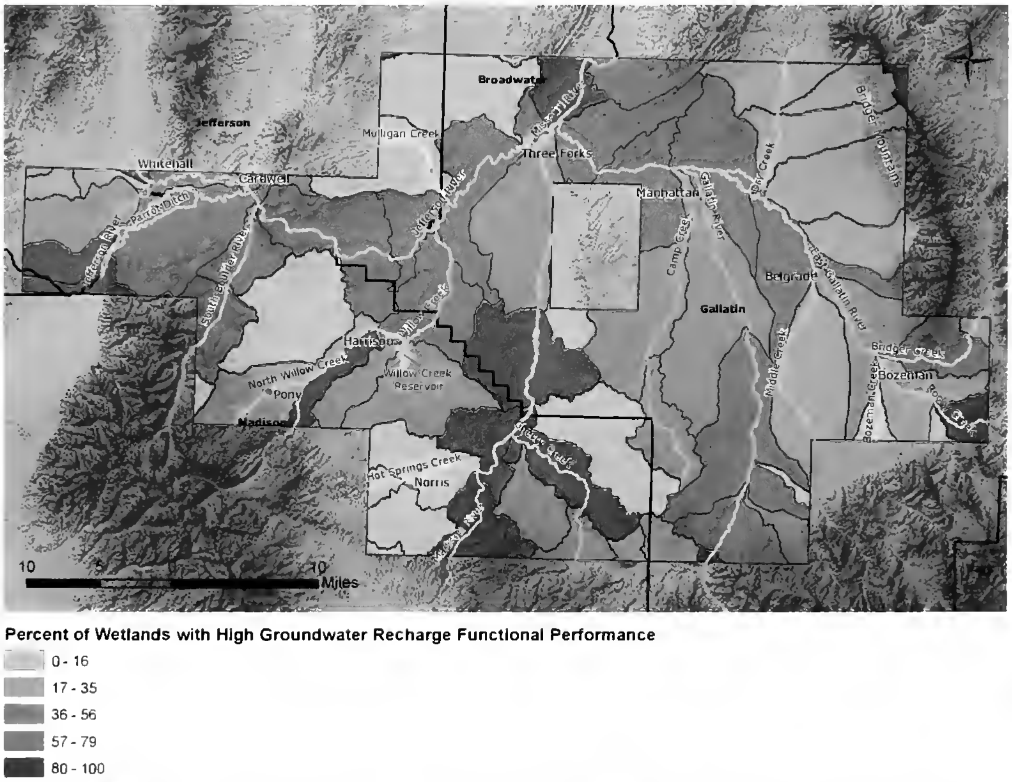

Figure 22. Wetland landscape profile of wetlands performing hydrologic functions for each sixth code hydrologic unit across the Gallatin project area: groundwater recharge.

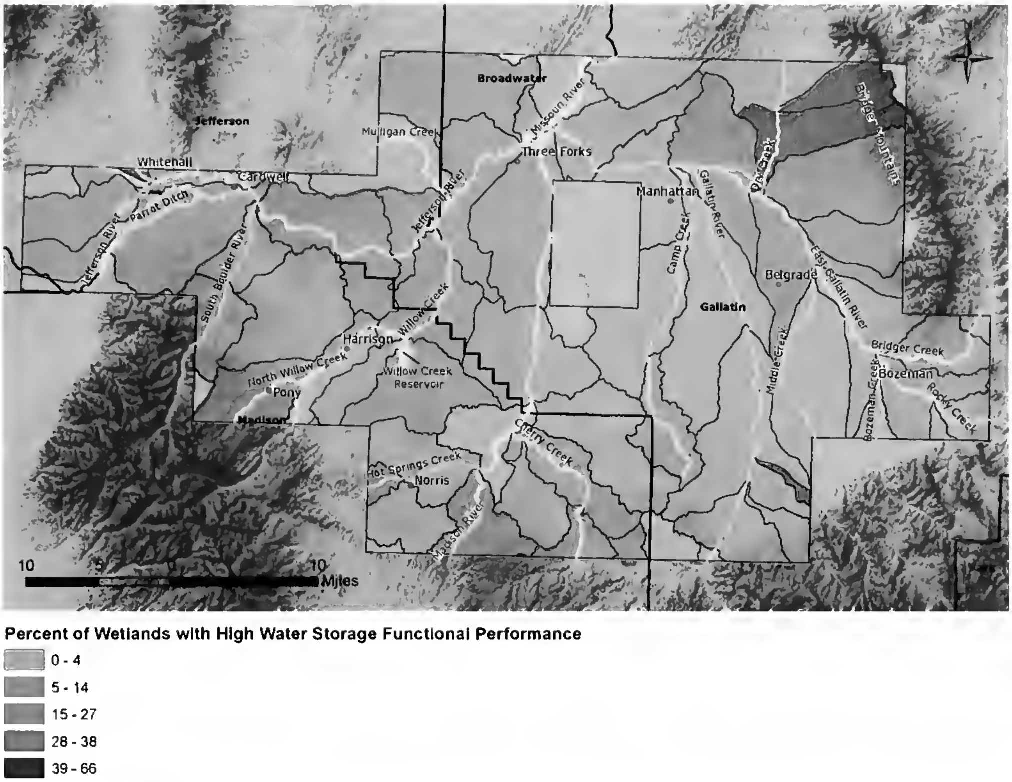

Figure 23. Wetland landscape profile of wetlands performing hydrologic functions for each sixth code hydrologic unit across the Gallatin project area: water storage.

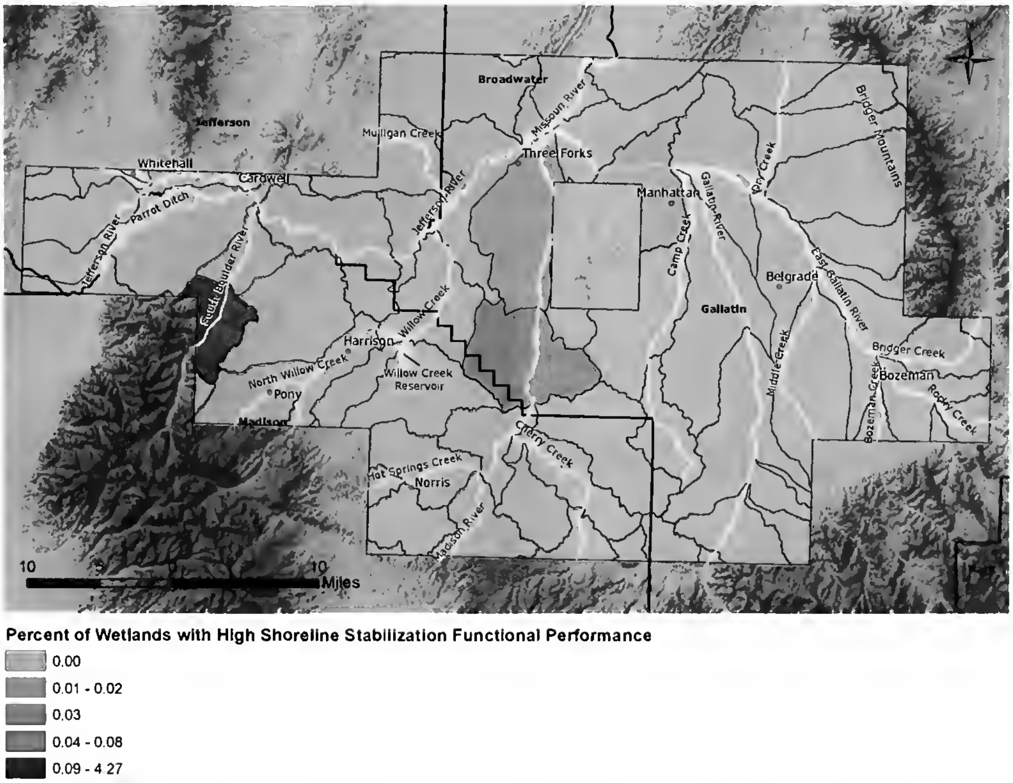

Figure 24. Wetland landscape profile of wetlands performing biogeochemical functions for each sixth code hydrologic unit across the Gallatin project area: shore stabilization.

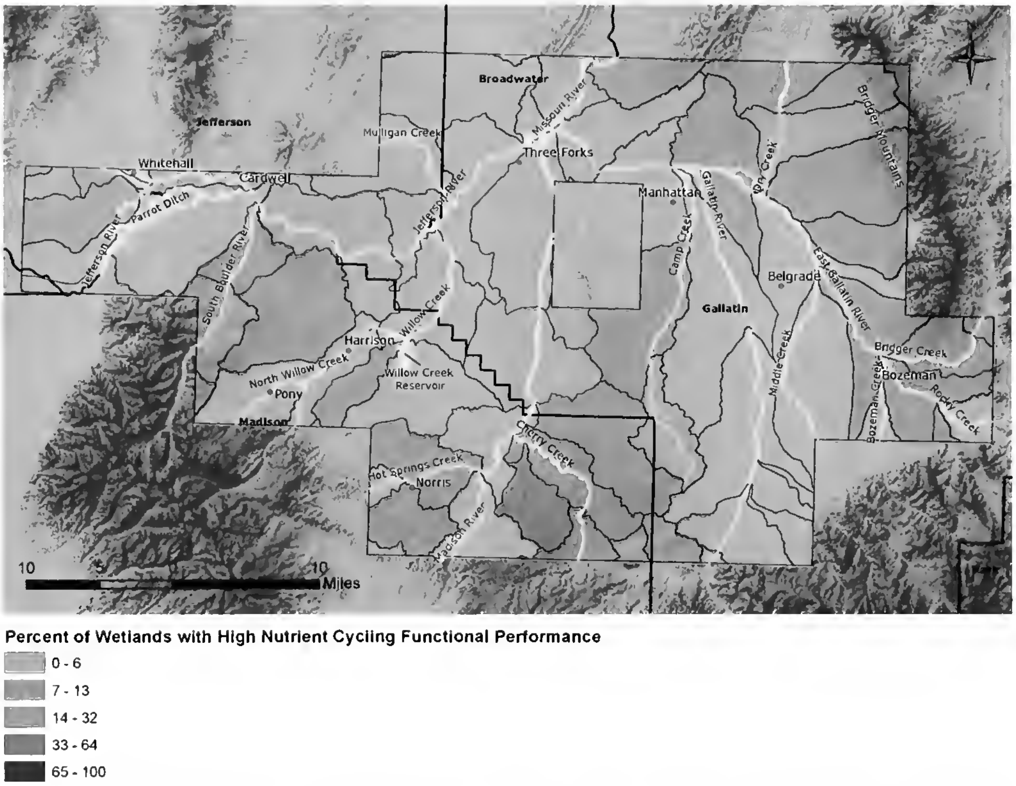

Figure 25. Wetland landscape profile of wetlands performing biogeochemical functions for each sixth code hydrologic unit across the Gallatin project area: nutrient cycling.

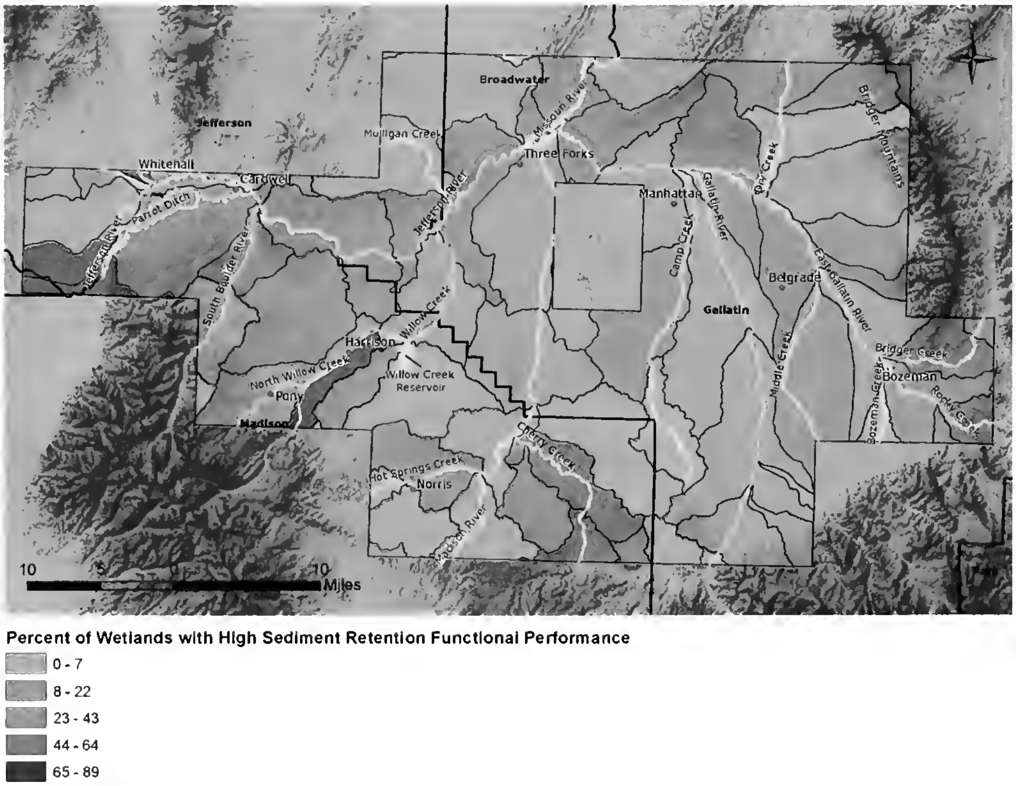

Figure 26. Wetland landscape profile of wetlands performing biogeochemical functions for each sixth code hydrologic unit across the Gallatin project area: sediment retention.

maintenance, particularly along the Jefferson River (Figure 28). Wetlands in these areas are generally wetter and thus less susceptible to invasion by non-native species common in drier wetland types. Wetlands with the potential for high terrestrial habitat function were concentrated along the East Gallatin River (Figure 29), whereas most wetlands with the potential for high aquatic habitat function were concentrated in areas along the Madison and portions of the Jefferson Rivers (Figure 30).

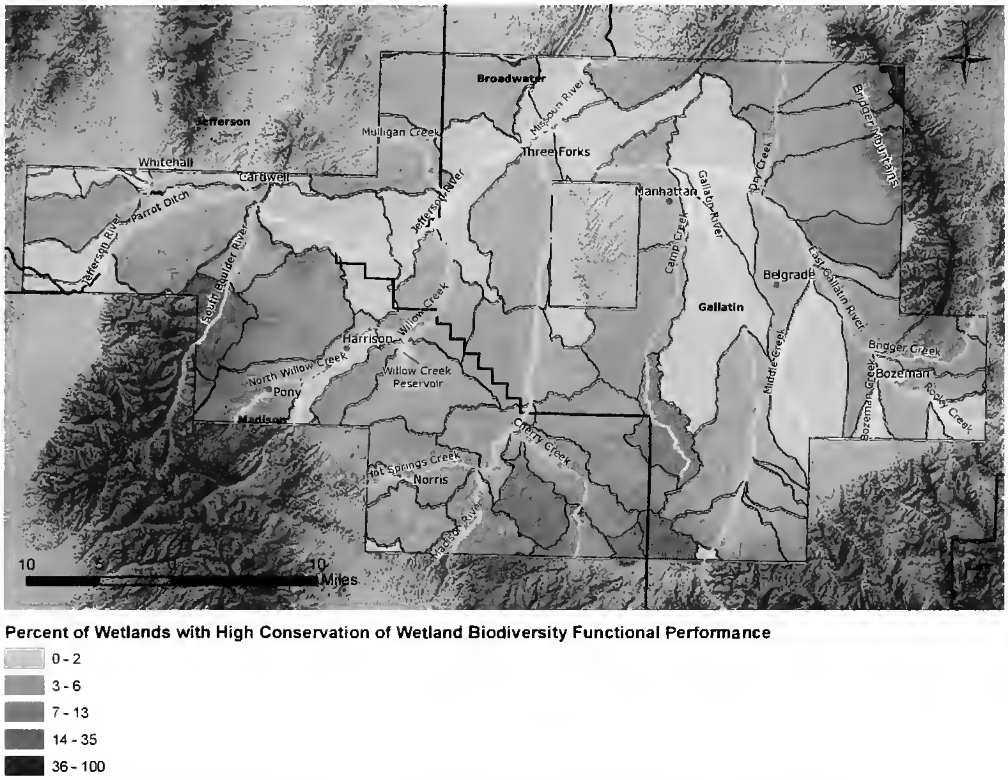

Figure 27. Wetland landscape profile of wetlands performing wildlife and plant habitat functions for each sixth code hydrologic unit across the Gallatin project area: conservation of biodiversity.

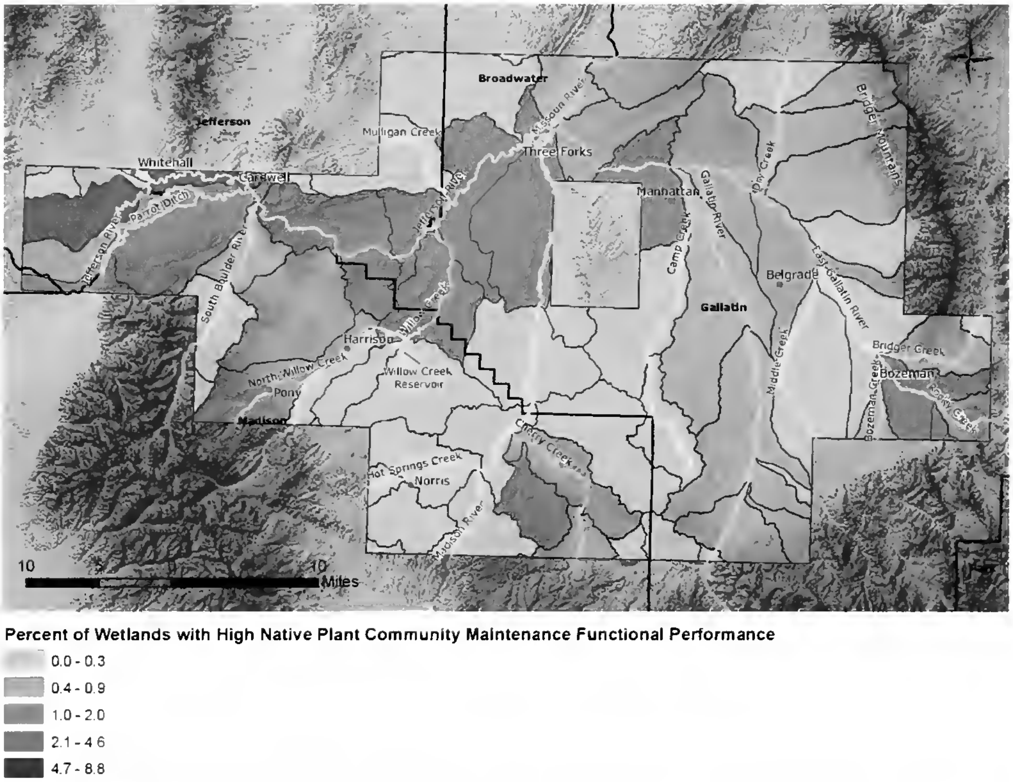

Figure 28. Wetland landscape profile of wetlands performing wildlife and plant habitat functions for each sixth code hydrologic unit across the Gallatin project area: plant community maintenance.

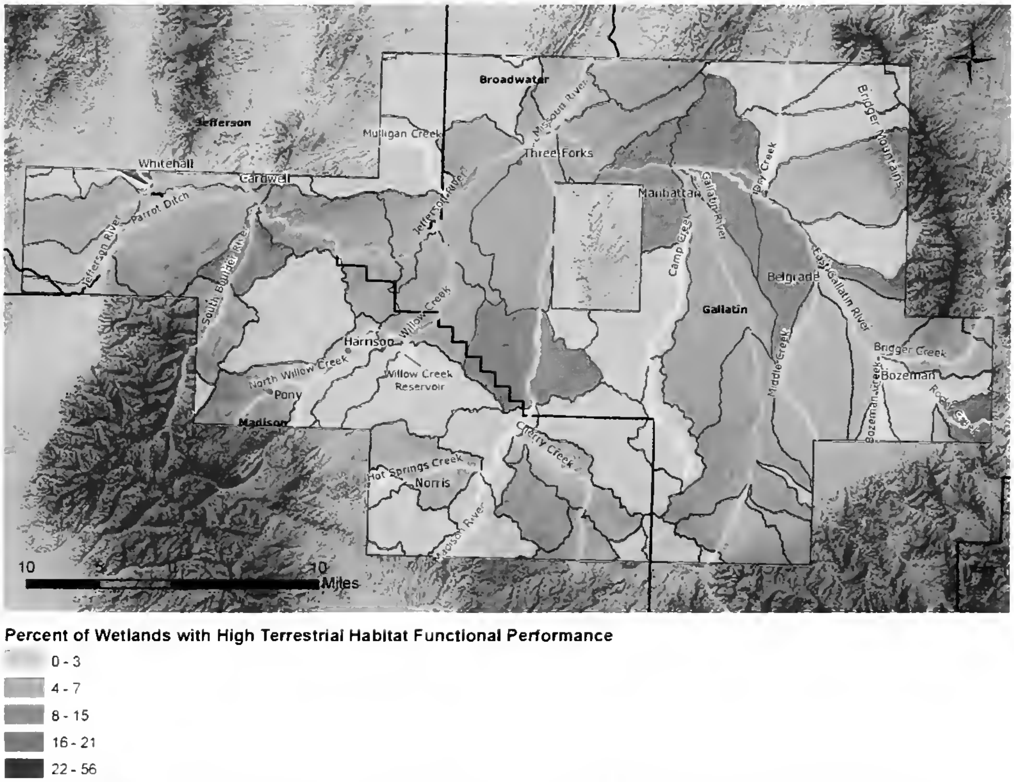

Figure 29. Wetland landscape profile of wetlands performing wildlife and plant habitat functions for each sixth code hydrologic unit across the Gallatin project area: terrestrial habitat.

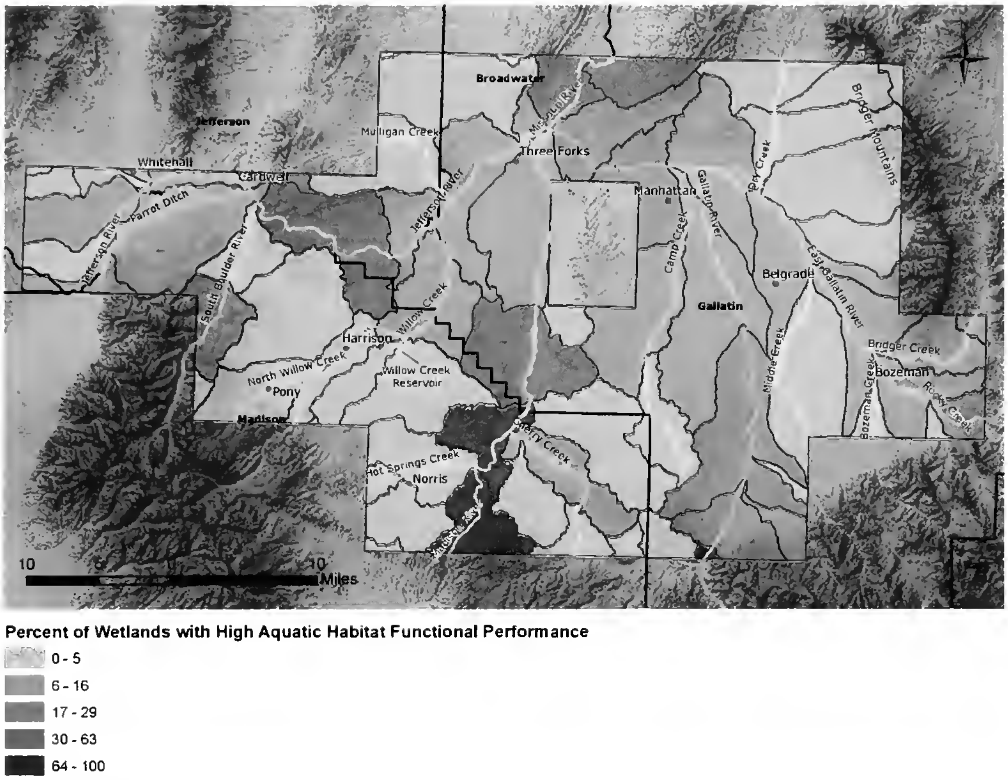

Figure 30. Wetland landscape profile of wetlands performing wildlife and plant habitat functions for each sixth code hydrologic unit across the Gallatin project area: aquatic habitat.

DISCUSSION

Our analysis shows an overall increase in wetland area based on mapping. We also found a change in wetland types Many wetlands mapped as palustrine scrub shrub in the 1980's mapping are now palustrine emergent wetlands. Examination of the aerial imagery revealed that much of the change is attributable to agricultural modifications (e.g., livestock grazing, stream dewatering, and conversion to hay pasture), although some change may be attributable to the mapping itself (e.g. areas mapped as wetlands in the 1980's being mapped as riparian now).

Despite overall wetland increases across the entire project area, concentrated wetland losses occurred in a few areas. In particular, much of the wetland change in the areas immediately around Bozeman was attributable to urban and rural development. This area has seen rapid growth and much of the valley bottom along the East Gallatin River has been subdivided. The wetland landscape profiling also revealed that the areas around Bozeman contain wetlands with the potential for high functional performance of several wetland functions, including groundwater recharge, streamflow maintenance, water storage, sediment retention, and terrestrial habitat. Continued impacts to wetlands in these important areas will reduce the ability of wetlands to perform these functions, potentially resulting in ecological and economic losses in these areas.

It is also important to note that differences between the scales of the imagery used in the historic and new mapping products make accurate quantification of wetland change problematic. We mapped over five times more lotic wetland acres using the 2005 imagery. The historic wetland mapping was digitized at a 1:58,000 scale and exhibits considerably more spatial error than the current mapping digitized at a 1:12,000 scale. The increased precision made possible by larger scale imagery can result in an increase in wetland acres mapped. To accurately compare historic and new wetland mapping products, one would need to map wetlands at a scale of 1:58,000 to correspond to the scale at which the historic mapping was completed, but current mapping standards and statewide mapping goals require a 1:12,000 scale. Furthermore, limitations exist with any wetland mapping effort derived almost exclusively from photointerpretation techniques (Tiner 2005). Factors such as photo quality, scale, and environmental conditions at the time of photo acquisition can affect mapping accuracy. Digital wetland maps are static and may not reflect the dynamic nature of wetlands subject to drastic annual and seasonal fluctuations in size and distribution. Comparisons between historic and updated wetland mapping are also limited by differences in imagery and mapping scale. Technological advances associated with mapping techniques have greatly increased our capacity to capture more detailed information. Additionally, temporarily and seasonally flooded wetlands that typically dry out by the end of the growing season may be difficult to reliably separate from upland areas. We also note that the wetland mapping used in this report was completed based on 2005 imagery, so there is a nearly five year time lapse, and very recent changes are not captured.

Limitations also exist with wetland functional assessments based solely on photointerpretation and best professional judgment. We emphasize that the functional capacity ratings assigned to wetlands in this project are only potential capacities. Data on actual functional capacity would require extensive field checking. The estimated changes in functional capacities may also be, in part, a by-product of changes in mapping conventions, specifically the addition of the riparian classification system. Palustrine forested and palustrine scrub-shrub wetlands associated with lotic features, which are most effective at performing hydrologic and habitat functions, may have been overmapped in the 1980's NWI wetland mapping. Our wetland change analysis revealed that some wetlands originally mapped as palustrine forested and palustrine scrub-shrub wetlands were mapped as riparian forest and riparian scrub-shrub in the new mapping, so this reduction in mapped wetland acres influences our estimated changes in functional capacity. Because riparian areas were not mapped in the original mapping effort, many forested and scrub-shrub areas along streams and rivers were mapped as wetland rather than being excluded completely. Additionally, it is often difficult to distinguish between palustrine and riparian types based on aerial imagery alone, and the original wetland mapping had only cursory ground-truthing. In addition to differences in photointerpretation, the dynamic nature of lotic systems naturally influences the type, location, and extent of floodplain wetlands; and changes can be expected over multiple decades. However, anthropogenic factors such as dams, riprap, and increased water demands have almost certainly impacted the hydrology of these floodplain wetlands.

Additionally, this assessment does not consider the condition of the adjacent uplands or the wetland itself; two factors critical to assessing the integrity of the wetland. Wetland function depends largely on wetland type (Brinson 1993), but we could not evaluate the effect that changes in wetland type between the mid to late 1980's and 2005 have had on changes in wetland function. Thus, extensive ecological integrity assessments are required to fully capture the condition and functional capacity of wetlands in the study area.

This analysis should be considered a preliminary assessment of changes in the Gallatin Valley wetlands and wetland functional capacity. Although this analysis provides general information on the ability of wetlands in the area to perform certain functions, it does not assess differences in functional capacity among wetlands of similar type and function. Despite these limitations, data from this analysis can provide very effective conservation tools. For example, detailed wetland and riparian maps can be used to identify areas with the potential to perform wetland functions most effectively, allowing natural resource managers and other stakeholders to focus or prioritize their conservation and restoration efforts. The wetland landscape profiling provides an understanding of the role of wetlands across the project area, particularly in increasingly developed landscapes. Finally, accurate digital wetland data at a watershed scale can also provide the foundation for initiation and tracking of watershed restoration and monitoring efforts, as well as a tool to inform watershed councils, local planners, land managers, and other stakeholders about the types and location of wetlands within the Gallatin Valley and the functions they perform.

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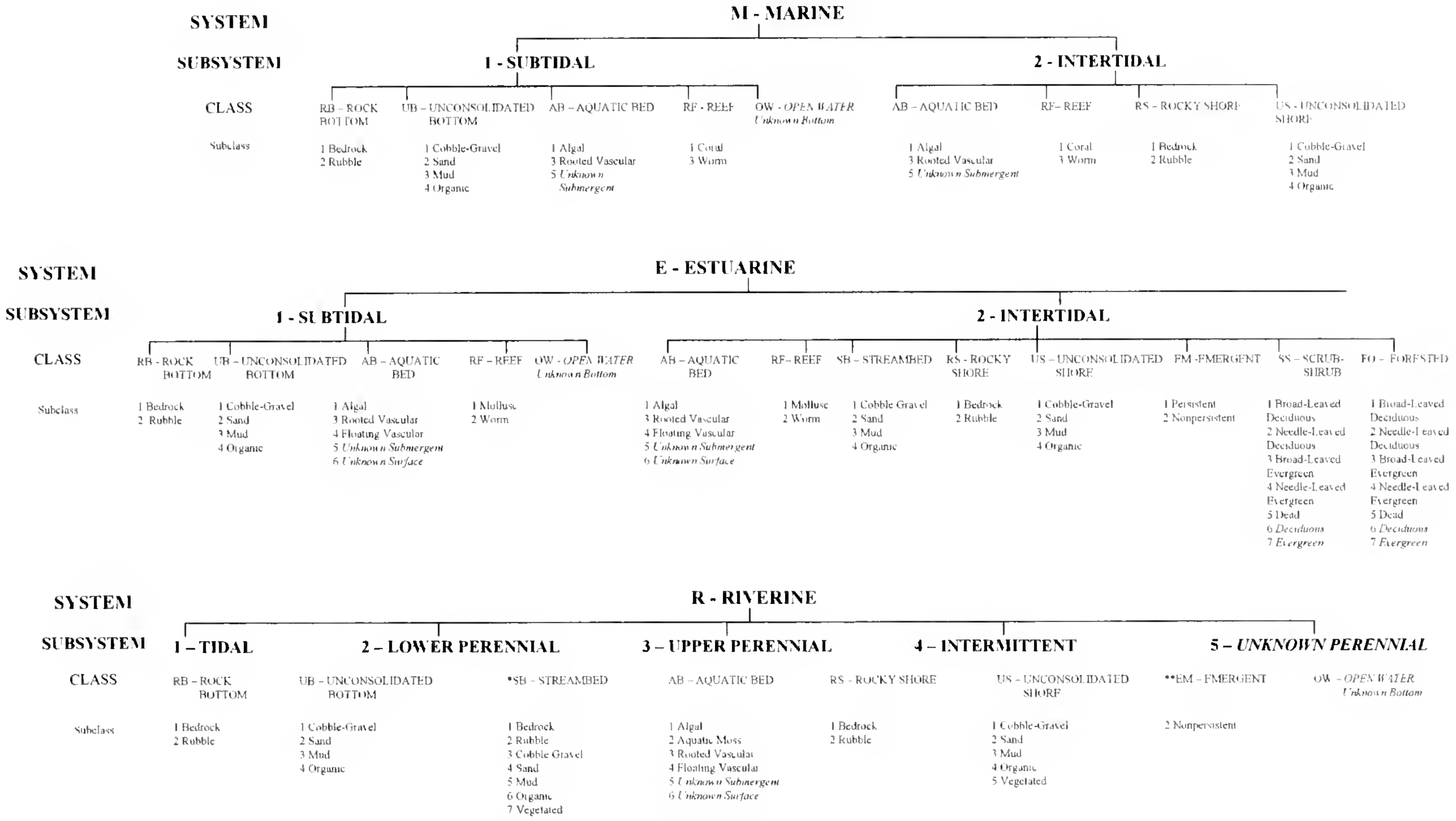
APPENDIX A. CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS OF THE UNITED STATES (COWARDIN ET AL. 1979)

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION



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

Subclass

SYSTEM P - PALUSTRINE

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

Subclass

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 Euhaline
- 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

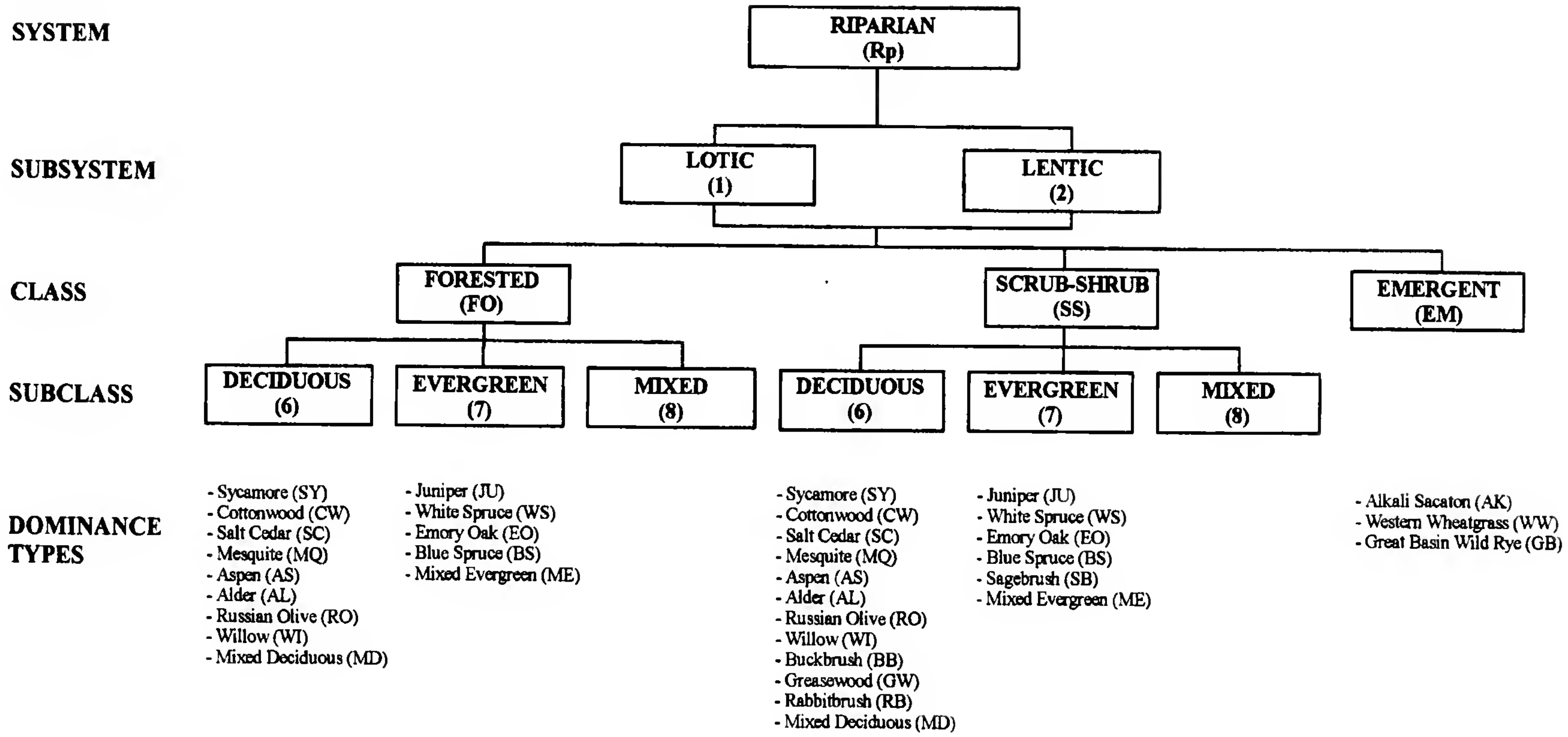
- g Organic
- n Mineral

SPECIAL MODIFIERS

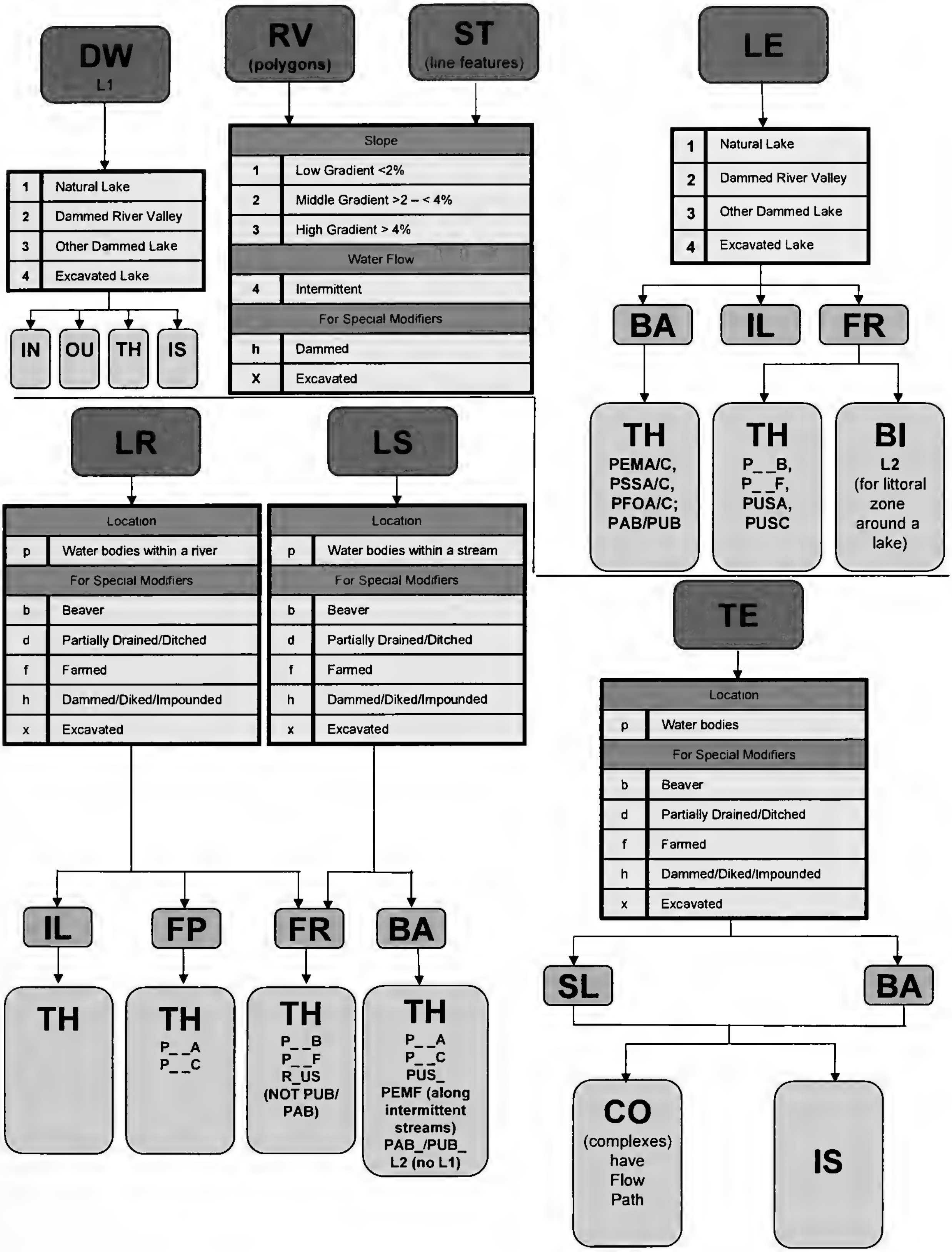
- b *Beaver*
- d *Partially Drained/Ditched*
- f Farmed
- h *Diked/Impounded*
- r Artificial Substrate
- s *Spoil*
- x Excavated

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

APPENDIX B. CLASSIFICATION OF RIPARIAN SYSTEMS (USFWS 1997)


SYSTEM
SUBSYSTEM
CLASS
SUBCLASS
DOMINANCE TYPES
RIPARIAN (Rp)
LOTIC (1)
LENTIC (2)
FORESTED (FO)
SCRUB-SHRUB (SS)
EMERGENT (EM)
DECIDUOUS (6)
EVERGREEN (7)
MIXED (8)
DECIDUOUS (6)
EVERGREEN (7)
MIXED (8)
- Sycamore (SY)
- Cottonwood (CW)
- Salt Cedar (SC)
- Mesquite (MQ)
- Aspen (AS)
- Alder (AL)
- Russian Olive (RO)
- Willow (WI)
- Mixed Deciduous (MD)
- Juniper (JU)
- White Spruce (WS)
- Emory Oak (EO)
- Blue Spruce (BS)
- Mixed Evergreen (ME)
- Sycamore (SY)
- Cottonwood (CW)
- Salt Cedar (SC)
- Mesquite (MQ)
- Aspen (AS)
- Alder (AL)
- Russian Olive (RO)
- Willow (WI)
- Buckbrush (BB)
- Greasewood (GW)
- Rabbitbrush (RB)
- Mixed Deciduous (MD)
- Juniper (JU)
- White Spruce (WS)
- Emory Oak (EO)
- Blue Spruce (BS)
- Sagebrush (SB)
- Mixed Evergreen (ME)
- Alkali Sacaton (AK)
- Western Wheatgrass (WW)
- Great Basin Wild Rye (GB)

APPENDIX C. FLOWCHART FOR HYDROGEOMORPHIC (HGM) CODING OF WETLAND POLYGONS



1	Natural Lake
2	Dammed River Valley
3	Other Dammed Lake
4	Excavated Lake

Slope	
1	Low Gradient <2%
2	Middle Gradient >2 – < 4%
3	High Gradient > 4%
Water Flow	
4	Intermittent
For Special Modifiers	
h	Dammed
X	Excavated

1	Natural Lake
2	Dammed River Valley
3	Other Dammed Lake
4	Excavated Lake

Location	
p	Water bodies within a river
For Special Modifiers	
b	Beaver
d	Partially Drained/Ditched
f	Farmed
h	Dammed/Diked/Impounded
x	Excavated

Location	
p	Water bodies within a stream
For Special Modifiers	
b	Beaver
d	Partially Drained/Ditched
f	Farmed
h	Dammed/Diked/Impounded
x	Excavated

Location	
p	Water bodies
For Special Modifiers	
b	Beaver
d	Partially Drained/Ditched
f	Farmed
h	Dammed/Diked/Impounded
x	Excavated

APPENDIX D. KEY TO HYDROGEOMORPHIC (HGM) MODIFIERS, ADAPTED FROM TINER (2003)

Key A-1: Key to Wetland Landscape Position

1. Wetland is completely surrounded by upland (non-hydric soils) .... **Terrene**
Go to couplet 'd' below
1. Wetland is not surrounded by upland but is connect to a waterbody or other wetland **2**

2. Wetland is located in or along a lake or reservoir (permanent waterbody where standing water is typically deeper than 6.6 feet or larger than 20 acres), including streamside wetlands in a lake basin ....**Lentic**
Go to couplet 'a' below

   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 lake basin. Streamside lentic wetlands are designated **Throughflow**, thereby emphasizing the stream flow through these wetlands.

2. Wetland does not occur along a lake or reservoir **3**

3. Wetland is located in a river or stream (including in-stream ponds), within its banks, or on its floodplain ***and*** is periodically flooded by the river or stream.....................................**4**
3. Wetland is not located in a river or stream or on its floodplain OR wetlands along streams are NOT subject to frequent overflows... **Terrene**

4. Wetland is the source of a river or stream, but there is ***no channelized flow*** through the wetland .... **Terrene**
4. Wetland is located in a river or stream, within its banks, or on its floodplain...........................**5**

5. Wetland is associated with a river (mapped as a 2-lined watercourse on 1:24,000 U.S.G.S. topographic map) or its floodplain.. **Lotic River**
Go to Modifiers 'b', 'c', and 'd' below
5. Wetland is associated with a stream (single-line watercourse on 1:24,000 U.S.G.S. topographic map) or its floodplain .... **Lotic Stream**
Go to Modifiers 'b', 'c', and 'd' below

   a. Wetland is associated with a natural water body ....**Natural Lake**
   a. Wetland is associated with a waterbody created by a dammed river valley .... **Dammed River Valley**
   a. Wetland is associated with a waterbody created by another obstruction.. **Other Dammed Lake**
   a. Wetland is associated with a waterbody that has been excavated............. **Excavated Lake**

Slope Modifiers

- **b.** Water flow is generally slow with extensive floodplain development (Cowardin's Lower Perennial Subsystem) .... **Low Gradient**
- **b.** Water flow is moderate to fast with little to some floodplain development (Cowardin's Upper Perennial Subsystem) .... **Middle Gradient**
- **b.** Water flow is rapid due to steep gradient with little or no floodplain development (Cowardin's Upper Perennial Subsystem) .... **High Gradient**

Water Flow Modifier

- **c.** Water flow is intermittent or ephemeral (as indicated on the high resolution National Hydrography Dataset) .... **Intermittent**

Other Special Modifiers

- **d.** Wetland is modified by a beaver dam .... **Beaver**
- **d.** Wetland is modified by a ditch or has been partially drained .... **Partially Drained/Ditch**
- **d.** Wetland has been farmed .... **Farmed**
- **d.** Water flow or wetland modified by dam, dike, or impoundment .... **Dammed/Diked/Impounded**
- **d.** Wetland or waterbody has been modified by excavation........ **Excavated**
- **d.** Wetland forms a waterbody less than 6.6 feet deep or smaller than 20 acres. This includes in-stream ponds .... **Pond**

Key B-1: Key to Landforms

1. Wetland hydrology is largely influenced by groundwater discharge to the surface (can occur on nearly flat landscapes) ***or*** wetland occurs on a slope of at least 4% .... **Slope**
1. Wetland hydrology is influenced by a number of sources **2**

2. Wetland occurs on an island........ **Island**
2. Wetland does not occur on an island........ **3**

3. Wetland occurs with the banks of a river or stream or along the shores of a pond, lake, or island ***and*** is either (1) vegetated ***and*** at least saturated or semi-permanently flooded ***or*** (2) a non-vegetated bank or shore that is temporarily or seasonally flooded .... **Fringe**
3. Wetland does not occur along a bank or shore........ **4**

4. Wetland occurs on a floodplain of a Lotic River .... **Floodplain**
4. Wetland does not occur on a floodplain of a Lotic River........ **5**

5. Wetland exists in a distinct depression in various landscape positions .... **Basin**
5. Wetland receives virtually no groundwater discharge (playa)........ **Flat**

Key C-1: Key to Water Flow Paths

1. Water levels fluctuate due to lake influences or variable river levels, but water does not flow through the wetland .... **Bidirectional**
1. Wetland is not influenced by fluctuating water levels...2

2. Wetland receives surface or groundwater from a watercourse, other waterbody, ***or*** from another wetland at a higher elevation ***and*** surface or groundwater passes through it to a watercourse, other waterbody, ***or*** another wetland at a lower elevation..... **Throughflow**
2. Water does not pass through the wetland to other wetlands or waters 3

3. Wetland is in a closed depression (based on closed elevation contours) or flat areas where water comes from surface water runoff and/or groundwater discharge. Isolated wetlands *lack channelized surface water inflow and outflow* .... **Isolated**
3. Wetland is not hydrologically or geographically isolated..4

4. Wetland exists in a sink where no outlet exists, yet water enters via an intermittent or perennial stream or from a wetland at a higher elevation..**Inflow**
4. Wetland receives no surface or groundwater inflow from a wetland or other permanent waterbody at a higher elevation ***and*** water is discharged from the wetland to a watercourse, waterbody, or other wetland at a lower elevation ....**Outflow**

Key D-1: Key to Waterbody Types

1. Waterbody is predominantly flowing water...2
1. Waterbody is predominantly standing water...3

2. Waterbody is a polygonal feature on a U.S.G.S. topographic map (1:24,000).................. **River**
2. Waterbody is a linear feature on a U.S.G.S. topographic map (1:24,000)...................... **Stream**
Go to couplets 'b', 'c', and 'd' below

3. Waterbody is permanently flooded and deep (> 6.6 feet) .... **Deep Water**
Go to couplet 'a' below

   a. Waterbody is created by a dammed river valley ....**Dammed River Valley**
   a. Waterbody is created by another obstruction................................... **Other Dammed Lake**
   a. Waterbody has been excavated .... **Excavated Lake**
   a. Waterbody is natural ....**Natural Lake**

Slope Modifiers

- **b.** Water flow is generally slow with extensive floodplain development. Stream slope is less than 2%. (Cowardin's Lower Perennial Subsystem)............... **Low Gradient**
- **b.** Water flow is moderate to fast with little to some floodplain development. Stream slope is between 2 and 4%. (Cowardin's Upper Perennial Subsystem)...**Middle Gradient**
- **b.** Water flow is rapid due to steep gradient with little or no floodplain development. Stream slope is greater than 4%. (Cowardin's Upper Perennial Subsystem)..**High Gradient**

Water Flow Modifier

- **c.** Water flow is intermittent or ephemeral (as indicated on the high resolution National Hydrography Dataset).. **Intermittent**

Other Special Modifiers

- **d.** Water flow is dammed...**Dammed**

APPENDIX E. PROCEDURE FOR CODING WETLAND POLYGONS WITH HYDROGEOMORPHIC MODIFIERS IN ARCGIS

The hydrogeomorphic (HGM) coding process has been semi-automated to populate each wetland polygon with an HGM code. Preparation for the semi-automated process involves exporting the wetland polygons to a new layer and adding fields for each of the HGM code components. Once the HGM coding process has been completed the exported table can be joined to the original NWI geodatabase to populate the geodatabase HGM_CODE field.

1. The average slope is calculated for each of the wetland polygons. Then the following fields are added to the table: Waterbody, Gradient, Lake_Mod, Water_Flow, Pond, Spec_Mod, Landform, and Flow_Path.
2. Each field is then populated in succession. Seven waterbody/landscape position types are included in the HGM code: deep water (DW), lentic (LE), riverine (RV), stream (ST), lotic river (LR), lotic stream (LS), and terrene (TE). The "DW" code is assigned to all wetlands attributed as an L1. Those wetlands coded as L2 are given the "LE" code. Additionally, all wetlands within 40 meters of lakes with an average slope less then 4% are coded as "LE". The "RV" code is assigned to rivers attributed as R2UBH or R3UBH. All other streams are coded as "ST" including R2/3UBF, R2/3UBG, and R4SB streams. Wetlands coded as "RV" within 300 meters of rivers and with an average slope less than 4% are assigned the "LR" code. Wetlands coded as "ST" within 100 meters of rivers and an average slope of less that 4% are coded as "LS". Then using the high resolution national hydrography dataset (NHD) layer, the perennial and intermittent streams are buffered by 100 meters and the ephemeral streams are buffered by 20 meters. All wetlands that intersect either the 100 meter or 20 meter buffer with an average slope of less than 4% are also assigned the "LS" code. The "TE" code is then assigned to any remaining uncoded wetlands.
3. Using the average slope value, each river and stream is assigned a gradient value. Those streams with an average slope less than 2% are given a "1" or low gradient value. Streams with an average slope between 2% and 4% are assigned a value of "2". A value of "3" is assigned those streams with an average slope greater than 4%. Additionally, streams attributed as R4SB or with a water regime of F (semipermantently flooded) are assigned a value of "4" for intermittent in the Water_Flow field.
4. Each deep water and lentic wetland is assigned a lake modifier. Natural lakes are given a "1". Dammed lakes are assigned a "3". And excavated lakes are assigned the value "4". The lentic wetlands are given the same lake modifier as the lake with which they are associated.
5. The Spec_mod field is populated with the special modifiers that a wetland polygon may contain. The possible special modifiers are "b" (beaver), "h" (dammed/impounded), "x" (excavated), "d" (drained), and "f" (farmed). Not all wetlands will have a special modifier.
6. The Pond field is populated with a "p" for all wetland polygons attributed as PAB (palustrine aquatic bed) or PUB (palustrine unconsolidated bottom).

7. The Landform field is populated for each waterbody type. There are three possible landform values possible for the lentic system. Wetlands that are islands within lakes are assigned "IL". Wetlands with the water regimes A or C and ponds are "BA" or basins. Wetlands with the water regimes B or F and shores along rivers and lakes are assigned "FR" or fringe. Ponds near lotic rivers and streams are also basins ("BA"). All other wetlands along lotic streams are also assigned "BA" except those wetlands with the water regimes B or F and shores, which are defined as "FR". Along lotic rivers, those wetlands having water regimes B or F and shores are also defined as "FR", but all other wetlands are defined as "FP" or floodplain. All terrene wetlands are defined as basins ("BA") except those with an average slope greater than 4%, which are defined as slope or "SL".
8. The Flowpath field is populated for each wetland type. All lotic rivers and streams are populated with "TH" or throughflow. Wetlands attributed with L2 a water regime of B or F or shores, (excluding ponds) are attributed as "BI" or bidirectional. All other lentic wetlands are defined as throughflow or "TH". All dammed lakes are also defined as "TH". Lakes or "DW" can also be defined as "IN", "OU", or "IS" for inflow, outflow, and isolated. Each lake is checked against the digital USGS topographic map to determine the Flowpath. Terrene wetlands are defined as either "IS" (isolated) or "CO" (complex). All terrene wetlands that are greater than 20 meters from another wetland are defined as isolated.
9. Once each field has been populated, the HGM_CODE field can be updated using the field calculator. The deep water code consists of the Waterbody, Lake_Mod, and a Flow_Path. The riverine code contains the Waterbody, Gradient, and Spec_Mod fields. The stream code includes the fields Waterbody, Gradient, Water_Flow, and Spec_Mod. Lentic polygons include the Waterbody, Lake_Mod, Landform, and Flow_path fields. Finally the lotic rivers and streams and terrene wetlands contain the fields: Waterbody, Pond, Spec_Mod, Landform, and Flow_path.

APPENDIX F. RELATIVE FUNCTIONAL PERFORMANCE LEVELS FOR WETLANDS CLASSIFIED WITH NATIONAL WETLAND INVENTORY (NWI) AND HYDROGEOMORPHIC (HGM) CODES.

(A RANK OF "1" INDICATES A HIGH PERFORMANCE LEVEL;
A RANK OF "2" INDICATES A MODERATE PERFORMANCE LEVEL;
AND A RANK OF "3" INDICATES A LOW PERFORMANCE LEVEL)

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
L1UBHh	DW2TH	529.1	1	1	3	1	2	1	1	1	2	1
L2ABGh	LE2FRBI	109.2	1	1	1	2	1	1	1	1	2	1
L2USAh	LE2FRBI	54.5	2	1	3	1	1	1	1	1	2	1
L2USCh	LE2FRBI	6.2	2	1	3	1	1	1	1	1	2	1
PABF	LRpBATH	231.3	2	2	3	3	3	1	3	3	3	2
PABF	LE2pBATH	0.0	2	1	3	3	3	1	3	3	3	2
PABF	LSpBATH	87.3	2	2	2	3	3	1	3	3	3	2
PABF	TEpBAIS	3.5	2	1	2	3	2	1	3	3	3	2
PABF	TEpBACO	8.5	1	1	2	3	3	1	3	3	3	2
PABFb	LRpbBATH	1.9	2	2	3	3	3	1	3	3	3	2
PABFb	LSpbBATH	9.0	2	2	2	3	3	1	3	3	3	2
PABFb	TEpbBACO	0.4	2	1	2	3	2	1	3	3	3	2
PABFh	TEphBACO	5.6	1	1	2	2	3	1	1	2	2	1
PABFh	LRphBATH	19.9	1	2	1	2	3	1	1	2	2	1
PABFh	LSphBATH	143.9	1	1	1	2	2	1	1	2	2	1
PABFh	TEphBAIS	3.9	1	1	1	2	1	2	3	2	2	2
PABFx	LRpxBATH	89.2	1	1	1	2	2	1	1	2	2	1
PABFx	LSpxBATH	181.3	1	1	1	2	2	1	1	2	2	1
PABFx	TEpxBACO	50.5	1	1	1	2	2	1	1	2	2	1
PABFx	TEpxBAIS	65.1	1	1	1	2	1	1	1	2	2	1
PABG	LRpBATH	26.7	2	2	3	3	3	1	3	3	3	2
PABGb	LSphBATH	1.3	2	2	2	3	3	1	3	3	3	2
PABGh	TEphBACO	2.3	1	1	2	2	3	1	1	2	2	1
PABGh	LSphBATH	64.3	1	1	1	2	2	1	1	2	2	1
PABGx	LRpxBATH	65.4	1	1	1	2	2	1	1	2	2	1
PABGx	LSpxBATH	140.1	1	1	1	2	2	1	1	1	2	1
PABGx	TEpxBACO	19.6	1	1	1	2	2	1	1	2	2	1
PABGx	TEpxBAIS	38.5	1	1	1	2	1	1	1	2	2	1
PABHx	LRpxBATH	24.7	1	1	1	2	2	1	1	2	2	1
PABKx	TEpxBACO	89.3	1	1	1	1	1	1	1	1	1	1
PABKx	TEpxBAIS	2.1	1	1	1	1	1	1	1	1	1	1
PEMA	LRFPTH	8774.4	2	2	3	2	3	1	1	1	1	1
PEMA	TEBAIS	298.9	3	1	3	3	2	1	1	1	1	1
PEMA	LE2BATH	27.2	2	1	3	1	2	1	2	2	1	1
PEMA	TEBACO	409.7	1	1	3	2	3	1	1	1	1	1
PEMA	TESLCO	410.9	1	1	3	2	3	1	1	1	1	1
PEMA	TESLIS	570.2	1	1	3	3	2	1	1	1	1	3
PEMA	LSBATH	9242.7	2	2	2	2	2	1	1	1	1	1
PEMAd	LRdFPTH	235.4	2	2	2	2	2	1	1	1	1	1
PEMAd	LSdBATH	22.4	2	2	2	2	2	1	1	1	1	1
PEMAf	LRfFPTH	599.1	2	2	2	2	2	1	1	1	1	1
PEMAf	LSfBATH	517.7	2	2	2	2	2	1	1	1	1	1
PEMAf	TEfBACO	52.2	1	1	2	2	2	1	1	1	1	1
PEMAf	TEfBAIS	43.2	1	1	2	2	2	1	1	1	1	1
PEMAf	TEfSLCO	0.8	1	1	2	2	2	1	1	1	1	1
PEMAf	TEfSLIS	14.0	1	1	2	2	2	1	1	1	1	1
PEMAh	LE2BATH	55.5	3	1	3	1	2	1	2	2	1	1
PEMAh	TEhBAIS	0.1	3	1	3	2	2	1	1	1	1	1
PEMAh	TEhSLCO	6.1	3	1	3	2	2	1	1	1	1	1
PEMAh	TEhSLIS	3.5	3	1	3	2	2	1	1	1	1	1
PEMAh	LRhFPTH	1.4	2	2	2	2	2	1	1	1	1	1
PEMAh	LShBATH	62.1	3	1	1	1	2	1	1	1	1	1
PEMAx	TExBACO	12.8	3	1	3	2	2	1	1	1	1	1
PEMAx	TExBAIS	19.8	3	1	3	2	2	1	1	1	1	1
PEMAx	TExSLCO	4.3	3	1	3	2	2	1	1	1	1	1
PEMAx	TExSLIS	3.8	3	1	3	2	2	1	1	1	1	1
PEMAx	LRxFPTH	35.5	3	1	1	1	2	1	1	1	1	1
PEMAx	LSxBATH	190.6	3	1	1	1	2	1	1	1	1	1
PEMB	TESLIS	5.8	1	1	2	3	2	1	3	3	1	3
PEMB	LSFRTH	14.6	1	2	1	3	3	1	3	3	2	3
PEMC	LRFPTH	2609.2	2	2	3	2	3	1	1	1	1	1
PEMC	TEBAIS	23.1	3	1	3	3	2	1	1	1	1	1
PEMC	TESLIS	30.8	2	1	3	3	2	1	1	1	1	3
PEMC	TEBACO	75.3	1	1	3	2	3	1	1	1	1	1
PEMC	TESLCO	27.3	1	1	3	2	3	1	1	1	1	3
PEMC	LSBATH	2598.6	2	2	2	2	2	1	1	1	1	1
PEMCd	LRdFPTH	15.3	2	2	2	2	2	1	1	1	1	1
PEMCf	TEfBACO	5.4	3	1	3	3	2	1	1	1	1	1
PEMCf	TEfBAIS	3.3	3	1	3	3	2	1	1	1	1	1
PEMCf	LRfFPTH	75.8	2	2	2	2	2	1	1	1	1	1
PEMCf	LSfBATH	3.3	2	2	2	2	2	1	1	1	1	1
PEMCh	LRhFPTH	1.5	2	2	3	1	3	1	1	1	1	1
PEMCh	LShBATH	30.8	3	2	2	1	3	1	1	1	1	1
PEMCh	LE2BATH	33.5	1	1	1	1	2	1	1	1	1	1
PEMCh	TEhBACO	0.7	1	1	1	1	1	1	1	1	1	1
PEMCh	TEhSLCO	1.2	1	1	1	1	1	1	1	1	1	1
PEMCh	TEhSLIS	1.1	1	1	1	1	1	1	1	1	1	1

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
PEMCx	LRxFPTH	75.0	2	2	3	2	3	1	1	1	1	1
PEMCx	TExBACO	28.3	3	1	3	2	2	1	1	1	1	1
PEMCx	TExBAIS	22.2	3	1	3	2	2	1	1	1	1	1
PEMCx	TExSLCO	2.6	1	1	2	2	2	1	1	1	1	1
PEMCx	TExSLIS	10.1	1	1	2	2	2	1	1	1	1	1
PEMCx	LSxBATH	453.4	3	1	1	1	2	1	1	1	1	1
PEMF	TEBACO	4.8	2	1	2	3	2	1	3	3	3	3
PEMF	TEBAIS	1.6	2	1	2	3	2	1	3	3	3	3
PEMF	TESLIS	1.1	2	1	2	3	2	1	3	3	3	3
PEMF	LRFRTH	169.1	1	2	1	3	3	1	3	3	3	3
PEMF	LSFRTH	362.0	1	1	1	3	1	1	3	3	3	3
PEMFb	LRbFRTH	0.5	2	2	3	3	3	1	3	3	3	3
PEMFh	LRhFRTH	1.5	1	2	3	2	3	1	1	2	2	1
PEMFh	LShFRTH	10.3	2	2	2	2	3	1	1	2	2	1
PEMFh	TEhBACO	0.5	1	1	1	2	1	1	1	2	2	1
PEMFh	TEhBAIS	0.3	1	1	1	2	1	1	1	2	2	1
PEMFh	TEhSLIS	0.2	1	1	1	2	1	1	1	2	2	1
PEMFx	LRxFRTH	6.4	2	2	3	2	3	1	1	2	2	1
PEMFx	LSxFRTH	9.0	2	2	3	2	3	1	1	2	2	1
PEMFx	TExBACO	0.6	2	1	2	3	2	1	1	2	2	1
PEMFx	TExBAIS	0.7	2	1	2	3	2	1	1	2	2	1
PEMKx	TExBACO	48.8	1	1	2	1	1	1	1	1	1	1
PFOA	LSBATH	3.3	3	2	3	2	3	3	2	3	2	3
PFOA	LRFPTH	1.3	3	1	3	2	3	3	2	2	2	3
PSSA	LRFPTH	2361.3	3	2	3	2	3	2	2	3	2	1
PSSA	LE2BATH	0.7	3	1	3	2	3	2	2	3	2	1
PSSA	TEBACO	127.1	3	1	3	3	2	1	2	2	2	1
PSSA	TEBAIS	52.5	3	1	3	3	2	1	2	2	2	1
PSSA	TESLIS	170.4	3	1	3	3	2	1	2	2	1	3
PSSA	TESLCO	378.6	1	1	3	2	3	1	2	2	1	3
PSSA	LSBATH	2004.6	3	2	2	2	2	2	2	2	2	1
PSSAb	LSbBATH	0.5	3	2	2	2	2	2	2	2	2	1
PSSAh	TEhBACO	0.2	3	1	3	3	2	1	2	2	2	1
PSSAh	TEhSLCO	1.9	3	1	3	3	2	1	2	2	2	1
PSSAh	LRhFPTH	0.4	3	2	2	1	3	1	1	2	1	1
PSSAh	LShBATH	3.7	3	2	2	1	3	1	1	2	1	1
PSSAx	LRxFPTH	5.7	3	2	3	2	3	2	2	3	2	1
PSSAx	TExBACO	4.4	3	1	3	3	2	1	2	2	2	1
PSSAx	TExBAIS	1.0	3	1	3	3	2	1	2	2	2	1
PSSAx	TExSLCO	1.3	3	1	3	3	2	1	2	2	2	1
PSSAx	TExSLIS	0.6	3	1	3	3	2	1	2	2	2	1
PSSAx	LSxBATH	37.7	3	2	2	1	3	1	1	2	1	1
PSSC	LRFPTH	705.9	3	2	3	2	3	2	2	3	2	1
PSSC	TEBACO	3.1	3	1	3	3	2	1	2	2	1	1
PSSC	TESLCO	1.1	3	1	3	3	2	1	2	2	2	1
PSSC	TESLIS	2.7	3	1	3	3	2	1	2	2	1	1
PSSC	LSBATH	217.7	3	2	2	2	2	2	2	2	2	1
PSSCb	LSbBATH	0.4	3	2	2	2	3	1	2	3	2	1
PSSCh	TEhBACO	0.2	3	1	3	3	2	1	2	2	2	1
PSSCx	LRxFPTH	3.3	3	2	3	2	3	2	2	3	2	1
PSSCx	LSxBATH	16.8	3	2	3	2	3	2	2	3	2	1
PSSCx	TExBACO	0.6	3	1	3	2	2	1	1	1	1	1
PSSCx	TExSLCO	0.4	3	1	3	3	2	1	2	2	2	1
PSSF	LRFRTH	2.6	3	2	3	3	3	2	3	3	3	3
PSSF	LSFRTH	1.3	3	2	3	3	3	2	3	3	3	3
PSSF	TEBACO	1.0	3	1	3	3	2	1	2	2	2	1
PSSFb	LRbFRTH	2.7	3	2	2	2	3	1	2	3	2	1
PSSFb	LSbFRTH	0.2	3	2	2	2	3	1	2	3	2	1
PSSFh	LRhFRTH	0.1	3	2	2	1	3	1	1	2	1	1
PUBFh	TEphBAIS	0.1	1	1	1	1	1	1	1	1	1	1
PUBFx	LRpxBATH	24.9	1	2	3	1	2	1	1	1	1	1
PUBFx	LSpxBATH	35.4	1	2	3	1	2	1	1	1	1	1
PUBFx	TEpxBACO	5.9	2	1	2	2	2	1	1	1	1	1
PUBFx	TEpxBAIS	18.3	1	1	1	1	1	1	1	1	1	1
PUBGx	LSpxBATH	9.4	1	2	3	1	2	1	1	1	1	1
PUBGx	TEpxBACO	24.4	2	1	2	2	2	1	1	1	1	1
PUBGx	TEpxBAIS	5.4	1	1	1	1	1	1	1	1	1	1
PUBKx	TEpxBAIS	0.7	1	1	1	1	1	1	1	1	1	1
PUSA	LSBATH	2.9	3	3	3	1	1	1	1	2	2	2
PUSA	LRFPTH	2.5	2	2	3	2	1	1	1	2	2	2
PUSA	TEBACO	0.1	3	1	3	2	1	1	1	1	2	1
PUSA	TEBAIS	2.5	3	1	3	2	1	1	1	1	2	1
PUSAh	LShBATH	8.5	2	3	3	1	1	1	1	1	2	1
PUSAh	LE2FRTH	3.6	2	2	3	2	1	1	1	2	2	2
PUSAh	TEhBACO	1.5	3	1	3	2	1	1	1	1	2	1
PUSAh	TEhBAIS	1.0	3	1	3	2	1	1	1	1	2	1
PUSAx	LSxBATH	1.6	3	3	3	1	1	1	1	2	2	2

NWI Code	HGM Code	Acres	Water Storage	Streamflow Maintenance	Groundwater Recharge	Nutrient Cycling	Sediment Retention	Shoreline Stabilization	Native Plant Community Maintenance	Terrestrial Habitat	Aquatic Habitat	Conservation of Wetland Biodiversity
PUSAx	LRxFPTH	0.4	2	2	3	2	1	1	1	2	2	2
PUSAx	TExBACO	0.0	3	1	3	2	1	1	1	1	2	1
PUSAx	TExBAIS	2.5	3	1	3	2	1	1	1	1	2	1
PUSC	LSBATH	5.9	3	3	3	1	1	1	1	2	2	2
PUSC	LRFPTH	10.4	2	2	3	2	1	1	1	2	2	2
PUSC	TEBACO	3.1	3	1	3	2	1	1	1	1	2	1
PUSC	TEBAIS	1.2	3	1	3	2	1	1	1	1	2	1
PUSCh	LShBATH	2.5	3	3	3	1	1	1	1	2	2	2
PUSCh	LRhFPTH	0.4	3	2	3	2	1	1	1	2	2	2
PUSCh	LE2FRTH	4.2	2	2	3	2	1	1	1	2	2	2
PUSCh	TEhBACO	0.0	3	1	3	2	1	1	1	1	2	1
PUSCh	TEhBAIS	1.1	3	1	3	2	1	1	1	1	2	1
PUSCx	LSxBATH	6.1	3	3	3	1	1	1	1	2	2	2
PUSCx	LRxFPTH	2.5	3	2	3	2	1	1	1	2	2	2
PUSCx	TExBACO	4.9	3	1	3	2	1	1	1	1	2	1
PUSCx	TExBAIS	0.5	1	1	1	1	1	1	1	1	1	1
R2ABG	ST1	22.4	1	2	3	1	1	1	1	1	3	1
R2ABG	ST14	12.9	1	2	3	1	1	1	1	1	3	1
R2ABG	ST2	7.2	1	2	3	1	1	1	1	1	3	1
R2ABG	ST24	2.0	1	2	3	1	1	1	1	1	3	1
R2ABG	ST3	11.0	1	2	3	1	1	1	1	1	3	1
R2ABG	ST34	0.1	1	2	3	1	1	1	1	1	3	1
R2UBF	ST1	93.9	1	2	3	1	1	1	1	1	3	1
R2UBF	ST14	51.3	1	2	3	1	1	1	1	1	3	1
R2UBF	ST2	5.5	1	2	3	1	1	1	1	1	3	1
R2UBF	ST24	7.6	1	2	3	1	1	1	1	1	3	1
R2UBFx	ST14x	15.4	1	2	3	1	1	1	1	1	2	1
R2UBFx	ST1x	57.5	1	2	3	1	1	1	1	1	2	1
R2UBFx	ST2x	6.8	1	2	3	1	1	1	1	1	2	1
R2UBFx	ST34x	20.3	1	2	3	1	1	1	1	1	2	1
R2UBG	ST1	64.5	1	2	3	1	1	1	1	1	3	1
R2UBG	ST14	18.6	1	2	3	1	1	1	1	1	3	1
R2UBG	ST2	1.5	1	2	3	1	1	1	1	1	3	1
R2UBG	ST3	0.4	1	2	3	1	1	1	1	1	3	1
R2UBH	RV1	4193.8	1	2	3	1	1	1	1	1	3	1
R2USA	LRFRTH	983.2	2	3	3	1	1	1	1	2	2	1
R2USA	LSFRTH	3.4	2	3	3	1	1	1	1	2	2	1
R2USC	LSFRTH	1.4	2	3	3	1	1	1	1	2	2	1
R2USC	LRFRTH	375.4	1	3	1	1	1	1	1	1	2	1
R3UBF	ST14	10.9	1	2	3	1	1	1	1	1	3	1
R3UBFh	ST14h	0.6	1	2	3	1	1	1	1	1	2	1
R3UBFx	ST14x	6.1	1	2	3	1	1	1	1	1	2	1
R3UBFx	ST24x	18.0	1	2	3	1	1	1	1	1	2	1
R3UBFx	ST34x	54.4	1	2	3	1	1	1	1	1	2	1
R3UBG	ST1	0.0	1	2	3	1	1	1	1	1	3	1
R3UBG	ST14	21.7	1	2	3	1	1	1	1	1	3	1
R3UBH	RV3	75.2	1	2	3	1	1	1	1	1	3	1
R3UBH	RV1	182.5	1	1	1	2	2	1	1	1	3	1
R3USA	LRFRTH	15.1	2	2	1	1	1	1	1	1	2	1
R3USC	LRFRTH	1.8	1	3	1	1	1	1	1	1	2	1
R4SBA	ST14	7.7	2	1	1	1	1	1	1	1	2	1
R4SBA	ST24	7.9	2	1	1	1	1	1	1	1	2	1
R4SBA	ST34	2.1	2	1	1	1	1	1	1	1	2	1
R4SBAx	ST14x	22.1	2	1	1	1	1	1	1	1	2	1
R4SBAx	ST24x	21.8	2	1	1	1	1	1	1	1	2	1
R4SBAx	ST34x	68.1	2	1	1	1	1	1	1	1	2	1
R4SBC	ST14	44.8	2	1	1	1	1	1	1	1	2	1
R4SBC	ST24	11.6	2	1	1	1	1	1	1	1	2	1
R4SBC	ST34	16.6	2	1	1	1	1	1	1	1	2	1
R4SBCx	ST14x	110.9	2	1	1	1	1	1	1	1	2	1
R4SBCx	ST24x	51.5	2	1	1	1	1	1	1	1	1	1
R4SBCx	ST34x	59.9	2	1	1	1	1	1	1	1	2	1

APPENDIX G. ACRES OF MAJOR LAND COVER AND LAND USE TYPES WITHIN EACH SIXTH CODE HYDROLOGIC UNIT IN THE GALLATIN PROJECT AREA FROM THE 2009 MONTANA LAND COVER THEME

Sixth Code Hydrologic Unit	Open Water	Developed Area	Pasture/Cultivated Cropland	Native Vegetation	Harvested Forest
Antelope Creek	38.3	584.5	3,390.8	26,832.3	0.0
Bear Creek	0.0	142.3	873.8	11,858.3	113.2
Big Bear Creek	2.4	165.0	893.1	11,552.7	1,220.7
Boulder River-Conrow Creek	2.0	681.6	1,325.2	33,832.1	0.0
Bozeman Creek	11.3	3,143.5	3,837.9	25,721.4	356.1
Burnt Creek	2.2	98.1	121.0	11,827.6	0.0
Cottonwood Creek	0.4	106.5	950.1	17,578.7	294.7
Dry Creek	0.0	0.0	1.3	4.8	0.0
Dry Hollow Creek	22.2	421.2	3,488.7	4,867.1	0.0
East Gallatin River-Belgrade	20.9	4,038.7	12,098.2	6,804.1	0.0
East Gallatin River-Bozeman	23.4	5,035.4	7,539.8	7,155.5	0.0
East Gallatin River-Kelly Creek	0.0	2,557.1	3,826.5	10,003.3	0.0
East Gallatin River-Nixon Gulch	9.6	873.1	8,519.5	19,522.9	0.0
Elk Creek	0.0	460.1	3,343.5	24,055.9	0.0
Ennis Lake	0.0	0.0	0.0	11.3	0.0
Fish Creek	6.4	480.1	2,685.4	5,642.8	0.0
Gallatin River-Central Park	58.0	3,227.6	26,917.9	11,682.8	0.0
Gallatin River-Gallatin Gateway	171.7	1,879.7	17,620.5	18,565.2	0.2
Gallatin River-Manhattan	20.2	2,340.7	11,811.1	15,127.2	0.0
Gallatin River-Missouri Headwaters	35.4	719.9	2,561.8	16,502.5	0.0
Gallatin River-Spanish Creek	68.5	108.3	0.0	9,818.7	176.8
Gallatin River-Wilson Creek	95.4	257.1	2,451.0	15,289.6	584.7
Jackson Creek	0.0	4.2	541.8	10,732.7	896.7
Jefferson River-Cardwell	154.3	865.3	6,452.3	26,039.4	0.0
Jefferson River-Mill Creek	54.0	242.0	1,039.9	4,831.5	0.0
Jefferson River-Sappington	280.7	1,033.2	1,130.7	28,308.1	38.5
Jefferson River-Three Forks	336.5	2,654.9	9,159.1	24,986.6	0.0
Jefferson Slough	89.6	2,970.3	2,487.0	9,295.8	0.0
Little Pipestone Creek	0.0	524.0	672.5	4,700.1	0.0
Lower Big Pipestone Creek	7.8	1,529.2	3,647.0	25,386.9	60.5
Lower Bridger Creek	0.0	71.6	1,142.7	11,532.2	22.2
Lower Camp Creek	5.8	1,211.6	18,692.0	13,926.1	0.0
Lower Cherry Creek	0.0	6.4	149.0	17,001.6	0.0
Lower Dry Creek	0.9	482.8	5,218.9	13,472.6	0.0
Lower Hot Springs Creek	3.6	517.1	804.6	15,113.4	0.0
Lower Hyalite Creek	25.8	5,553.0	27,485.0	5,248.7	0.0
Lower North Meadow Creek	0.0	0.0	0.0	1,053.5	0.0
Lower South Boulder Creek	0.2	314.9	2,330.5	8,313.3	0.0
Lower Whitetail Creek	0.0	1,200.3	2,020.2	13,232.7	0.0
Madison River-Bear Trap Canyon	139.2	0.0	0.9	14,062.0	0.0
Madison River-Red Mountain	247.5	406.8	205.5	12,859.9	0.0
Madison River-Three Forks	342.3	2,583.1	7,717.5	22,337.7	0.0
Madison River-Willow Springs	174.1	796.6	3,900.8	23,978.3	0.0
Middle Cherry Creek	0.0	0.0	0.0	6,435.6	0.0

Sixth Code Hydrologic Unit	Open Water	Developed Area	Pasture/Cultivated Cropland	Native Vegetation	Harvested Forest
Middle South Boulder Creek	0.0	0.0	18.2	12,502.5	0.0
Milligan Creek	2.0	1,051.5	757.3	28,408.2	0.0
Missouri River-Clarkston	283.1	9.1	2,253.3	32,709.5	34.0
Missouri River-Trident	225.1	91.8	312.9	13,975.2	0.0
Mud Spring Gulch	3.8	1,392.4	3,058.4	30,878.3	0.0
North Fork Spanish Creek	0.0	0.0	188.1	3,893.7	0.0
North Fork Willow Creek	34.9	427.7	4,017.8	15,390.8	2.2
Norwegian Creek	423.4	733.5	1,336.1	21,297.1	0.0
Pass Creek	0.0	205.5	2,230.2	10,631.3	91.8
Piedmont Swamp	10.2	1,051.5	3,653.0	11,438.2	0.0
Pole Creek	0.0	0.0	6.7	11,900.1	0.0
Rattlesnake Creek	19.8	1,400.6	3,758.7	31,356.7	0.0
Rey Creek	0.0	435.9	5,426.2	11,627.4	0.0
Rocky Creek	0.0	505.7	526.9	19,954.3	747.7
Ross Creek	3.3	492.6	5,997.3	6,667.6	0.0
Smith Creek	12.5	622.9	7,762.0	19,999.0	0.0
South Fork Willow Creek	0.9	338.3	2,960.3	3,894.3	0.0
Spanish Creek	21.1	0.2	0.0	8,967.6	0.0
Upper Bridger Creek	0.0	0.0	575.8	7,245.6	586.0
Upper Camp Creek	0.0	175.9	3,221.4	10,355.8	0.0
Upper Dry Creek	0.0	762.1	4,185.0	29,747.0	0.4
Upper Hot Springs Creek	0.0	4.7	43.8	2,839.5	0.0
Upper South Boulder Creek	0.0	0.0	0.0	1,514.1	46.7
Upper South Fork Sixteenmile Creek	0.0	0.0	0.0	3,476.0	359.6
Warm Springs Creek	0.0	1,940.6	5,737.1	20,436.4	0.0
Willow Creek	51.3	329.5	1,206.3	10,633.1	125.4