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# Applying Wetland Rating Systems to Assess Functions of Depressional Wetlands Created by a Mass Wasting Feature, Table Mountain, Washington

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# APPLYING WETLAND RATING SYSTEMS TO ASSESS FUNCTIONS OF DEPRESSIONAL WETLANDS CREATED BY A MASS WASTING FEATURE, TABLE MOUNTAIN, WASHINGTON

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by

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# ABSTRACT

APPLYING WETLAND RATING SYSTEMS TO ASSESS FUNCTIONS OF DEPRESSIONAL WETLANDS CREATED BY A MASS WASTING FEATURE, TABLE MOUNTAIN, WASHINGTON

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The formation of wetlands in the Swauk Watershed has been primarily controlled by mass wasting events, which includes landslide activity. Landslide activity has been the primary influential process in shaping the landscape where wetland systems have formed on the surface of landslide deposits. The wetland sites used in this study, near the base of Table Mountain, were chosen because they inhabit the same ancient landslide, have the same underlying geology, and vary in aspect and elevation. The elevational gradient of the sites ranges from 1300 – 1600 m and the individual wetlands differ in terms of north- and south-facing aspects. Until this research, no studies had analyzed wetland function by using the Washington State Wetland Rating System in subalpine environments. Therefore, supplemental methods were used to enhance the quantification of ecological function. Results indicate high-elevation wetlands perform highest with regard to ecological function. In addition, elevation was found to be more influential over aspect in terms of influencing function scores. Findings of this research indicate this method is effective in terms of quantifying the ecological function of subalpine wetlands based on statistically significant analysis.

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# CHAPTER I

## INTRODUCTION

Mass wasting events are the only natural processes that create depressions in the landscape that facilitate the creation of wetland systems in the Swauk Watershed, especially near the base of Table Mountain (Lillquist, 2001; Wenatchee National Forest, 1997). Similar mass wasting occurs in mountainous environments throughout the world, resulting from underlying geomorphology and steep terrain (Cruden & Varnes, 1996), and sometimes result in wetland creation. However, very little has been published relating landslides to subalpine wetland ecology (Sharp, Sojda, Greenwood, Rosenberry, & Warren, 2012). A study in Poland by Margielewski, Michczynski, and Obidowicz (2010) analyzed the impacts of middle and late Holocene climate changes on two subalpine landslide peat bog systems. These peat bog systems formed in depressions located near the head scarp of the landslide area. The underlying geology consisted of shales interbedded with thick sandstones which crop out in the landslide area. In this study, landslide formation was influenced by erosional undercutting of the slope by local streams and associated tributaries. A similar study in Italy measured successional changes pertaining to an active landslide by analyzing palustrine deposits (Gioia, Di Leo, Giano, & Schiattarella, 2010). Primary landslide types that influenced these changes included rotational and translational slides, which created depressions in the back rotated section of the slope (Cruden & Varnes, 1996; Gioia et al., 2010).

Additionally, a mass wasting study in northern California focused on soil parent material in a wetland meadow created by a landslide (Lee, Graham, Laurent, & Amrhein, 2004). The wetland meadow was situated in a depression created by a rotational landslide. Water levels are sustained throughout most of the year by groundwater flow, ephemeral streams, and overland flow during spring runoff (Lee et al., 2004). The authors collected soil samples to analyze soil nutrients, in turn finding calcium/magnesium ratios high in areas surrounding the wetland meadow and low amounts of calcium/magnesium in the wetland soil (Lee et al., 2004). Stein, Mattson, Fetscher, and Halama (2004) studied soil properties, underlying geology, groundwater characteristics, and vegetation pertaining to slope wetlands situated in bedrock landslides in the Santa Ana Mountains located in southern California. These wetlands are supported by the fractured underlying geology which creates groundwater fed wetlands (Stein et al., 2004). However, literature pertaining to subalpine wetland function and landslides is sparse, and no studies have been conducted in Washington State regarding these wetland types in terms comparing subalpine wetland ecological functions across elevational gradients and differences in aspect.

This thesis compares subalpine wetland ecological functions, characteristics, and controls across a spatial gradient in terms of elevational and aspect differences. Wetland ecological functions include the physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. There are many valuable functions that wetlands perform, and they can be grouped into three categories: 1) functions that improve water quality, 2) functions that change the water regime in a watershed, and 3) functions that provide habitat for plants and animals (Sheldon et al., 2005). However, the utilization of the Washington State Wetland Rating System (WSWRS) has not been applied to subalpine wetland environments (Hruby, 2008). Although tailored for Eastern Washington, the development of the WSWRS was based on wetland sites that were below 1000 m in elevation (Hruby, 2004).

The purpose of this thesis is to compare ecological functions and characteristics of wetlands near Table Mountain that have been created by a single prehistoric mass wasting event in terms of elevation and aspect (Lillquist, 2001). The principal research questions are: (1) does wetland ecological function differ with elevation, and (2) does wetland ecological function differ in terms of north and south facing aspects? Wetland function is analyzed over a spatial gradient by utilizing the WSWRS as a method to determine a functional rating score to compare among wetland sites. There are no documented studies that analyze wetland function using the WSWRS over elevational gradients and aspect in subalpine landscapes. In addition to the WSWRS, a modified version of the Wetland Ecosystem Services Protocol for the United States (WESPUS) is used as a supplement to enhance the quantification of wetland function.

The significance of the study includes the use of the WSWRS to quantify wetland function in subalpine regions to further understand subalpine wetland environments in Washington State. Furthermore, wetland systems in general will be better understood by conducting this study because of the lack of wetland research in the Swauk Watershed (Lillquist, 2001). Management implications associated with the project include wetland protection and future land use planning that will take into consideration the location of wetlands, understanding their ecological characteristics, functions, controls, and importance. The findings resulting from this thesis will potentially provide additional biological data for future management plans.

Chapter I of this thesis has established the problem, purpose, and significance associated with the research question. Chapter II provides a scientific literature background in terms of wetland definitions, types of depressional wetlands, geomorphic controls and landslides, wetland classification, wetland function, elevation and aspect, and wetland assessment methods. Chapter III provides a biophysical overview of the Swauk Watershed and the specific wetland sites. Background information is provided describing the actual location, climate, geology, topography, wetland soils, hydrology, flora, disturbances, and management associated with the surrounding area. Chapter IV describes the methodology used to locate, identify, and classify the wetlands used in this study, characterize ecological function, data collection, and statistical analysis. Chapter V provides the results of the study focusing on significant findings. Chapter VI explains how the results are supported by scientific literature. Lastly, Chapter VII provides a brief summary of the research while providing further research suggestions and management implications.

# CHAPTER II

# LITERATURE REVIEW

This section is divided into seven subsections describing wetland definition, depressional wetlands, geomorphic controls, wetland classification, wetland function, elevation and aspect, and assessment methods. Wetland definitions will be explained in terms of legal aspects, types, and biophysical requirements. A discussion of depressional wetlands with regard to the subalpine setting will provide background information. Finally, wetland functions, classification methods based on certain wetland attributes, and functional assessment methods are described to provide the literature context for this thesis.

## Wetland Definition

According to the U.S. Army Corps of Engineers (USACE) and the Washington Department of Ecology (WDOE), a wetland is defined as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (WDOE, 1997, pp. 9). Regulatory wetlands must have three of the following characteristics: hydric soils, hydrophytic vegetation, and wetland hydrology. Indicators are determined in the field through the use of Washington State specific field guides such as the 1997 *Washington State Wetlands Identification and Delineation Manual* and the national 1987 USACE *Wetland Delineation Manual*.

Hydric soils are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions (USACE, 1998). The scarcity of oxygen causes reduced conditions, which causes higher accumulations of organic matter, forming a reduction in macronutrients, and contributing to denitrification (Cronk & Fennessy, 2001; Gambrell & Patrick, 1978). These conditions are most common in wetland systems (Mitsch & Gosselink, 2007). When wetlands are dry for part of the year, the upper part of the soil profile may become oxidized, allowing seed germination and the occasional invasion of upland plants (Gambrell & Patrick, 1978).

Hydrophytic vegetation are plants that possess a range of adaptations that enables them to survive in oxygen-deficient soil conditions resulting from excessive water content (Cowardin, Carter, Golet, & LaRoe, 1979; Mitsch & Gosselink, 2007; Tiner, 1998). Hydrophytes are not restricted to aquatic plants inhabiting bodies of water such as ponds, lakes, rivers, and estuaries, but also include plants that are adapted to periodic flooding or saturated soil conditions commonly found in seasonal, and depressional wetlands (Kolka & Thompson, 2006; Tiner, 1998).

Wetland hydrology is when a wetland has enough saturation to support hydrophytic vegetation and hydric soils. This occurs when the area is inundated or saturated to the surface for at least two consecutive weeks during the growing season, or equivalent to 5% of the growing season (WDOE, 1997).

## Depressional Wetlands

Wetlands resulting from depressions are the most common types of wetlands found in North America (Sharitz & Pennings, 2006). Examples range from bogs in Alaska to cypress domes in Florida. Other examples include prairie potholes, Carolina bays, seasonal wetlands, and wet meadows. Seasonal wetlands and wet meadows are most commonly found in mountainous environments (Loheide et al., 2009; Palik, Buech, & Egeland 2003). Depressional wetlands are found in high numbers, but they do not represent the greatest area of wetlands (Whigham & Jordan, 2003). Most are relatively small, ranging in size from less than an acre, but can be as large as several hundred hectares (Sharitz & Pennings, 2006).

Depressional wetlands, without inlets or outlets, are primarily hydrologically isolated from surface water connections, but most appear to be linked to other waters and wetlands through groundwater or periodic surface flows from surrounding areas (Whigham & Jordan, 2003; Winter, Rosenberry, Buso, & Merk, 2001). Depressional wetlands have been shown to improve water quality, reduce erosion (because of water retention), increase sediment retention, contribute to groundwater recharge, and retain nutrients (Manger, Gernes, Jacobson, Brooks, & Engstrom, 1995; Wenatchee National Forest, 1997; Whigham & Jordan, 2003). Vegetation in wetlands can vary from forest to marsh, and soils can either be organic or mineral depending on the geomorphic setting and climate (Lewis, 2001).

Bogs are specific depressional wetland communities dominated by sphagnum moss (*Sphagnum* spp.), sedges (*Carex* spp.), ericaceous shrubs (*Erica* spp.), or evergreen trees rooted in deep peat and are noted for their acidic water (Calloway, 2004). Examples include blanket bogs that carpet mountain sides in Europe and floating bogs can be found on shorelines in temperate and boreal regions (Keddy, 2000), which include northern glaciated climates such as the Great Lakes area, Canada, and Alaska (Kolka & Thompson, 2006).

In comparison, seasonal wetlands are generally small, concave depressions that are only wet during various times in the average climate year; examples include vernal pools and subalpine depressional wetlands found in the western U.S., Canada, and

Mexico (Geertsema & Pojar, 2007; Mitsch & Gosselink, 2007). Palik et al. (2003) list other seasonal depressional wetlands existing from the Great Lakes to the northeastern U.S.. Hydrologic outputs associated with these systems are through evapotranspiration and groundwater recharge during high runoff periods (Mitsch & Gosselink, 2007; Whigham & Jordan, 2003). Vegetation varies from forested to marsh depending on the duration of saturation, period of saturation, and climate of the area. Mineral soils are typically found in seasonal wetlands because water does not pond long enough to lead to the redox conditions associated with more saturated wetlands (Calloway, 2004). The origin of these systems in glaciated areas is mainly the result of landscape alterations associated with glacial deposition. In nonglaciated mountainous regions, geology and erosional/depostional environments control where seasonal wetlands occur (Kolka & Thompson, 2006; Lillquist, 2001).

Wet meadows are another type of wetland community found in mountainous regions, dominated by herbaceous plants rooted in the occasionally flooded soils. Examples include wet prairies found along river floodplains, herbaceous meadows on the shorelines of large lakes, or wet meadows found in mountainous environments, such as the Cascade Range (Keddy, 2000; Wenatchee National Forest, 1997). Vegetation includes wetland obligate and facultative grasses, forbs, and sedges that are mostly germinated from seed banks (Cronk & Fennessy, 2001). Wet meadows in the Cascade Range support highly productive and diverse wetland vegetation communities dominated by sedges, rushes, grasses and other herbaceous species (Loheide et al., 2009). Wet meadow soils develop from fluvial deposits that are composed of silt and clay with subsurface layers of sand, gravel, or cobble (Wenatchee National Forest, 1997).

Subalpine wet meadows potentially exist where channel obstructions or a change in slope gradients have resulted from seismic uplift, or where intruded volcanic dikes, extruded lava flows, ash flows, glacial moraines, or rock slides resist erosion and induce sediment deposition (Cronk & Fennessy, 2001; Keddy, 2000; Wenatchee National Forest, 1997). Subalpine wet meadows also exist as open-basin wetlands with a fluctuating water table beneath (Wenatchee National Forest, 1997). These wetlands are also characterized by being extremely diverse with annual precipitation greater than 20 inches near the Cascade Crest in Washington State (Kovalchik & Clausnitzer, 2004).

## Geomorphic Controls and Landslides

Mountains have numerous geomorphic controls as a result of steep slopes, high relief, and weathered bedrock (Price, 1981). Mass wasting features such as landslides and talus are common. Landslides are a common occurrence in all mountainous environments throughout the world, including the Cascade Mountains in Washington (Butler, 1979; Butler, Oelfke, & Oelfke, 1986). There are distinct categories of landslides: translational slides, rotational slides, flows, and complex slide-flows (Cruden & Varnes, 1996; Lillquist, 2001). Translational slides are the most common type in the Swauk Watershed (Lillquist, 2001). They are characterized by having a rough, linear escarpment and a hummocky zone that includes ponds and wetlands (Cruden, & Varnes 1996; Lillquist, 2001). Rotational slides have curved planes and rotate as they slide downslope (Cruden, & Varnes 1996; Lillquist, 2001). They can be characterized by having scalloped main scarps at their heads, step-like longitudinal profiles, and hummocky topography also inhabiting wetlands (Lillquist, 2001). Flows are likely triggered by rapid snow melts as well as diminished tree root strength as a result from logging (Lillquist, 2001). Complex slide-flows are similar to rotational slides in that they have hummocky terrain that will facilitate wetland formation (Cruden & Varnes, 1996; Lillquist, 2001).

Geomorphic controls influence many factors of wetland hydrology (Stein et al., 2004). Depressional wetlands are characterized by having the most influence from underlying geology in regard to hydrology because of the areas they inhabit. They can be saturated areas that occur at stratigraphic changes where ground water discharges to the land surface (USACE, 1998). Underlying geology also influences water chemistry of wetlands in terms of groundwater flows contacting subsurface minerals (Nelson, Rhoades, & Dwire, 2011). Additionally, geology plays an important role in subalpine settings pertaining to landslide occurrences based on interbed development (Margielewski et al., 2010). Finally, underlying geology influences wetland soil development by providing parent materials derived from unconsolidated mineral and organic particles (Stein et al., 2004).

## Wetland Classification

Wetland classification methods were originally developed to organize and understand wetlands on a regional scale and to determine their distribution and extent (Mitsch & Gosselink, 2007). More recently, classification methods based on the protection of wetland ecological values have been developed. Cowardin et al. (1979) states that the primary goal of a classification method is to create a restricted boundary on wetland ecosystems for the purpose of evaluation, inventory, and management. Other classification methods have been developed based on either wetland hydrology, vegetation structure, landscape position, or a combination of these characteristics (Mitsch & Gosselink, 2007). Two common classification systems utilized in Washington State include the Cowardin classification (Cowardin et al., 1979) and the hydrogeomorphic (HGM) classification (Brinson, 1993).

The United States Fish and Wildlife Service (USFWS) uses the Cowardin classification system for wetland inventory and determination of wetland distribution. The Cowardin classification system, entitled "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin et al., 1979), was based on the geologic and hydrologic origins of wetlands. The classification system is designed for use over a wide geographic area and for use by individuals and organizations with various interests and objectives (Cowardin et al., 1979). Of the wetlands and deepwater habitats, five systems exist: marine, estuarine, riverine, lacustrine, and palustrine (Mitsch & Gosselink, 2007). Palustrine systems, including depressional wetlands, are all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens (Mitsch & Gosselink, 2007).

The Cowardin classification emphasizes that wetlands are characterized by hydrologic, geomorphic, chemical, or biological factors (Cronk & Fennessy, 2001). Dominant vegetation structures (e.g., forest, scrub shrub, or emergent aquatic) are determined next to describe the general appearance of the wetland (Mitsch & Gosselink, 2007). Functions are determined based on vegetation structure and setting (e.g., estuarine or freshwater) in terms of the hydrologic regime, ranging from saturated or temporarily flooded to permanently flooded (Cowardin et al., 1979). Finally, modifiers are potentially added for different soil types (organic or mineral) or disturbance processes (e.g., impoundment, beaver activity). The resulting Cowardin classification system is based on a variety of geographic factors, functions such as hydrology regime, anthropogenic disturbances, and vegetation (Cowardin et al., 1979).

A more recently developed classification method, called the HGM approach, is based on three parameters: wetlands' geomorphic setting within the landscape, its water source, and hydrodynamics (Cronk & Fennessy, 2001; Mitsch & Grosselink, 2007). The HGM approach emphasizes the topographic setting and the hydrology of the wetland that in turn influence its function (Brinson, 1993; Hruby, 2004; Sheldon et al., 2005). The geomorphic setting refers to a wetlands' situation on the landscape, topographically, in terms of capturing flows and storing water (Brinson, 1993). Different geomorphic settings include depressional, riverine, and lake-fringe wetlands. Water source refers to hydrologic inputs pertaining to precipitation, groundwater discharge, and surface or near surface inflow (Brinson, 1993; Mitsch & Grosselink, 2007). Depressional wetlands in terms of geomorphic setting are typically found higher in watersheds, therefore relying heavily on precipitation and groundwater seepage (Brinson, 1993; Shaffer, Kentula, & Gwin, 1999). Precipitation is the primary input for nearly all wetlands and it varies with climate, therefore, making climate regimes a useful metric for comparison (Brinson, 1993). Hydrodynamics described by Brinson (1993) refers to work performed by the flow of water. This includes processes that involve sediment transport, hypersaline dilution, and nutrient transport within a wetland system (Brinson, 1993; Shaffer et al., 1999).

The WDOE currently utilizes the HGM approach to assess the physical, chemical, and biological functions of wetlands (WDOE, 1997). Four main HGM classes of wetlands found in Washington State include lake-fringe, slope, riverine and depressional (Sheldon et al., 2005). Lake-fringe is a type of wetland that is formed alongside a body of water that is greater than 20 acres. Slope wetlands occur on hill or valley slopes where water flows on surface, or under surface. Riverine wetlands are areas close to a stream channel that can be influenced by potential flooding. Finally, depressional wetlands occur when there is a lower elevation area compared to the surrounding landscape and have no surface outlet (Brinson, 1993; Hruby, 2004). In addition to surface outflow characterization, the HGM approach classifies soil characteristics, persistent vegetation based on wetland indicators, seasonal ponding, and storage depths (Hruby, 2004). As the majority of subalpine wetlands in Washington State are located on federal lands, many of these have not been classified or studied by WDOE, inhibiting their management (Hruby, 2004; Sharp et al., 2012).

## Wetland Function

Wetland functions include physical, chemical, and biological processes and their influence on vegetation, wildlife, and hydrology (Tiner, 1998). These functions are not necessarily performed continually throughout the season, but most operate on a frequent basis (Tiner, 1998). A wetland's ability to perform these functions are based on specific factors, including its position on the landscape and hydrologic connectivity (Hruby, 2004; Keddy, 2000). Three major functions that wetlands perform include improving water quality, maintaining water regimes, and providing suitable habitat for vegetation and wildlife species (Hruby, 2004).

Water quality functions performed by wetlands have been shown to remove organic and inorganic nutrients (especially phosphorus and nitrogen), as well as toxic substances from water (Mitsch & Grosselink, 2007). An additional function pertaining to water quality includes sediment trapping. Wetlands retaining sediment from overland flow or flood waters will substantially reduce sediment loading in nearby waterways resulting in a reduction of turbidity and protected shorelines (Tiner, 1998). Hydrologic functions performed by wetlands also help maintain water regimes through floodwater storage, which reduces peak flows during storm events, recharges groundwater, and reduces erosion. Habitat functions include providing various wildlife niches by producing habitat areas for migratory birds, native plants, and mammals (Hruby, 2004; Sheldon et al., 2005).

Wetland functions commonly performed by seasonal, depressional, and wet meadows in subalpine settings, although poorly understood due to lack of research, include water storage, sediment retention, habitat, and nutrient retention and cycling (Cooper, 1990; Sharp et al., 2012; Tiner, 1998). Water storage pertains to flood and storm damage protection by retaining flood waters that otherwise would flow into areas potentially prone to flood damage, thereby also providing a water source during dry seasons, groundwater recharge, and aesthetic appreciation (Tiner, 1998: Zedler, 2006). In addition, wetland water depth plays an important role in vegetation biodiversity. Sharp et al. (2012) analyzed wetland storage depths in montane wetland systems in Montana. The authors found that wetlands with greater water depths and fluctuations have higher biodiversity. Subalpine wet meadow vegetation studies in the Sierra Nevada Mountains similarly found overall vegetation diversity to be correlated with water level variations, indicating greater water level fluctuations increases biodiversity (Cooper et al., 2006; Loheide et al., 2009) as surface water enters the wetland carrying sediment particles, some of the sediment will settle out along with nutrients adsorbed to the sediment particles. The amount and type of sediment that will be retained in the wetland depends on the size of sediment particles and the residence time (Jackson, 2006). Nutrient retention and cycling increases plant and aquatic productivity while decreasing harmful sulfates (Tiner, 1998). Additionally, wetland plants remove nutrients such as nitrogen and phosphorus from flood waters while preventing eutrophication (nutrient overloading) of nearby bodies of water and streams (Jackson, 2006; Tiner, 1998).

## Wetland Elevation and Aspect

Few studies have analyzed wetland function over an elevational gradient; most wetland elevational studies relate to fen environments centered in the Rocky Mountains (Cooper, 1990; Cooper & Andrus, 1994; Johnson, 1996). These examples relate specifically to (1) species richness increasing as the amount of water decreases at the site (Cooper, 1990; Cooper & Andrus, 1994) and (2) zones near the wetland margin containing a greater number of vascular plants than zones in the center of the wetland (Cooper & Andrus, 1994). Cooper (1990) studied a subalpine wetland system in Rocky Mountain National Park with an elevation of 2,865 m, focusing on hydrology, water chemistry, soils, and vegetation pertaining to elevational changes. The wetland, a 63-ha complex occupying a creek valley, was carved out by Pleistocene glacial events (Cooper, 1990). Hydrology was analyzed via peizometers that were placed along four transects which spanned the entire wetland along with water level measurements taken throughout 1987-1988. Water samples were taken to determine the amount of calcium, magnesium, sodium, iron, aluminum, copper, and zinc via inductively coupled plasma analysis. Soil was sampled from hand dug pits from the wetland and tested for oxidation-reduction potential weekly along with temperature. Chemical and texture analysis was performed in a laboratory setting measuring pH, percent organic matter via loss at ignition, and texture via hydrometer method. The author utilized the releve method of Braun-Blanquet to study the wetland vegetation (Westhoff & Maarel, 1978). This approach uses floristic criteria to classify vegetation via random quadrant sampling. Vegetation was sampled and dried in a laboratory setting to measure percent loss. Results of the study found a strong correlation between vegetation and hydrology pertaining to water table depths and species richness. Specifically, Cooper (1990) found higher species richness within areas experiencing greater water table fluctuations.

Bliss (1963) has similarly described an alpine bog plant community in the Presidential Range in New Hampshire in terms of quantitative descriptions of plant communities related to soils and climatic factors pertaining to aspect. Climatic factors included snow impacts on bog plant communities, relating aspect and duration of snow cover to community type and seasonality. Soil samples were obtained and chemical analysis was conducted to determine pH, organic matter, total nitrogen, calcium, potassium, and phosphorus. Vegetation communities were determined via transects that covered 6.2% of the study area, and species were grouped based on dominance. Results indicated that snow depth and rate of snow melt both influenced soils and vegetation characteristics. In terms of soil, south-facing bog systems had better developed soils with deeper profiles. Total nitrogen was found to correlate with organic matter in all soils, and calcium/nitrogen ratios were 17:1. Soil pH was found to be low in all soils, ranging from 4.0 to 4.3. In terms of dominant vegetation communities related to aspect, a gradient was observed where increasing snow depth, soil moisture, and decreasing sunlight led to a more sedge dominated vegetation community (Bliss, 1963).

In a related study, Coop and Givinish (2007) concluded that north-facing alpine wet meadows have more clay-rich soil substrates based on a study conducted in the Jemez Mountains of northern New Mexico. The study area has an elevation range of 2700 to 3000 m and a semi-arid, and continental climate characterized by a mean annual precipitation of approximately 60 cm (Coop & Givinish, 2007). Finally, a subalpine vegetation study conducted in the central Cascade Range in Oregon found that surface temperature and available soil moisture limits the survival of seed germination, where north-facing alpine wet meadows have more favorable environments for seed germination, promoting greater species diversity (Miller & Halpern, 1998).

## Wetland Assessment Methods

Wetland assessment methods quantify ecological conditions as outlined in the Clean Water Act (1972), which states the principal goal is to restore the physical, chemical, and biological integrity of the waters of the United States (Fennessy, Jacobs, & Kentula, 2007). Condition can be defined as the relative ability of a wetland to support and maintain its complexity and capacity for self-organization with regard to species composition, physio-chemical characteristics, and functional processes as compared to wetlands of similar characteristics without human alterations (Fennessy et al., 2007). Other characteristics of a good wetland assessment method includes being rapid, an on-site assessment, and that it can be verified (Fennessy et al., 2007). Wetland assessment methods commonly used in the United States include the Wetland Evaluation Technique (WET) developed by Adamus (1983) and the HGM assessment developed by Smith, Ammann, Bartoldus, and Brinson (1995) is based on the HGM approach first developed by Brinson (1993) (Somerville & Pruitt, 2006).

The WET assesses 11 functions and values including: groundwater recharge, groundwater discharge, floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, wildlife diversity/abundance, aquatic diversity/abundance, recreation potential, and uniqueness/heritage. Each of these functions and values are evaluated on a scale of high, moderate, and low based on effectiveness/opportunity, and social significance/habitat suitability (Somerville & Pruitt, 2006). Effectiveness/opportunity refers to the wetland's capability to carry out ecological functions associated with its chemical, physical, or biological characteristics (e.g., floodwater storage). Social significance is based on the wetland's value perceived by society in terms of economic value (e.g., utilized for flood protection or water treatment) or any unique classification it holds (e.g., endangered species habitat) (Mitsch & Gosselink, 2007). However, WET has been criticized due to the lack of variability with the method and the inability to account for regional variations in wetland systems (Novitzki, Smith, & Fretwell, 1995; Somerville & Pruitt, 2006).

The HGM functional assessments are guided by regional HGM guidebooks developed for a specific ecoregion. HGM functional assessments estimate the functional capacity, magnitude, or level at which a wetland performs a function based on a regional reference wetland (Somerville & Pruitt 2006). Functional capacity is based on an indirect qualitative or direct quantitative measurement of the physical wetland characteristics (Smith et al., 1995). The HGM approach is a useful approach terms of classifying wetlands; however, other methods, such as the WSRWS, expand on the HGM approach to further assess wetland function (Fennessy et al., 2007).

The WSWRS utilizes the HGM approach to assess wetland functions (Hruby, 2008). The WSWRS is a rating system based on a wetland's sensitivity to disturbance, rarity, the functions provided, and whether it can be replaced. The rating system groups wetlands based on an estimate of value or level of functioning on a scale (high, medium, or low), primarily intended for use with vegetated, freshwater wetlands (Hruby, 2008). Three main categories scored pertaining to depressional wetlands include water quality function, hydrologic function, and habitat function. Water quality functional scores are based on whether the wetland has the potential to improve water quality. Water quality scores are derived from determining presence of surface inlet/outlets, the surface area seasonally ponded, and upstream land uses (e.g., grazing, untreated stormwater discharges, urban areas). Hydrologic functional scores are based on whether the wetland has the potential to reduce flooding and stream erosion. Hydrologic scores are derived from classifying surface inlet/outlet, depth of storage basin, and impoundment characteristics (e.g., headwater of stream, known flooding problems downstream). Finally, habitat functional scores measure the extent to which a wetland can provide habitat. Habitat function scores are the most complex to calculate based on the number of criteria to measure. Scores are derived from vegetation characteristics (e.g., emergent plant size, aquatic bed presence, tree cover), vegetation species richness, interspersion of habitat, and type of priority habitats.

The WSWRS method was developed for assessing wetlands below 1000 m in elevation, perhaps limiting its relevance for assessing subalpine wetlands (Hruby, 2008). A potentially more suitable method for calculating wetland ecological function is the WESPUS. Similar to the WSWRS method, WESPUS uses a list of indicators to determine a functional score (Adamus, Morlan, & Verble, 2010), including elevation and wetland position in the landscape. Despite that the WESPUS utilizes more wetland function assessment indicators, the WSRWS is the primary assessment method used in Washington State (Hruby, 2008).

# CHAPTER III

# STUDY AREA

The study area for this research is a portion of the Swauk Watershed (Figure 1), and the watershed is bordered by Teanaway Ridge to the west and Table Mountain to the east. The county line follows the watershed's northern boundary, while its southern boundary is the point at which Swauk Creek enters the Yakima River. The study area can be characterized by the following aspects: climate, geology, topography, wetland soils, hydrology, flora, natural disturbance, human disturbance, and management.

## Climate

The Swauk Watershed is located on the eastern side of the Cascade Range and is influenced by the seasonal migration of the Aleutian Low and Hawaiian High pressure systems, resulting in cold, snowy winters and hot, dry summers respectively (Mass, 2008). Situated at a high-elevation, the study area exhibits lower temperatures, and more precipitation than the surrounding lowlands (Price, 1981). The average summer air temperature in the watershed is 57º F and the average winter air temperature is 28º F (Natural Resource Conservation Service [NRCS], n.d.a). Diurnal temperature ranges can be substantial (59º F during summer and 54º F during winter) and influence vegetation, soil, and geomorphic processes especially during the summer season when the ground does not have snow for insulation (NRCS, n.d.a; Wenatchee National Forest, 1997).

According to NRCS (n.d.a), the area receives approximately 35.5 inches of precipitation annually for the upper areas of the watershed, 70% of which falls in the form of snow (Figure 2). The average April 1 snowpack for Blewett Pass (located

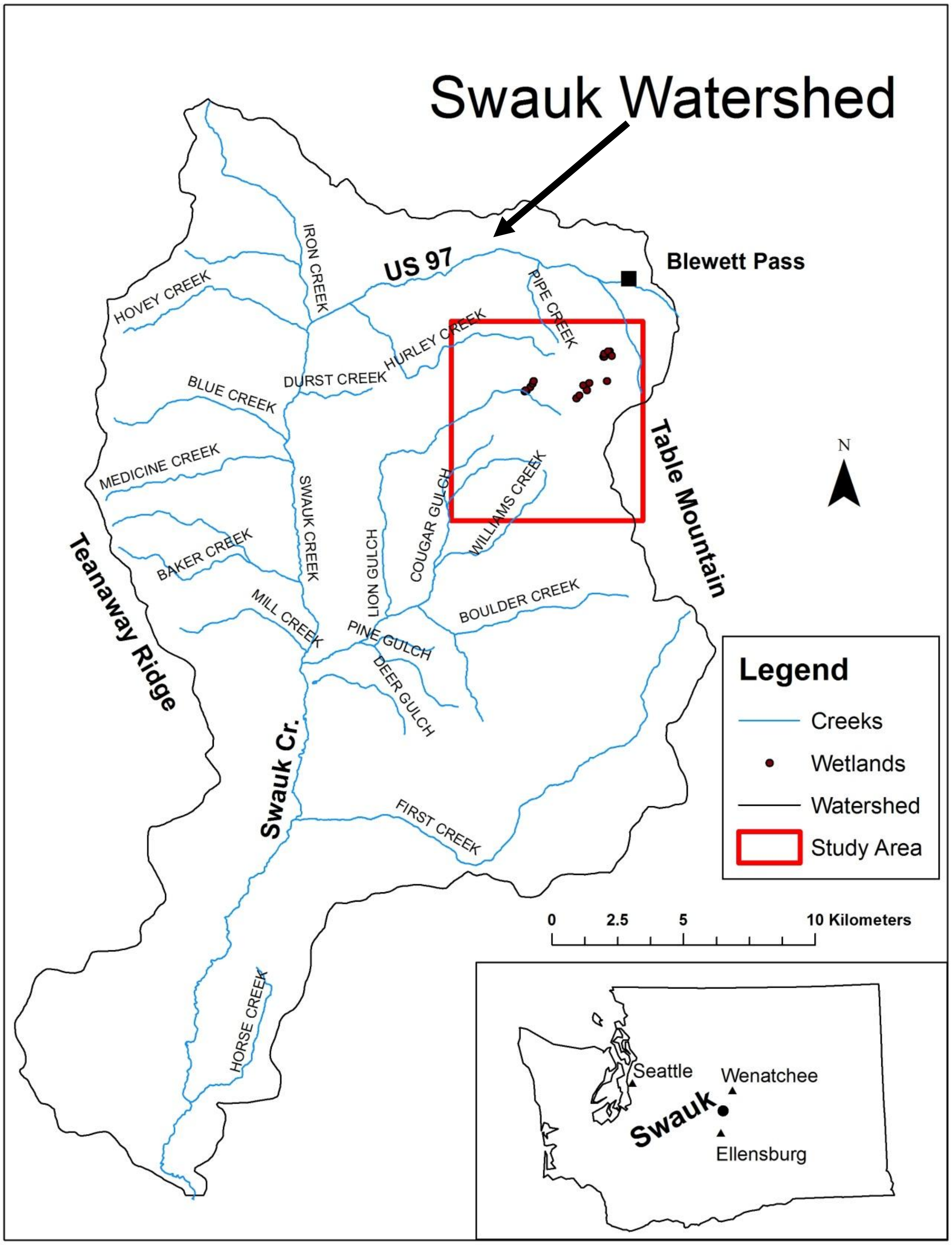


*Figure 1*. Swauk Watershed with study area location. Data adapted from Lillquist (2001)

1.6 km north of study area) is 40 inches. Topographic variations of the landscape cause differences in precipitation totals, though this variation ranged only between 35 – 38 inches between the low- and high-elevation wetlands examined in this study (Figure 3; Wenatchee National Forest, 1997).

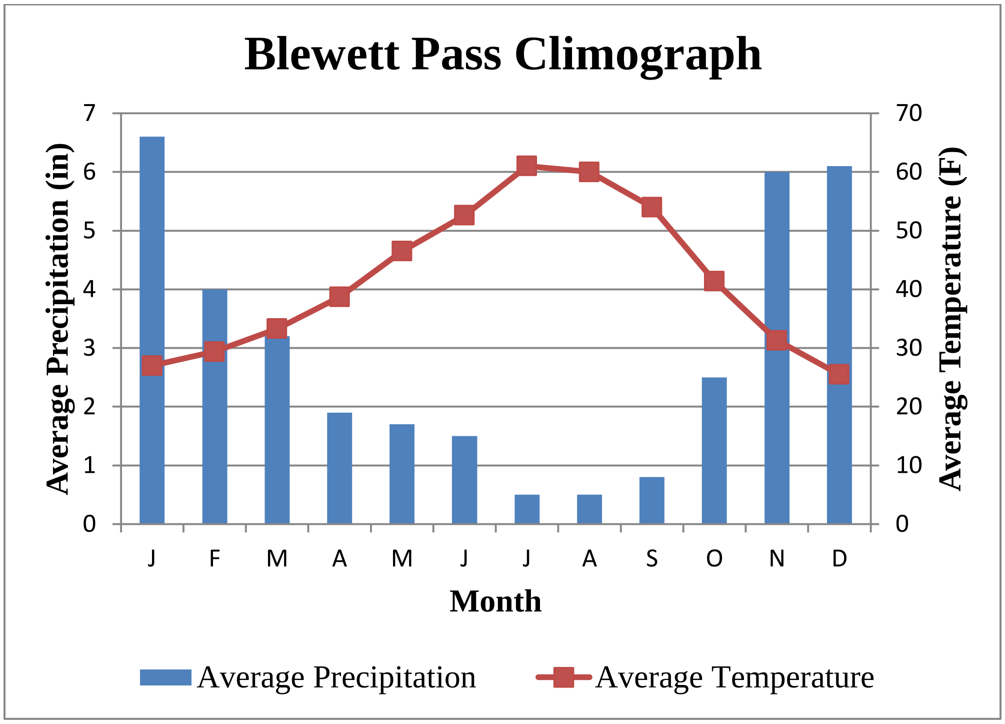


*Figure 2*. Climograph of 1990 - 2012 Blewett Pass SNOTEL data (NRCS, n.d.a).

Geology

The geology of the Swauk Watershed consists of Columbia River Basalts in the east and sedimentary and volcanic rocks of the Swauk Formation and Teanaway Basalt in the central and western portions (Tabor, Waitt, Frizzell, Byerly, & Bentley, 1982). Landslide activity is directly tied to the underlying geology (Lillquist, 2001; Tabor et al., 1982). The basalts that flowed out over the pre-existing sedimentary formations became highly fractured over time, and as water moved down through this formation, it came in contact with the folded sedimentary bedding planes (Lillquist, 2001; Wenatchee National

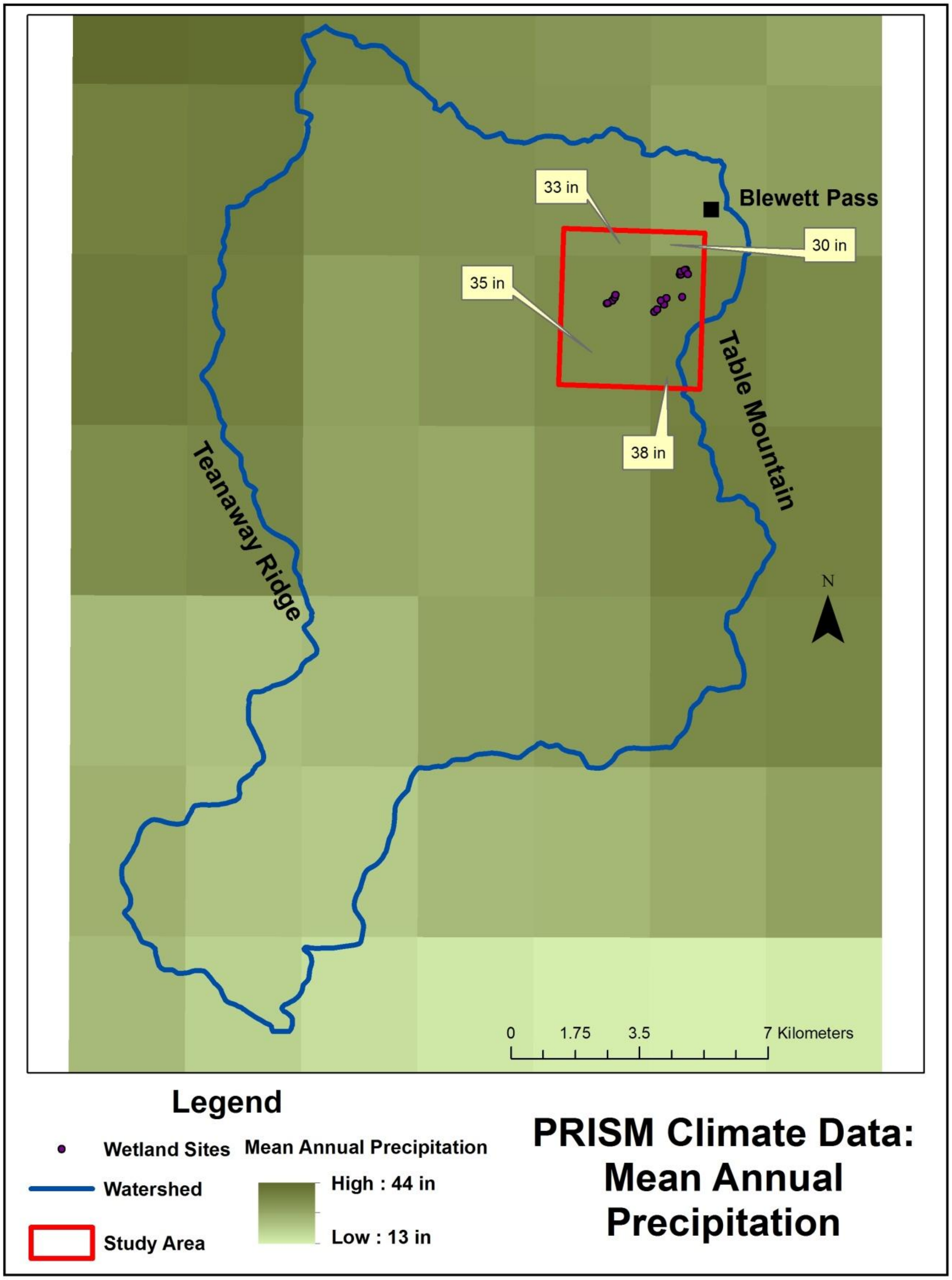


*Figure 3*. Mean annual precipitation data for the Swauk Watershed (PRISM Climate Group, n.d.).

Forest, 1997). As the slip planes became saturated with water, the basalts collapsed and weathered away leaving remnant ancient landslide slopes along the eastern margin of the watershed near Table Mountain (Figure 4). As a result, the current surface geology is comprised of mostly landslide deposits, folded sedimentary materials of the Swauk Formation, and Teanaway Basalts (Lillquist, 2001; Wenatchee National Forest, 1997).

Mass wasting processes (Figure 5) had significant effects in shaping the landscape within the watershed and these processes continue to operate. Most of the large landslides occurred along the Table Mountain Escarpment (Wenatchee National Forest, 1997). The most common types of landslide in the watershed are translational slides, which are characterized by having hummocky terrain that facilitates wetland development (Lillquist, 2001). The study area, which includes the 18 wetland sites, is located on the remnants of an inactive-mature slide-flow landslide surface near the base of Table Mountain (Lillquist, 2001; Wenatchee National Forest, 1997). K. Lillquist obtained a radiocarbon date on a wood sample from the bottom of a sag pond near the study area in order to determine the age of the landslide on which the wetlands sit. The radiocarbon date was sent to Beta Analytic of Miami, Florida, and the landslide's minimum age is dated to be approximately 4,190 +/- 40 $^{14}$C years before present (BP) (K. Lillquist, personal communication, November 23, 2015). This calibrates to a median probability age of 4,725 calendar years BP with a two sigma age range of 4,584 – 4,843 calendar years BP (Reimer et al., 2013).

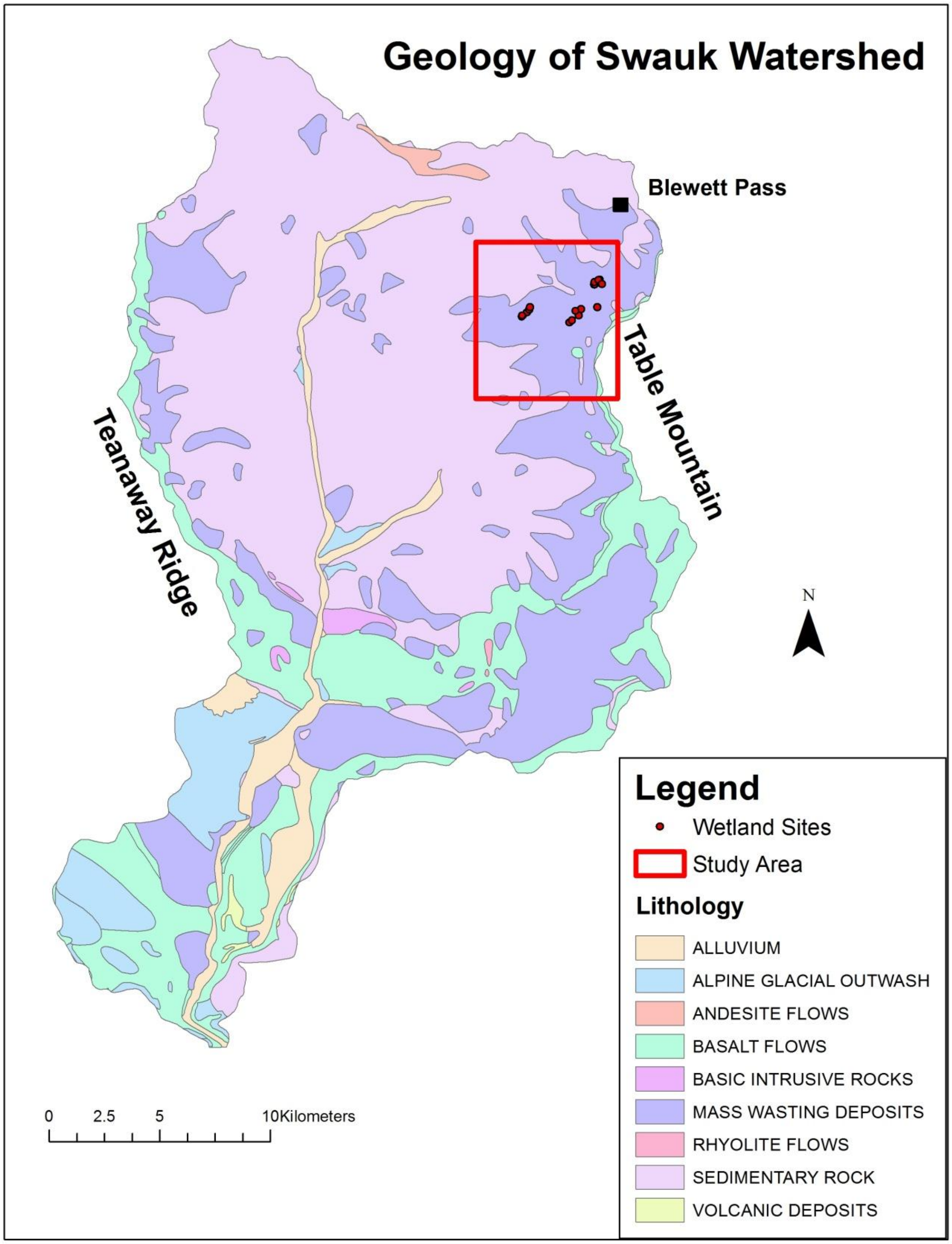


*Figure 4*. Geology of Swauk Watershed. Adapted from Tabor et al. (1982).

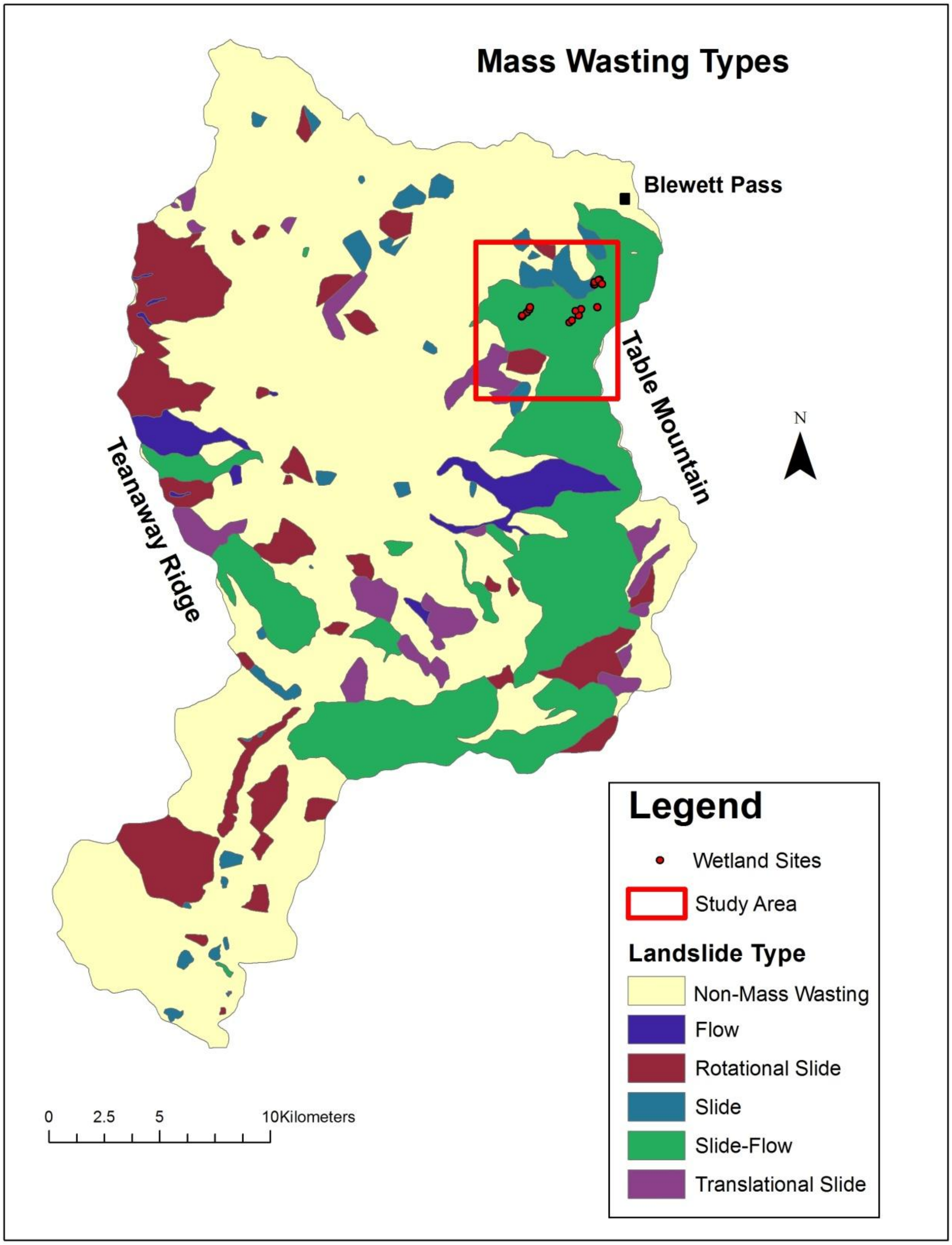


*Figure 5.* Mass wasting types in Swauk Watershed. Data adapted from Lillquist (2001).

## Topography

The study area topography (Figure 6) varies widely in both slope angle and elevation, as interpreted from contour line interpretation. The northeastern extent of the study area has moderately steep slope angles to the east of the mid-elevation wetland sites, within the slide-flow landslide boundary (Lillquist, 2001). The southeastern extent has the steepest slope angles to the east of the high-elevation wetland sites, due to the closer proximity to the summit of Table Mountain. The southwestern extent has shallower slope angles, where the low-elevation wetlands occur within the landslide boundary. Finally, the northwestern extent of the study area is outside of the complex slide-flow boundary. Figure 7 illustrates approximate wetland site position on the slide-flow landslide deposit. The high-elevation wetlands are found on the main body depression of the landslide deposit, while the mid-elevation wetlands are found near the base of the main body, and low-elevation wetlands are found near the toe.

## Wetland Soils

Subalpine wetland soils in the study area (Figure 8) are predominately of the Bograp variant loam series, which are tied to mountain slopes and have parent materials derived from residuum and colluvium associated with basalt, are well drained, and consist of ashy sandy loam found under coniferous type forest (NRCS, 2003). Hakker clay loams are classified as having parent material derived from colluvium, are poorly drained, and are associated with hydric soils in areas with perched water tables. Nard loam is characterized by having residuum and colluvium parent materials associated with sandstone, are moderately well drained, and are also associated with hydric soil indicators in areas with perched water tables. Finally, Ainsley variant gravelly loams, also well

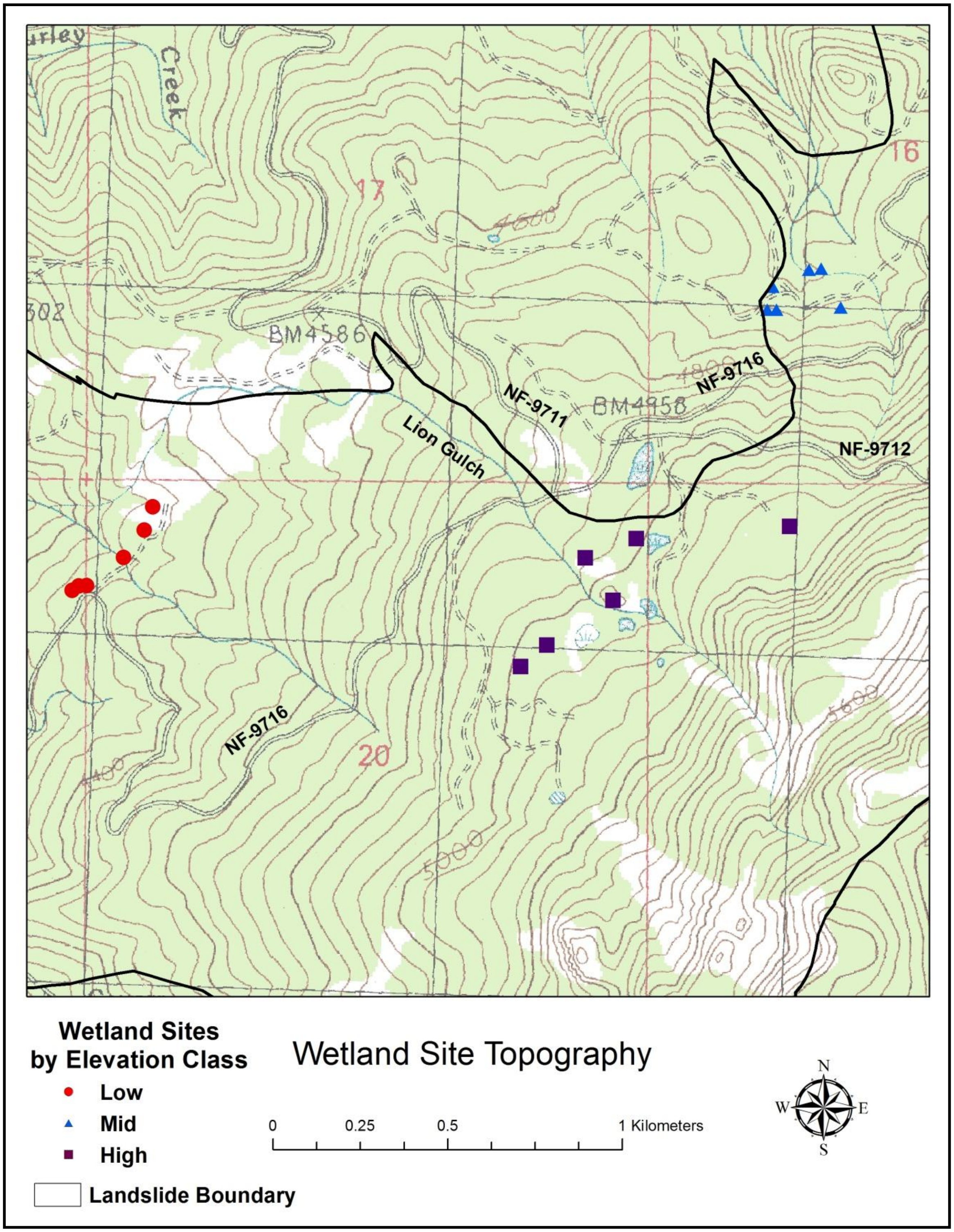


*Figure 6*. Study area topographic map with wetland sites.

drained, have parent materials of colluvium and residuum derived from andesite and basalt (NRCS, 2003).The wetland soils in the watershed have been influenced by historical grazing activity. Heavy grazing activity in the early 20th century caused soil compaction, which slowed water infiltration rates, therefore, increasing surface soil erosion (Erickson, 2001; Wenatchee National Forest, 1997).

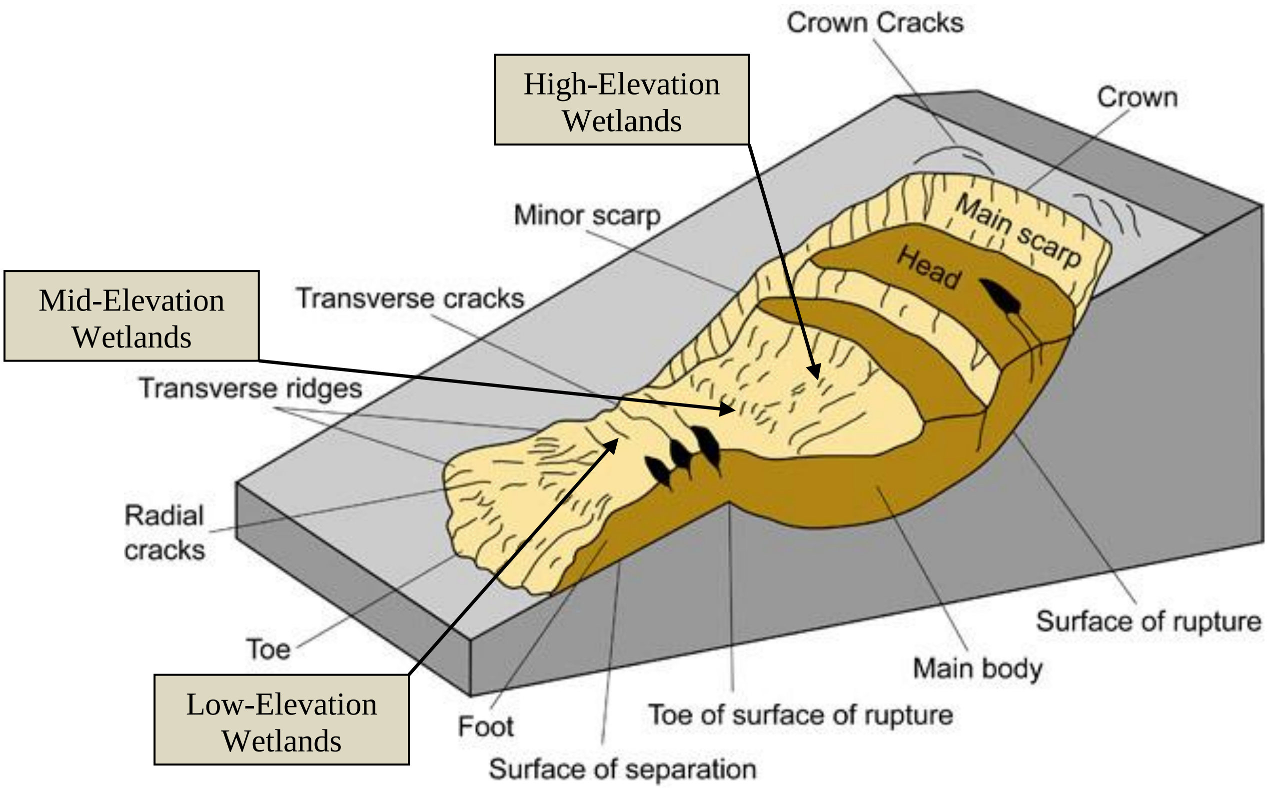


*Figure 7*. Wetland site position on landslide (modified from Idaho Geological Survey, n.d.). *Note.* Wetland placement is approximate.

## Hydrology

The combination of soils derived from sandstones and steep slopes both contribute to the hydrologic system by routing water quickly from hillslope to valley floor, therefore, strongly influencing peak flows in the study area (Wenatchee National Forest, 1997). Depressional wetlands alter runoff patterns by intercepting this runoff and

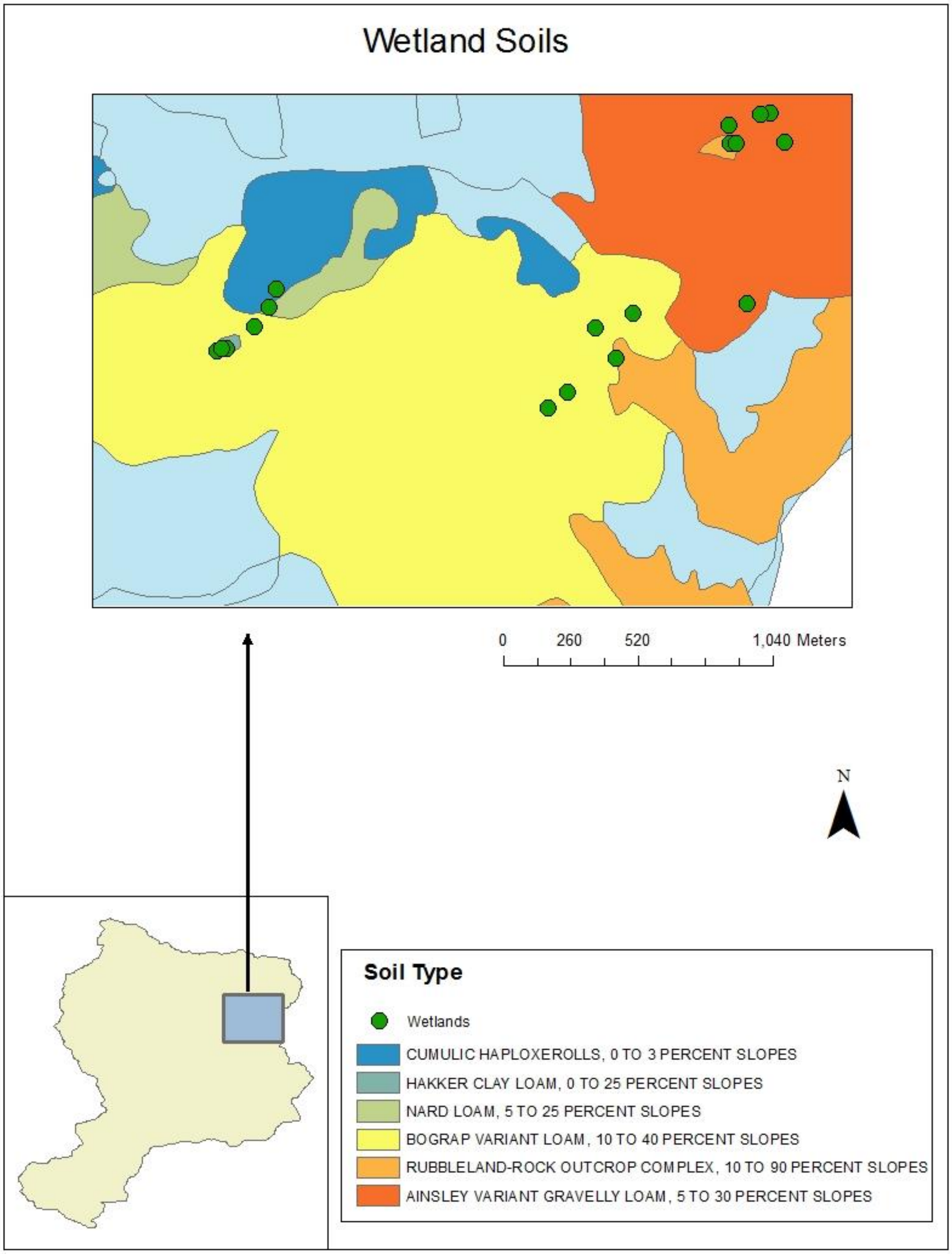


*Figure 8*. Wetland soils in study area. Adapted from NRCS (2003).

acting as water storage, in turn slowing runoff, increasing groundwater recharge, and reducing erosion (Keddy, 2000; Mitsch & Gosselink, 2007). Runoff and snowmelt are the two primary processes that inundate the wetlands in the study area; early to mid-summer, wetlands are at maximum water depth (21 - 49 cm) due to peak snowmelt (Brinson, 1993; Mass, 2008; Wenatchee National Forest, 1997).

Flora

Upland vegetation within the study area include ponderosa pine (*Pinus ponderosa*), Douglas-fir *(Pseudotsuga menziesii*), grand fir (*Abies grandis*), and subalpine fir (*Abies lasiocarpa*) (Wenatchee National Forest, 1997). Riparian vegetation is predominantly red alder (*Alnus rubra*), dogwood (*Cornus* spp.), Rocky Mountain maple (*Acer glabrum*), and grand fir (*Abies grandis)* (Wenatchee National Forest, 1997). Dominant wetland vegetation consists of sedges (*Carex scopulorum* and *Carex limnophila*), alpine timothy (*Phleum alpinum)*, green fescue (*Festuca viridula*), tufted hairgrass (*Deschampsia caespitosa*), Baltic rush (*Juncuas balticus*), and buttercup (*Ranunculus orthorhynchus*). Many of these species and other grasses, sedges, and forbs were either suppressed or eradicated in wetlands as a result of grazing and re-vegetation prior to 1996 (Kovalchik, & Clausnitzer, 2004). Other native species, such as western false hellebore (*Veratum californicum*), larkspur (*Delphinium* spp.), and waterleaf (*Hydrophylum* spp.), also inhabit these wetlands (Kovalchik, & Clausnitzer, 2004; Wenatchee National Forest, 1997; Williams & Lillybridge, 1987).

Wetlands in the Swauk Watershed have not been studied specifically before this research. The individual ecological characteristics are unknown (Wenatchee National Forest, 1997). Figure 9 illustrates National Wetland Inventory (NWI) distribution

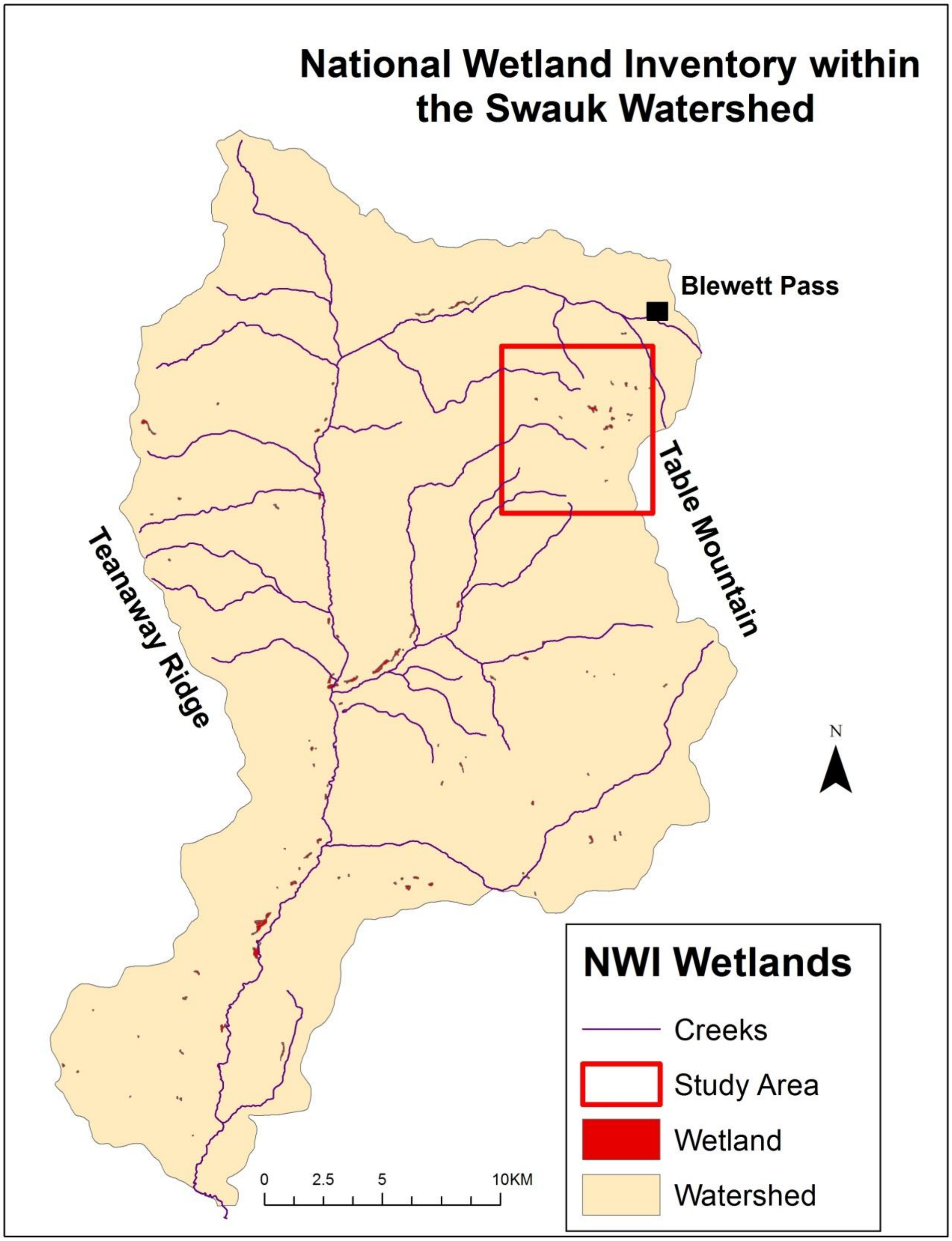


*Figure 9*. Wetland distribution throughout the Swauk Watershed (U.S. Fish and Wildlife Service, 1996).

throughout the Swauk Watershed. The NWI shows a uniform distribution of wetlands throughout the watershed, with the exception of near the base of Table Mountain, where wetlands are more concentrated.

## Natural Disturbances

Historically, disturbances that influenced the Swauk Watershed landscape and wetland vegetation include fire, insect infestation, and disease. Fire had a significant impact in the development of the watershed throughout history, shown through tree ring analysis conducted by the U.S. Forest Service (Wenatchee National Forest, 1997; Wright & Agee, 2004). Frequent, low-intensity fires were typical of lower elevations in this watershed. The higher elevation areas of the watershed experienced a less frequent fire regime (approximately every 30 years), especially in the subalpine fir zone (Wright & Agee, 2004). Currently, as a result of fire suppression, greater frequency of stand-destroying fires occurs due to overgrowth and fuel loading. These fires cause higher amounts of erosional runoff altering watershed in terms of sediment loading in wetlands and potential infrastructure washout including roadways and buildings (Wenatchee National Forest, 1997).

The study area wetland vegetation and surrounding forest have been subject to insect and pathogen influences, altering species composition (Wenatchee National Forest, 1997). According to Wenatchee National Forest (1997), forest insects and pathogens influence the vegetation in the Swauk Watershed, including the study area, by altering stand composition, structure, and continuity. Historic insect and pathogen disturbance regimes varied with the tree species. Grand fir were mostly influenced by mountain pine beetle. Once the tree became large enough to support beetle larvae, outbreaks occurred that killed it thus contributing to stand-replacing fires The current insect and pathogen disturbance regime in the Swauk Watershed includes Indian paint fungus, which has moved into grand fir forests from higher-elevation subalpine fir forests as a result of longer fire-return intervals. The Indian paint fungus leads to wood decay resulting in tree mortality (Wenatchee National Forest, 1997). The historic insect and pathogen disturbance regime for the subalpine fir trees in the Swauk Watershed, including the study area, include mountain pine beetle (*Dendroctonus ponderosae*), spruce beetle (*Dendroctonus rufipennis*), Douglas-fir beetle (*Dendroctonus pseudotsugae*), and fir engravers (*Scolytus ventralis*). The spruce beetle typically attacked old windblown trees, which most likely suffered from tomentosus root disease. The Douglas-fir beetles and fir engraver beetles killed small numbers of trees. The highest mortality occurred during prolonged drought events (Wenatchee National Forest, 1997).

## Human Disturbances

Historic land uses in the Swauk Watershed that have played a role in influencing wetland systems, include grazing and logging. Currently there are about 5,500 acres of private land (as a result of mining claims and homesteads) and roughly 48,000 acres of federal land within the boundaries of the Swauk Watershed (Wenatchee National Forest, 1997). Grazing directly influences wetlands through vegetation loss and soil compaction resulting in both positive and negative impacts. Marty (2005) conducted a wetland study in California pertaining to cattle grazing and found that plant diversity increases with cattle grazing. However, some negative aspects include increased runoff resulting from soil compaction and increased potential to spread invasive plant species (Wenatchee National Forest, 1997). The United States Forest Service (USFS) estimates that 60% of the Swauk Watershed has been influenced by timber removal in the last 100 years, and a majority of the early logging sales came from dead timber as a result of fire and insect infestation (Wenatchee National Forest, 1997). According to Elliott, Hitchcock, and Krueger (2002), logging (tree-stand removal) in the Swauk Watershed may decrease evapotranspiration resulting in higher amounts of subsurface flow and channel erosion influencing wetland pool levels. Main

Current Swauk Watershed land uses mainly consist of winter recreation (e.g., cross-country skiing, snowshoeing, snowmobiling), summer recreation (e.g., hiking, camping, off-highway vehicle use), small timber operations, and grazing (Wenatchee National Forest, 2003; Wenatchee National Forest, 1997).

## Management

Wetlands in the Wenatchee National Forest are protected according to Executive Order # 11990 and the Wenatchee National Forest Management Plan (1990) which states "areas that are inundated by surface or ground water with a frequency sufficient enough to support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Under normal circumstances the areas does or would support prevalence of vegetative or aquatic life." Wetlands are also protected in the Wenatchee National Forest in terms of future planning according to Section 219.23 of the National Forest Management Act; part f of Section 219.23 states that "adoption of measures, as directed in applicable Executive orders, to minimize risk of flood loss, to restore and preserve floodplain values, and to protect wetlands."

Essentially, Swauk Watershed wetlands are considered a management priority in terms of maintenance and enhancements. According to Wenatchee National Forest

(2003), activities that impact wetland habitats such as logging, road construction, campgrounds, and recreation activities are to be regulated to limit adverse impacts.

# CHAPTER IV

# METHODS

## Introduction

To develop an understanding of ecological function for wetlands near Table Mountain, the following procedure was used: 1) wetland identification; 2) wetland classification; 3) ecological function characterization; and 4) statistical analysis.

## Wetland Identification

Digital wetland data compiled by the USFWS was overlaid with landslide data from the Swauk Watershed adapted from Lillquist (2001) in a Geographic Information System (GIS) to determine the number of potential wetlands within the study area boundary consisting of one contiguous landslide deposit. According to NWI data, there are 15 wetlands in the study area, seven of which are classified as freshwater forest/shrub wetlands and the other eight are freshwater emergent wetlands. The NWI data was first compiled in 1976, and has a small margin of error because the USFWS produced the data through stereoscopic analysis of high altitude aerial photographs (Gray, 2011). The use of aerial photography in the Swauk Watershed to identify wetlands was problematic because trees restrict the amount of exposed wetlands. Therefore, the NWI data, missed small wetlands in forested portions of the watershed (Wardrop et al., 2007). For this reason, field checks were done to confirm the presence of wetlands in the study area, using topographic maps to locate depressions that potentially contain additional wetlands. Field observations revealed an additional three wetlands, resulting in 18 total.

## Wetland Classification

Wetlands identified through the NWI data and additional field checks were confirmed to be depressional wetlands according to the HGM classification method. Distinguishing features taken into consideration included whether the wetland was isolated (no obvious inflow or outflow), or had either an intermittently flowing outlet or a highly constricted permanently flowing outlet (Brinson, 1993; Hruby, 2004; Sheldon et al., 2005). It was assumed from the general topographic characteristics of landslide deposits that all the identified wetland sites were depressional.

The wetlands were delineated in the field according to the USACE *Wetland Delineation Manual* (1987), using indicators of hydrophytic vegetation, hydric soils, and wetland hydrology. Hydrophytic vegetation was sampled utilizing three transect lines to capture presence, and identifications were done using dichotomous keys compiled by Hitchcock and Cronquist (1973). Transect lines started and ended at hydric soil indicators that were determined by examining soil samples along wetland boundaries. Transect lines were evenly spaced across each wetland at approximately ¼, ½, and ¾ of the width respectively. Wetland vegetation indicator status (e.g., facultative, obligate, upland) was utilized for supporting evidence along with ponding and hydric soil indicators associated with wetland identification. Vegetation classified as facultative or obligate supported positive wetland identification, while upland status was used to support wetland boundary delineation, in addition to soil samples lacking hydric soil indicators. Hydric soil indicators, outlined in USACE (1987), were used in addition to vegetation for determining the extent of wetland boundaries. Soil profiles, exposing approximately eight inches of soil, were examined for hydric indicators including low chroma colors (via

Munsell soil chart), gleyed colors, high organic content, organic streaking, and redoximorphic features (yellow/red streaks in soil profile). Wetland hydrology was determined by visually inspecting each wetland for depth and duration of ponding. In addition, each wetland was recorded via Global Positioning Satellite (GPS) and integrated into GIS for elevation calculations and inventory purposes. Wetland area was measured by utilizing the final three vegetation transect lengths that spanned the width of each wetland, as well as wetland length, to create an ellipse, upon which, surface area was calculated by utilizing $A = \pi ab$, where a = middle transect length and b = wetland length. Both wetland width and length were measured in the field via metric tape measure.

## Data Collection

Wetlands were identified in late June 2010, sampled in mid-July to mid-August 2010, and once more to collect soil samples in late September 2010. One water depth measurement was taken during peak runoff (late July), and the second measurement was taken during low levels during late September 2010. Water measurements were taken and recorded at the deepest location of each wetland. Wetland function data was calculated and recorded during the sampling period following the assessment with the WSWRS and the modified WESPUS. Vegetation transect data was collected in the field and was used to determine dominance, percent similarity, species richness, and diversity. Finally, soil data were measured in the laboratory.

### *Wetland Function: Washington State Wetland Rating System*

Following identification and determination of potential wetlands, the sampling period began with the WSWRS. Utilizing the depressional wetlands sections of the form, function data was collected according to WSWRS. The first step associated with the WSWRS consists of the determination of the HGM classification. The WSWRS developed questions specific to each HGM class, therefore determining the appropriate HGM class was a priority. The three main categories of functions assessed included water quality, hydrology, and habitat. In each category, the WSWRS determines the potential and opportunity for a wetland to perform the function. The potential aspect is based on actual characteristics of a wetland, such as the size of the wetland, depth, and duration of ponding. Opportunity is based on the situation of wetland in terms of its surroundings. For example, if a wetland is in a flood prone area, the wetland has the opportunity to reduce flooding through water retention. Scores were calculated based on potential and then multiplied by the scores for wetland opportunity. This determines a final functional rating score for each wetland. Finally, to reduce bias, the functional scores were placed into one of four categories to determine the level of function performance.

Variables measured for depressional wetlands are noted in Table 1 and scoring forms are located in Appendix A. Most of these variables were assessed through visual estimation, except for storage depth and vegetation richness. Storage depths were measured relative to bank full indicators (e.g., wetland boundary, high water mark) with a graduated staff at the low point in each wetland, while vegetation richness was measured by counting the number of different vegetation species present along each transect line per wetland site.

Table 1

*WSWRS Variables Assessed for Depressional Wetland HGM Class*

| WSWRS Variables | Classes | Method |
|---|---|---|
| *Water Quality* | | |
| Inlet/Outlet | No surface outlet<br>Intermittent flowing outlet<br>Highly constricted permanent flowing outlet<br>Permanent flowing outlet | Visual Estimation |
| Soil: Clay or Organic | Yes/No | Visual Estimation |
| Vegetation Cover | > 2/3 of area<br>1/3 to 2/3 of area<br>1/10 to < 1/3 of area<br>< 1/10 of area | Visual Estimation |
| Seasonal Ponding | > 1/2 total area<br>1/4 - 1/2 total area<br>< 1/4 total area | Visual Estimation |
| Special Pollutant Sources | Grazing, untreated stormwater, tilled fields, residential area drainage, golf courses, fed by groundwater high in phosphorus or nitrogen | Visual Estimation |
| *Hydrology* | | |
| Inlet/Outlet | No surface outlet<br>Intermittent flowing outlet<br>Highly constricted permanent flowing outlet<br>Permanent flowing outlet | Visual Estimation |
| Storage Depth | 6 Classes raging from < 6 inches to > 3 feet | Quantitative measurement |
| Flooding Problems | Headwater of river<br>Drains to river with flooding problems<br>No surface outlet<br>Other | Visual Estimation |

Table 1 (Continued)

| WSWRS Variables | Classes | Method |
|---|---|---|
| *Habitat* | | |
| Vegetation Structure | Aquatic bed<br>3 classes of emergent plant height (0-40 in.)<br>Scrub/Shrub<br>Forested | Visual Estimation |
| Open Surface Water | Yes/No | Visual Estimation |
| Vegetation Richness | > 9 Species<br>4-9 Species<br>< 4 Species | Quantitative Measurement |
| Interspersion of Habitat | Low<br>Moderate<br>High | Visual Estimation |
| Special Habitat Features | Loose rocks, cattails, standing snags, ponded vegetation, beaver activity, presence of invasive species | Visual Estimation |
| Buffers | 10 classes ranging from 330 ft to 0 ft | Visual Estimation |
| Wet Corridors | 30 ft wide > 1/4 mile long permanent flowing water<br>30 ft wide > 1/4 mile long seasonal flowing water<br>Wetland within 1/2 mile of any stream | Visual Estimation |

*Wetland Function: Wetland Ecosystem Services Protocol for the United States*

Additional variables were assessed from a modified version of WESPUS. These variables were measured during the sampling period. Variables are in question format with categorical answers dependent on wetland characteristics. Variables measured consisted of ponding characteristics, woody debris, surrounding landscape, and ground characteristics. Most were assessed through visual estimation, except for woody debris greater than 4 inches in diameter and downed wood pieces. For downed wood greater than 4 inches in diameter, individual downed pieces were counted that appeared to be greater than 4 inches in diameter up to three pieces, upon which, classified that wetland as having several. As for downed wood pieces, similarly, downed wood pieces were counted up to three pieces, upon which, classified that wetland as having several downed wood pieces. Table 2 lists all 15 additional variables that were measured from the modified version of WESPUS.

Table 2

*WESPUS Variables*

| WESPUS Variables | Classes | Method |
|---|---|---|
| *Vegetation* | | |
| % Seasonally Ponded | >75; 50-75; 25-50; 5-25; <5 | Visual Estimation |
| % Shaded by Canopy | >75; 50-75; 25-50; 5-25; <5 | Visual Estimation |
| Woody Debris >4 in Diameter | Few; Several | Measurement |
| % Unshaded Vegetation | >95; 50-95; 25-50; 5-25; <5 | Visual Estimation |
| % Herbaceous Cover | >80 Grasslike; 50-80 Grasslike 50-80 Non-Grasslike; >80 Non-Grasslike | Visual Estimation |
| Downed Wood Pieces | Few, Several | Measurement |
| % Woody Vegetation | >95; 50-95; 25-50; 5-25; <5 | Visual Estimation |
| *Land use* | | |
| Public Access | Unrestricted; Restricted | Visual Estimation |
| Land Uses | Timber; Grazing; None | Visual Estimation |

Table 2 (Continued)

| **WESPUS Variables** | **Classes** | **Method** |
|---|---|---|
| Natural Landcover in 100ft Buffer Upslope | Impervious Surface; Bare Pervious Surface<br>Cultivated Row Crops; Artificial Areas<br>Mowed Grazing Land; Other; >90% Natural | Visual Estimation |
| *Physical Characteristics* | | |
| Vegetation Height | Uniform; Very Diverse | Visual Estimation |
| % Bare Ground | <5; 5-20; 20-50; >50 | Visual Estimation |
| Upland Inclusion | Many; None (or one clump) | Visual Estimation |
| Ground Irregularity | Several, Intermediate, Few or None | Visual Estimation |
| % Wetland Edge Slope | >75; 50-75; 25-50; 1-25; <1 | Visual Estimation |

*Vegetation Sampling*

Vegetation data was collected for the purpose of species composition via the three transects used for each wetland delineation, determining species dominance, diversity, richness, and similarity (Figure 10). The three transect lines were spaced evenly across each wetland and started and ended at the wetland boundary with transect lengths varying from 4.2 – 50.3 m. Vegetation species identification was determined by utilizing dichotomous keys derived by Hitchcock and Cronquist (1973). Vegetation cover was calculated by dividing the length of which a particular vegetation community had contact with the transect lines by the total length. Vegetation cover data was used to determine species dominance, diversity, richness, and similarity. The 50/20 Rule was used for determining dominant communities, in which vegetation cover for each species, per wetland, was ranked from the highest percent cover to the lowest. An individual vegetation species that exceeded 50% cover was considered a dominant species, along with any lower ranked individual species having 20% or more coverage. If one individual species did not equal or exceed 50% cover, the highest ranked species in terms of percent cover was selected until the cumulative percent cover of selected individual species reached or exceeded 50% (USACE, 1998).

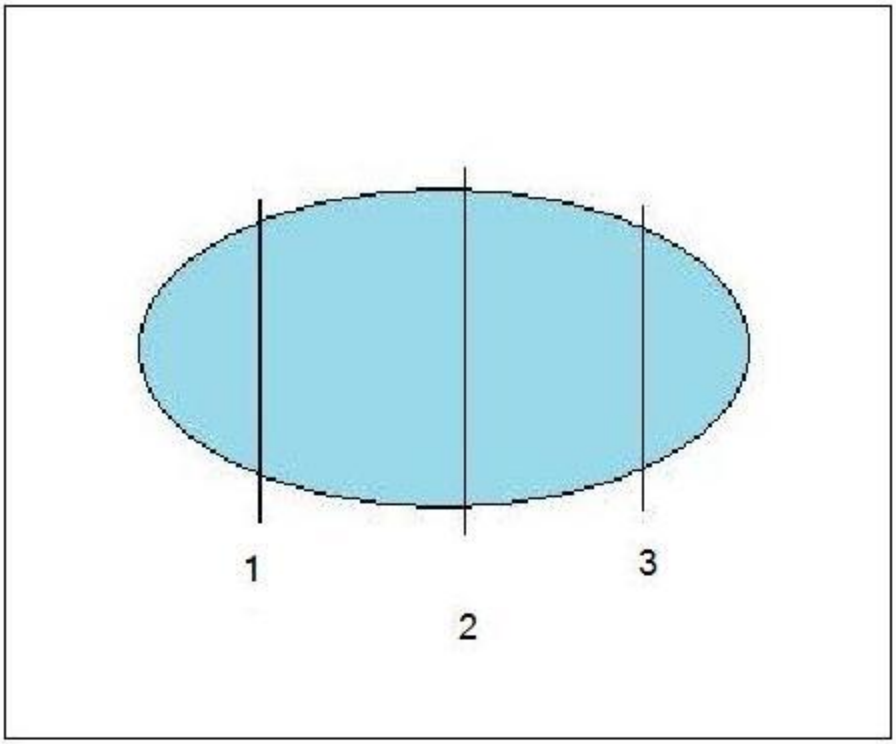


*Figure 10.* Vegetation sampling transect lines.

*Soil Analysis*

Eighteen soil samples were obtained in late September 2010 and analysis began shortly after consisting of organic matter, percent sand, pH, and macronutrient analysis. One soil sample was taken from the center of each wetland site by removing the top two inches of duff layer, and excavating a sample approximately eight inches deep by four inches wide by four inches long (Hruby, 2004). Soil samples were first dried for 24 hours in a Sheldon Manufacturing VWR International Model 1320 Gravity Convection

Laboratory Oven. Organic matter was determined through loss at ignition, which utilized a Thermo Scientific Thermolyne Type F6000 Furnace to burn off organic matter at a temperature of 400 degrees Celsius for 10 hours according to the Natural Resource Conservation Service soil analysis manual (NRCS, 2004). The pH levels of hydric soils were recorded with an IQ120 ISFET pH Tester in the laboratory. Forty grams of soil was placed in a beaker and mixed with 40 ml of distilled water to create a solution from which the pH reading was taken (NRCS, 2004). Percent sand and silt was calculated through the use of the sieve shaker method which utilized six different sized sieves to remove very coarse sand (size 16), coarse sand (size 35), medium sand (size 60), fine sand (size 120), very fine sand (size 230), and silt (remnants). Each sample was placed in the mechanical Tyler RX-29 Ro-tap sieve shaker for 20 minutes to allow sufficient separation and then weighed (NRCS, 2004).

Finally, macronutrient concentrations were measured using the LaMotte model STH-14 soil test kit and recorded according to steps outlined in the LaMotte Instruction Manual (2001). Macronutrients concentrations included nitrate and nitrite nitrogen, ammonia nitrogen, phosphorus, potassium, calcium, magnesium, aluminum, and ferric iron. First, a soil slurry was made by mixing 4 grams of soil with 14 ml of extraction solution. Concentrations of each macronutrient in pounds per acre or parts per million were estimated by adding drops or tablets of reagent solution to soil extract samples, and comparing color changes to graduated color charts.

*Statistical Analysis*

Species diversity was calculated by using Simpson's Index:

$D = 1 - \sum p^2 i$

Where $D$ = Simpson's Index

$Pi$ = Proportion of species $i$ in the community.

Utilizing transect data, species richness was calculated using the jackknife estimate method. This method uses presence/absence of vegetation species for each transect and its associated wetland:

$\hat{S} = s + \left(\frac{n-1}{n}\right)k$

Where $\hat{S}$ = Jackknife estimate of species richness

$s$ = Observed total number of species in $n$ transects

$n$ = Total number of transects samples

$k$ = Number of unique species (species found only in one transect).

Finally, percent similarity was calculated using the coefficient of community method. This method measures the difference in proportion of each dominant vegetation community found among each wetland site between two elevation classes (e.g., low vs high, low vs mid, mid vs high):

$C = \frac{2W}{a+b}(100)$

Where $C$ = Measure of similarity between two elevation classes (0 to 100)

$a$ = Sum of scores for one class

$b$ = Sum of scores for the second class

$W$ = Sum of lower scores for each species.

Statistical analysis was conducted to identify differences in wetland characteristics between the combination of elevation and aspect in association with ecological functions ($p < 0.05$). Due to small sample sizes, nonparametric statistical tests were utilized. The Kruskal-Wallis one way nonparametric analysis of variance (AOV) test was used to compare wetland function scores, vegetation community structure, and soil characteristics by elevation classes (low, mid, high). Spearman Rank correlations were used to compare soil texture, organic matter, aspect, wetland area, vegetation classes, and soil macronutrients to actual elevation to determine positive or negative correlations with changes in elevation. The chi-square test was utilized to compare WESPUS variables by aspect and elevation classes. The Wilcoxon Rank Sum test was used to compare WESPUS variables containing two classes (Table 3) by wetland function scores, macronutrients, and soil texture. The Wilcoxon Rank Sum test was

Table 3

*List of WESPUS Variables*

| **Vegetation** | **Land Use** | **Physical Characteristics** |
|---|---|---|
| % Seasonally Ponded | Public Access * | Vegetation Height * |
| % Shaded by Canopy | Land Uses | % Bare Ground |
| Downed Woody Debris > 4’’ Diameter * | Natural Landcover Upslope | Upland Inclusion * |
| % Unshaded Vegetation | | Ground Irregularity |
| % Herbaceous Cover | | % Wetland Slope |
| % Woody Vegetation | | |
| Downed Wood Pieces * | | |

*Note.* Asterisk (*) notes WESPUS variables containing two classes.

also utilized to compare aspect classes to wetland function scores, vegetation community structure, general soil characteristics, and soil macronutrients. Kruskal-Wallis AOV was used to compare WESPUS variables containing three or more classes to wetland function scores, vegetation community structure, general soil characteristics, and soil macronutrients.

# CHAPTER V

# RESULTS

This chapter will describe results found from data analysis of 18 wetlands according to methods written in chapter IV. The analysis is divided into elevation and aspect categories in terms of comparison. The third category describes analysis between WESPUS variables and wetland function scores, general soil characteristics, and soil macronutrients.

## Elevation

Wetlands surveyed were distributed across an elevational gradient ranging from 1300 – 1600 m. Three elevation classes were derived comprising of low (1300 – 1400 m), mid (1401 – 1500 m), and high (1501 – 1600 m) categories (Figure 11).

### *Wetland Function*

Table 4 contains the median and interquartile range of wetland function scores. Wetland function scores consist of Habitat Function, Hydrologic Function, Water Quality, and Total Function. Values were calculated according to the Wetland Rating System for Eastern Washington rating form. In general, habitat function scores (median = 18.5) were found to be highest and water quality scores (median = 11) were lowest. In terms of variability, water quality had the least amount of variability (interquartile range = 2.75) and total function had the most variability (interquartile range = 11.75). Habitat function (interquartile range = 5.75) and hydrologic function (interquartile range = 5.0) had moderate variability relative to water quality and total function scores.

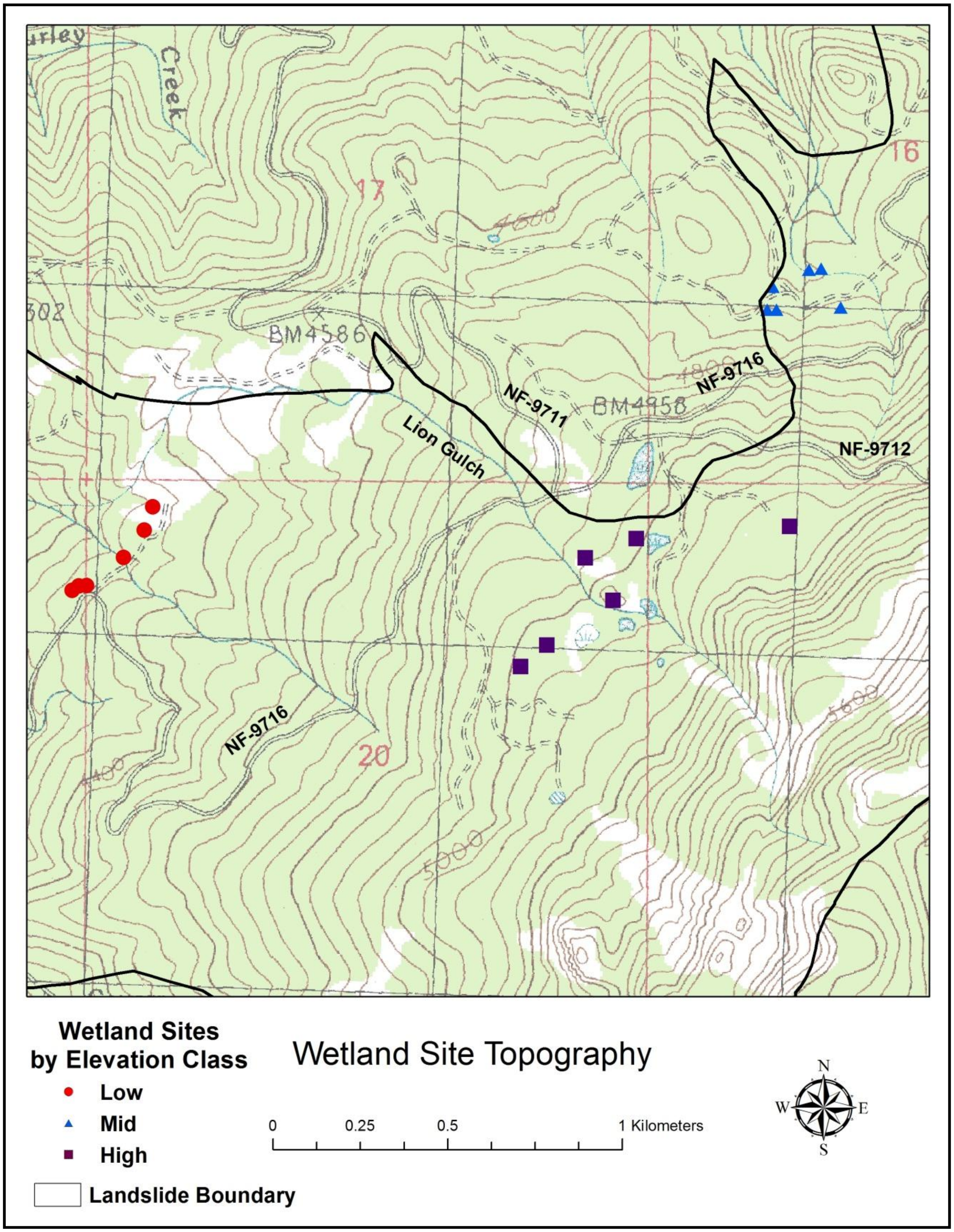


*Figure 11*. Location of wetland sites by elevation classes in the study area.

Table 4

*Descriptive Statistics for Wetland Function Scores*

| **Variable** | **Median** | **Interquartile Range** |
| --- | --- | --- |
| Habitat Function | 18.5 | 5.75 |
| Hydrologic Function | 12 | 5.0 |
| Water Quality | 11 | 2.75 |
| Total Function | 41 | 11.75 |

There were significant differences in habitat, hydrologic, and total function scores between elevation classes (Kruskal-Wallis, $p < 0.05$). Habitat function was found to be highest (median = 22.0) among high-elevation wetlands, while low- (median = 18.5) and mid-elevation (median = 12.5) wetlands scored significantly lower (Table 5). With regard to hydrologic function, high-elevation wetlands scored significantly higher (median = 15.0) than low- (median = 9.0) and mid-elevations (median = 10.0). High-elevation wetlands also scored significantly higher in terms of total function (median = 49.0), while low- (median = 40.0) and mid-elevation wetlands (median = 32.5) scored less. Function scores are highest among high-elevation wetlands (median = 49.0) and lowest among the mid-elevation wetlands (median = 32.5). There were no significant differences in water quality function scores.

There were significant correlations found among hydrologic and total function compared to elevation (Spearman Rank, $p < 0.05$; Table 6). Hydrologic function positively correlated with elevation (coefficient = 0.51) and total function also positively correlated with elevation (coefficient = 0.52).

Table 5

*Median Values of Wetland Function Scores Using Kruskal-Wallis Test to Compare Differences in Elevation Classes.*

| **Variable** | **Low Elevation Class** Median (I.Q.R.) | **Mid Elevation Class** Median (I.Q.R) | **High Elevation Class** Median (I.Q.R.) |
|---|---|---|---|
| Habitat Function* | 18.5 (6.0) | 12.5 (4.8) | 22.0 (6.75) |
| Hydrologic Function* | 9.0 (7.0) | 10.0 (2.0) | 15.0 (4.0) |
| Water Quality | 10.5 (2.5) | 11.0 (4.5) | 12.0 (2.0) |
| Total Function* | 40.0 (9.8) | 32.5 (8.0) | 49.0 (5.75) |

*Note.* I.Q.R. = interquartile range. * Significant values ($p < 0.05$)

Table 6

*Comparing Elevation with Significant Function Variables Using Spearman Rank Correlation Test*

| **Variable** | **Coefficient** | **P Value** |
|---|---|---|
| Hydrologic Function | 0.51 | 0.033 |
| Total Function | 0.52 | 0.028 |

*Note.* Results based on a 0.05 level of significance.

*Vegetation*

Table 7 outlines only dominant vegetation communities that were found among the 18 wetland sample sites. The vegetation community with the highest occurrence was the woolly sedge (*Carex pellita*). The woolly sedge community was mainly found in the high-elevation wetlands. Dominant vegetation communities found at mid-elevation wetlands, each having one occurrence, included Columbian sedge (*Carex aperta*)/three-stamen rush (*Juncus ensifolius*), water moss (*Fontinalis antipyretica*), horsetail

Table 7

*Dominant Vegetation Communities Found Among the 18 Wetland Sites*

| **Vegetation Communities** | **Elevation Class** | **Occurrence** |
|---|---|---|
| Columbian sedge (*Carex aperta*)/Three-stamen rush (*Juncus ensifolius*) | Mid | 1 |
| Water moss (*Fontinalis antipyretica*) | Mid | 1 |
| Horsetail (*Equisetum* spp.) | Mid | 1 |
| Nodding beggartick (*Bidens cernua*)/Meadow sedge (*Carex pansa*) | Mid | 1 |
| June grass (*Koeleria macrantha*) | Mid | 1 |
| Woolly sedge (*Carex pellita*) | 3 Low; 6 High | 9 |
| Thick headed sedge (*Carex pachystachya*) | Mid | 1 |
| Yellow water buttercup (*Ranunculus flabellaris*) | Low | 1 |
| Meadow foxtail (*Alopecurus pratensis*)/Swamp smartweed (*Polygonum hydropiperoides*) | Low | 1 |
| Wool-grass (*Scirpus cyperinus*) | Low | 1 |

(*Equisetum* spp.), nodding beggartick (*Bidens cernua*)/meadow sedge (*Carex pansa*), June grass (*Koeleria macrantha*), and thick headed sedge (*Carex pachystachya*). Dominant vegetation communities found at low-elevation wetlands included woolly sedge, yellow water buttercup (*Ranunculus flabellaris*), meadow foxtail (*Alopecurus pratensis*)/swamp smartweed (*Polygonum hydropiperoides*), and wool-grass (*Scirpus cyperinus*). Each dominant low-elevation vegetation communities had only one occurrence, except for the woolly sedge community, which was found at all three sites

Table 8 outlines all vegetation species found throughout the wetland sites. No sensitively listed vegetation species were found. Woolly sedge (*Carex pellita*) was found to be the most dominant species. According to the NRCS (n.d.b), the woolly sedge (*Carex pellita*) is threatened and/or endangered in Tennessee and Kentucky; however, not in Washington State. In addition, it is a native monocot with an obligate (OBL) wetland indicator status and was found mainly in high-elevation wetlands. Four notable vegetation species were found in at least 1/3 of the wetland sites. These vegetation species include false hellebore (*Veratrum californucum*), June grass (*Koeleria* macrantha), three-stamen rush (*Juncus ensifolius*), and Timothy grass (*Phleum pratense*). False hellebore is a native, facultative (FAC) species that was found at ten wetland sites. In terms of overall percent cover, false hellebore was found to be low (median = 4.6) and had low variability (interquartile range = 4.2) relative to other species. June grass is a native, FAC species that was found at nine wetland sites having a moderate overall percent cover (median = 12.0) with moderate variability (interquartile range = 9.4). Three-stamen rush is a native species with a wetland indicator status of facultative-wetland (FACW). Three-stamen rush was found at eight wetland sites having a low overall percent cover (median = 5.2) with moderate variability (interquartile range = 8.3). Timothy grass is an introduced, FAC species that was found at seven wetland sites having a moderate overall percent cover (median = 7.0) with higher variability (interquartile range = 14.2). The remaining 22 vegetation species were found in 1 – 5 wetlands, with median percent coverage ranging between 0.9 – 34.6.

The Kruskal-Wallis test was used to determine significant differences in percent vegetation cover of dominant vegetation species by elevation classes. Only one vegetation species community was found to be significantly different: woolly sedge. This

Table 8

*Vegetation Species List Outlining All Species Found Throughout Wetland Sites.*

| **Vegetation Species** | **Number of Wetlands** | **Wetland Indicator Status** | **General Information** | **Percent Cover Median** (I.Q.R) |
|---|---|---|---|---|
| Columbian sedge (*Carex aperta*) | 1 | OBL | Native | 34.6 (0.0) |
| Timothy grass (*Phleum pratense*) | 7 | FAC | Introduced | 7.0 (14.2) |
| Three-stamen rush (*Juncus ensifolius*) | 8 | FACW | Native | 5.2 (8.3) |
| False hellebore (*Veratrum californicum*) | 10 | FAC | Native | 4.6 (4.2) |
| Crawford's sedge (*Carex crawfordii*) | 1 | FACW | Native | 15.7 (0.0) |
| Meadow sedge (*Carex pansa*) | 2 | FAC | Native | 32.1 (12.7) |
| Water moss (*Fontinalis antipyretica*) | 2 | OBL | Native | 31.5 (6.7) |
| Horsetail (*Equisetum spp.*) | 4 | FACW | Native | 11.1 (18.1) |
| Nodding beggartick (*Bidens cernua*) | 2 | OBL | Native | 24.2 (22.6) |
| June grass (*Koeleria macrantha*) | 9 | FAC | Native | 12.0 (9.4) |
| Woolly sedge (*Carex pellita*) | 11 | OBL | Native | 55.2 (25.2) |

Table 8 (Continued)

| **Vegetation Species** | **Number of Wetlands** | **Wetland Indicator Status** | **General Information** | **Percent Cover Median** (I.Q.R) |
|---|---|---|---|---|
| Wild strawberry (*Fragaria vesca*) | 1 | FAC | Native | 2.4 (0.0) |
| Thick headed sedge (*Carex pachystachya*) | 5 | FAC | Native | 5.3 (6.9) |
| One sided sedge (*Carex unilateralis*) | 2 | FACW | Native | 7.0 (5.0) |
| Western water hemlock (*Cicuta douglasii*) | 1 | OBL | Native | 3.2 (0.0) |
| Common spike rush (*Eleocharis palustris*) | 4 | OBL | Native | 11.5 (7.7) |
| Willow (*Salix* spp.) | 1 | FACW | N/A | 1.4 (0.0) |
| Sunflower (*Aster* spp.) | 1 | N/A | N/A | 0.9 (0.0) |
| Wool-grass (*Scirpus cyperinus*) | 3 | OBL | Native | 13.8 (23.8) |
| Broadleaf cattail (*Typha latifolia*) | 1 | OBL | Native | 11.3 (0.0) |
| Brewer’s rush (*Juncus breweri*) | 2 | FACW | Native | 8.7 (1.0) |
| Kentucky bluegrass (*Poa pratensis*) | 2 | FAC | Introduced | 21.6 (1.8) |
| Yellow water buttercup (*Ranunculus flabellaris*) | 1 | OBL | Native | 36.2 (0.0) |
| Awl-fruited sedge (*Carex stipata*) | 1 | OBL | Native | 2.5 (0.0) |

Table 8 (Continued)

| **Vegetation Species** | **Number of Wetlands** | **Wetland Indicator Status** | **General Information** | **Percent Cover Median** (I.Q.R) |
|---|---|---|---|---|
| Meadow foxtail (*Alopecurus pratensis*) | 2 | FAC | Introduced | 21.5 (9.3) |
| Swamp smartweed (*Polygonum hydropiperoides*) | 1 | OBL | Native | 32.2 (0.0) |
| Baltic rush (*Juncus arcticus*) | 1 | FACW | Native | 20.2 (0.0) |

*Note*. OBL = obligate, FAC = facultative, FACW = facultative-wetland

finding is likely tied to the woolly sedge community being the only dominant vegetation community that was found in more than one elevation class. Woolly sedge's percent cover was highest in the high-elevation wetlands (median =71.4), while percent cover was less in the low- (median = 54.4) and mid- (median = 18.5) elevation class wetlands. Greater coverage variability was found among high-elevation wetlands (interquartile range = 30.8), while the lowest variability was found among mid-elevation wetlands (interquartile range = 2.8). Low-elevation wetlands were found to have higher coverage variability (interquartile range = 21.5) when compared to mid-elevation wetlands.

Coverage of four vegetation species were found to be significantly correlated with actual elevation (Spearman rank, $p < 0.05$; Table 9). Woolly sedge was moderately correlated (coefficient = 0.59) with elevation. In terms of negative correlation, wool grass, Brewer's rush (*Juncus breweri*), and Kentucky bluegrass (*Poa pratensis*) were found to be negatively correlated with elevation, with correlation coefficients ranging between -0.48 to -0.65.

Table 9

*Comparing Actual Elevation with Individual Vegetation Species Percent Cover Using Spearman Rank Correlation Test*

| **Species** | **Coefficient** | **P Value** |
|---|---|---|
| Woolly sedge | 0.59 | 0.012 |
| Wool grass | -0.65 | 0.004 |
| Brewer's rush | -0.51 | 0.031 |
| Kentucky bluegrass | -0.48 | 0.045 |

*Note.* Results based on a 0.05 level of significance.

Vegetation was also measured in terms of species richness by utilizing the jackknife estimate method and significant differences were found among elevation classes using the Kruskal-Wallis test (Table 10). Species richness was found to be higher in the low-elevation wetlands (median = 0.69), while the mid- (median = 0.66) and high-elevation (median = 0.47) wetlands were lower. Greater species richness variability was found among high-elevation wetlands (interquartile range = 0.37) when compared to mid- (interquartile range = 0.21) and low-elevation wetlands (interquartile range = 0.20). Differences in species diversity and percent similarity were found to be insignificant between elevation classes ($p > 0.05$). However, species percent similarity coefficients for comparative elevation classes included low vs. high = 41.7, low vs. mid = 20.0, and mid vs. high = 22.9. This indicates that vegetation species composition was more similar between low- and high-elevation wetlands, and least similar between low and mid-elevation wetlands.

Table 10

*Median Values of Species Richness Compared to Elevation Classes Using Kruskal-Wallis Test*

| **Variable** | **Low Elevation Class** Median (I.Q.R.) | **Mid Elevation Class** Median (I.Q.R) | **High Elevation Class** Median (I.Q.R.) |
|---|---|---|---|
| Species Richness | 0.69 (0.20) | 0.66 (0.21) | 0.47 (0.37) |

*Note*. I.Q.R. = interquartile range. Results based on a 0.05 level of significance.

### *Soil*

Table 11 outlines general soil characteristics associated with sampled wetland sites. The percentage of organic matter among wetland sites was low (median = 34.4) with high variability (interquartile range = 35.0). In general, the 18 wetland sites collectively have slightly acidic soils (pH median = 5.0) with little variability (interquartile range = 0.5). In terms of substrate texture, higher concentrations of very course sand (median = 21.0) were found with the highest variability (interquartile range = 16.0) when compared to other texture classifications. Course and fine sand textures were similarly concentrated among wetland sites (medians = 16.8 & 16.2) with moderate variability (interquartile ranges = 5.3 & 4.6). Very fine sand and silt were similarly concentrated among wetland sites (medians = 10.7 & 10.6) having lower variability with very fine sand (interquartile range = 3.8) when compared to silt (interquartile range = 9.0).

In terms of soil macronutrients measured in pounds per acre, aluminum had the highest concentration (median = 125.0) with the lowest variability (interquartile range = 33.8) compared to remaining macronutrients. Ammonia nitrogen had the lowest

Table 11

*General Soil Characteristics*

| **Soil Variable** | **Median** | **Interquartile Range** |
|---|---|---|
| Organic Matter % | 34.4 | 35.0 |
| pH | 5.0 | 0.5 |
| Very course sand % | 21.0 | 16.0 |
| Course sand % | 16.7 | 5.3 |
| Medium sand % | 19.5 | 7.8 |
| Fine sand % | 16.2 | 4.6 |
| Very fine sand % | 10.7 | 3.8 |
| Silt % | 10.6 | 9.0 |
| Nitrate Nitrogen (lbs. per acre) | 10.0 | 5.0 |
| Phosphorus (lbs. per acre) | 100.0 | 100.0 |
| Potassium (lbs. per acre) | 105.0 | 57.5 |
| Aluminum (lbs. per acre) | 125.0 | 33.8 |
| Ammonia Nitrogen (lbs. per acre) | 5.0 | 0.0 |
| Calcium (ppm) | 1400.0 | 400.0 |
| Ferric Iron (lbs. per acre) | 35.0 | 35.0 |
| Magnesium (lbs. per acre) | 10.0 | 0.0 |
| Nitrite Nitrogen (ppm) | 1.00 | 0.0 |

concentration (median = 5.0) among wetland sites with no variability (interquartile range = 0.0). Nitrate nitrogen and magnesium macronutrients were found similarly concentrated among wetland sites (medians = 10.0 & 10.0) while nitrate nitrogen had little variability (interquartile range = 5.0) and magnesium had no variability (interquartile range = 0.0). Phosphorus and potassium were also found similarly concentrated among wetland sites (medians = 100.0 & 105.0) with phosphorus having higher variability (interquartile range = 100.0) than potassium (interquartile range = 57.5). Soil macronutrients measured in parts per million (ppm) included calcium and nitrite nitrogen. Calcium concentrations were found to be substantially higher (median = 1400.0) than nitrite nitrogen (median =1.0). Similar to variability, calcium had substantially higher variability (interquartile range = 400.0) when compared to nitrite nitrogen, which had no variability (interquartile range = 0.0).

No significant differences were found in soil characteristics with elevation, except potassium (Kruskal-Wallis test, $p < 0.05$). Potassium was highest in the mid-elevation wetlands (median = 140.0), while the low- (median = 100.0) and high-elevation wetlands (median = 132.5) had reduced potassium levels. In terms of potassium concentration variability, high-elevation wetlands had the most variability (interquartile range = 76.3) while mid- (interquartile range = 55.0) and low-elevation wetlands (interquartile range = 0.0) had less.

## Aspect

Sampled wetlands were divided into one of two categories based on whether south- or north-facing in terms of aspect. The sample set was found to represent nine north- and nine south-facing wetlands (Figure 12). No significant results were found comparing wetland function scores, vegetation community structure, general soil characteristics, soil macronutrients, and WESPUS variables by aspect classes (Wilcoxon Rank Sum test or chi-square test, $p > 0.05$).

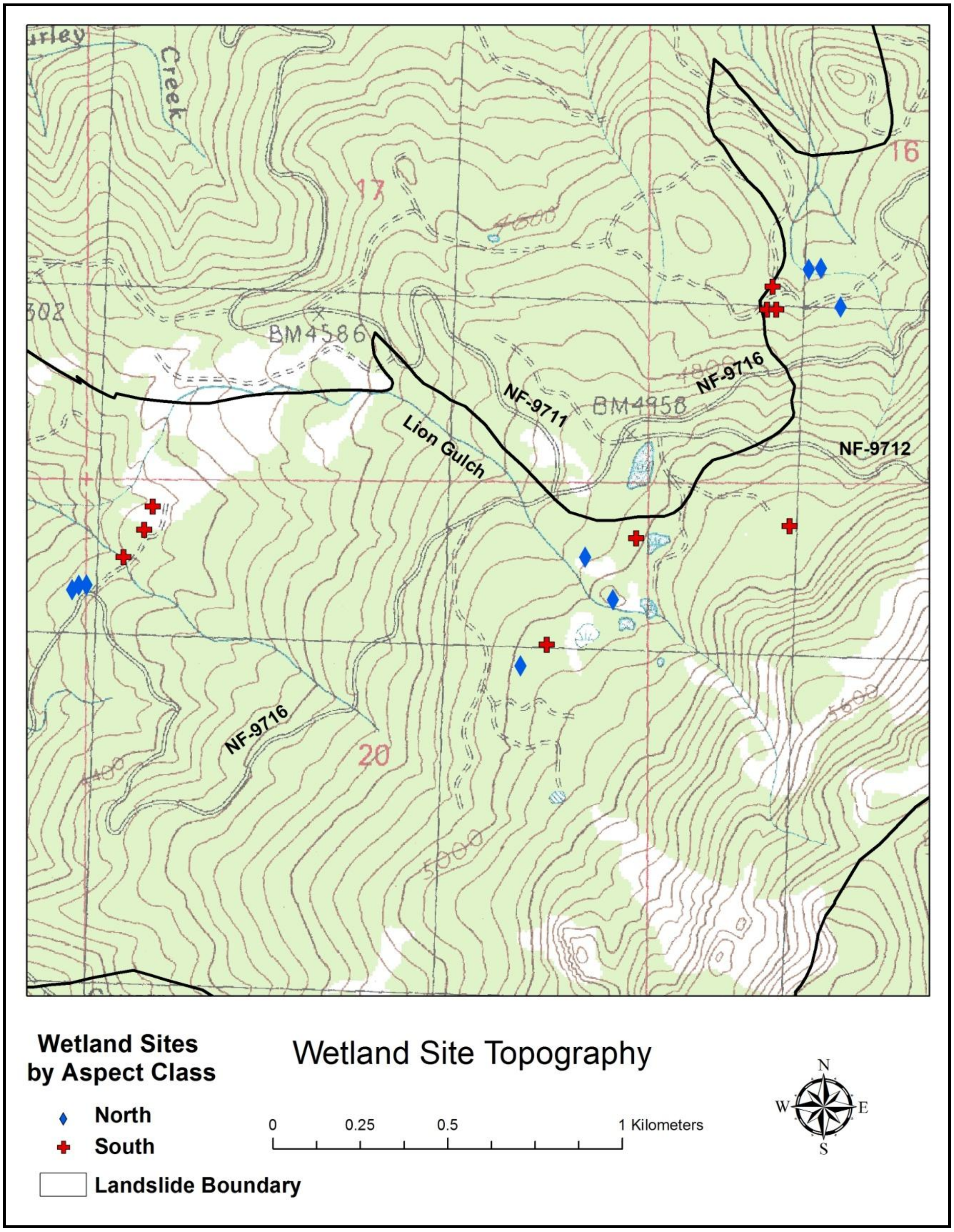


*Figure 12*. Location of wetland sites by aspect classes in the study area.

## WESPUS Variables

Table 12 outlines WESPUS physical characteristic classes associated with wetland sites. The majority of wetland sites have a more diverse vegetation height (61%). In terms of the percent of bare ground, 50% of wetland sites fall into the 5 - 20% category and 5% fall into the > 50% category. A majority (78%) of wetland sites do not have many upland inclusions. Similarly with ground irregularity, the majority of wetland sites (56%) have few to none and one site has several (5%). Percent wetland edge slope is found mostly in the 1 - 25% category among wetland sites (56%).

Table 12

*WESPUS Physical Characteristic Variables (Percentage of Wetland Sites by Class)*

| | | | | | |
|---|---|---|---|---|---|
| **Vegetation Height** | | *Uniform* | *Very Diverse* | | |
| | | 39 | 61 | | |
| **% Bare Ground** | *<5* | *5-20* | *21-50* | *>50* | |
| | 28 | 50 | 17 | 5 | |
| **Upland Inclusion** | | *Many* | *None (or 1 clump)* | | |
| | | 22 | 78 | | |
| **Ground Irregularity** | *Several* | *Intermediate* | *Few or None* | | |
| | 5 | 39 | 56 | | |
| **% Wetland Edge Slope** | *>75* | *51-75* | *26-50* | *1-25* | *<1* |
| | 0 | 0 | 11 | 56 | 33 |

Table 13 outlines WESPUS land use classes associated with wetland sites. Regarding public access, the majority of wetland sites have restricted access (67%), while the remaining sites have relatively unrestrictive access points (33%). The majority of wetland sites have no classified land uses nearby (78%) and few have low-impact grazing (22%). Most of the wetland sites have natural buffers 100 feet upslope (78%) and few have bare pervious areas, mainly tied to dirt Forest Service roads (22%).

Table 13

*WESPUS Land Use Variables (Percentage of Wetland Sites by Class)*

| | | | | |
|---|---|---|---|---|
| **Public Access** | *Unrestricted* | *Restricted* | | |
| | 33 | 67 | | |
| **Land Uses** | *Timber* | *Grazing* | *None* | |
| | 0 | 22 | 78 | |
| **Natural Landcover (100ft Upslope)** | *Impervious Surface* | *Bare Pervious Surface* | *Other* | *>90% Natural* |
| | 0 | 22 | 0 | 78 |

Table 14 outlines WESPUS vegetation classes associated with wetland sites. Pertaining to percent seasonally ponded among wetland sites, the distribution is tied for the > 75% and 51 - 75% categories (39% each) with a few sites falling into the 26 - 50% category (22%). In terms of percent of wetland sites shaded by canopy, most of them fall into the 5 - 25% category (39%) and one site is > 75% shaded (5%). Wetland sites mainly have few downed wood pieces greater than four inches in diameter (56%), while few sites have several (44%). Wetland sites having unshaded vegetation areas are found mainly in the 26 - 50% category (33%) and one site at < 5%. Wetland sites are split evenly regarding herbaceous cover being mostly grass-like and 50 - 80% grass-like. The amount of general downed wood pieces in wetland sites are split evenly between few and several. Finally, the percent of woody vegetation found in wetland sites is mainly small, with 61% of wetland sites having < 5% woody vegetation.

Elevation, aspect, and soil variables were tested for significant differences between WESPUS variables using Wilcoxon Rank Sum test ($p < 0.05$; Table 15). Habitat function was found to be higher with several downed woody debris pieces (median = 22.0) rather than few downed woody debris pieces (median = 15.5). Overall function was

Table 14

*WESPUS Vegetation Variables (Percentage of Wetland Sites by Class)*

| | | | | | |
|---|---|---|---|---|---|
| **% Seasonally Ponded** | *>75* | *51-75* | *26-50* | *5-25* | *5* |
| | 39 | 39 | 22 | 0 | 0 |
| **% Shaded by Canopy** | *>75* | *51-75* | *26-50* | *5-25* | *<5* |
| | 5 | 17 | 17 | 39 | 22 |
| **Downed Woody Debris >4 in Diameter** | *Few* | *Several* | | | |
| | 56 | 44 | | | |
| **% Unshaded Vegetation** | *>95* | *51-95* | *26-50* | *5-25* | *<5* |
| | 22 | 22 | 33 | 17 | 5 |
| **% Herbaceous Cover** | *>80 Grasslike* | *50-80 Grasslike* | *50-80 Non-Grasslike* | *>80 Non-Grasslike* | |
| | 50 | 50 | 0 | 0 | |
| **Downed Wood Pieces** | *Few* | *Several* | | | |
| | 50 | 50 | | | |
| **% Woody Vegetation** | *>95* | *51-95* | *26-50* | *5-25* | *<5* |
| | 0 | 0 | 5 | 33 | 61 |

found to be higher with several downed woody debris pieces (median = 47.0) rather than few downed woody debris pieces (median = 34.5). Percent silt was found to be higher with several downed woody debris pieces (median = 16.9) rather than few downed woody debris pieces (median = 9.4). Percent herbaceous cover was found to be > 80% with higher concentrations of coarse sand (median = 19.6) and 50 - 80% cover with less concentrations of coarse sand (median = 15.2). No significant differences were found between WESPUS variables and aspect, elevation classes using chi-square test ($p > 0.05$).

Table 15

*Comparing WESPUS Variables with Significant Variables Using Wilcoxon Rank Sum Test ($p < 0.05$)*

| **Variables** | **Downed Woody Debris** Median (I.Q.R.) | | **Herbaceous Cover** Median (I.Q.R.) | | **Vegetation Height** Median (I.Q.R.) | | **Downed Wood > 4 inches in Diameter** Median (I.Q.R) | |
|---|---|---|---|---|---|---|---|---|
| | Few | Several | 50-80% | >80% | Diverse Height | Uniform Height | Few | Several |
| Habitat Function | 15.5 (7.5) | 22.0 (8.3) | | | | | | |
| Total Function | 34.5 (11.3) | 47.0 (10.0) | | | | | 35.0 (10.5) | 46.0 (12.0) |
| Coarse Sand | | | 15.2 (5.5) | 19.6 (5.8) | 15.7 (4.7) | 20.8 (5.3) | | |
| Silt | 9.4 (6.5) | 16.9 (8.0) | | | | | | |

## Soil Characteristics

The Spearman Rank Correlation test was utilized to determine whether macronutrients, soil texture, and organic matter were significantly correlated to function and soil variables.

### *Macronutrients*

Macronutrients with significant relationships include calcium, ferric iron, and potassium (Table 16). Calcium was found to be negatively correlated with habitat function -0.57, while ferric iron and potassium were found to be negatively correlated with organic matter, with correlation coefficients of -0.62 and -0.65, respectively. Finally, potassium was found to be negatively correlated with organic matter with a correlation coefficient of -0.65. The remaining macronutrients were not significantly correlated with function variables and soil characteristics (Spearman rank, $p > 0.05$).

*Texture*

Very coarse sand was found to be negatively correlated with habitat function (-0.49) and total function (-0.48). Soil pH was found to be negatively correlated with very fine sand, fine sand, and medium sand (-0.59, -0.64, and -0.61). Finally, pH was found to be positively correlated with very coarse sand (0.73).

*Organic Matter*

Three soil texture classes were significantly correlated with amounts of organic matter, including fine, medium, and very coarse sand (Table 16). Organic matter was found negatively correlated with fine and medium sand (-0.56 and -0.69). Conversely, organic matter was found positively correlated with very coarse sand (0.65).

Table 16

*Comparing Soil Macronutrients and Texture to Function Variables*

| **Variable** | **Coefficient** | **P Value** |
|---|---|---|
| *Macronutrients* | | |
| Calcium & Habitat Function | -0.57 | 0.0141 |
| Ferric Iron & Organic Matter | -0.62 | 0.0074 |
| Potassium & Organic Matter | -0.65 | 0.0041 |
| *Soil Texture* | | |
| Habitat Function & Very Coarse Sand | -0.49 | 0.0427 |
| Total Function & Very Coarse Sand | -0.48 | 0.0447 |
| pH & Very Fine Sand | -0.59 | 0.0122 |
| pH & Fine Sand | -0.64 | 0.0053 |

Table 16 (Continued)

| **Variable** | **Coefficient** | **P Value** |
| --- | --- | --- |
| pH & Medium Sand | -0.61 | 0.0090 |
| pH & Very Coarse Sand | 0.73 | 0.0009 |
| *Organic Matter* | | |
| Organic Matter & Fine Sand | -0.56 | 0.0182 |
| Organic Matter & Medium Sand | -0.69 | 0.0021 |
| Organic Matter & Very Coarse Sand | 0.65 | 0.0041 |

*Note.* Spearman Rank Correlation: Significance at $p < 0.05$.

# CHAPTER VI

# DISCUSSION

Eighteen wetlands from the Swauk Watershed were categorized by elevation and aspect in the study area. Wetlands were surveyed using the WSWRS to determine ecological function based on hydrology, habitat, and water quality. In addition to the rating system, the WESPUS was used as a supplement to aid in the quantification of ecological function. Vegetation structure and soil characteristics were also quantified in each wetland. Vegetation structure included species dominance, diversity, richness, and similarity. Soil characteristics included macronutrient concentrations, texture, and organic content.

This section will provide information related to statistically significant wetland ecological function findings outlined by elevation, aspect, WESPUS variables, and soil characteristics. The elevation section discusses statistically significant relationships associated with wetland function scores, vegetation cover, and soil macronutrients compared with elevation. Similarly, the aspect section discusses the relationship of significant differences among wetland function score and vegetation cover associated with aspect. Next, the WESPUS section outlines statistically significant relationships associated with wetland function scores and soil texture pertaining to WESPUS habitat characteristics; such as, downed woody debris, and vegetation characteristics. Finally, the soil section discusses statistically significant relationships with soil macronutrients, texture, and organic matter.

## Elevation

### *Wetland Function*

Wetland functions include physical, chemical, and biological processes and their influence on vegetation, wildlife, and hydrology (Tiner, 1998). These functions are not necessarily performed continually throughout the season, but most operate on a frequent basis (Tiner, 1998). A wetlands' ability to perform these functions is based on factors including its position in the landscape and hydrologic connectivity (Hruby, 2004; Keddy, 2000). Three major functions that wetlands perform include improving water quality, maintaining water regimes in terms of hydrology, and providing suitable habitat for vegetation and wildlife species (Hruby, 2004).

The three main function variables assessed according to the WSWRS included hydrologic, habitat, and water quality function. Hydrologic, habitat, and total function were found significant among the 18 wetland sites. Despite that water quality function was found to be insignificant statistically, high-elevation wetlands scored the highest.

Hydrologic function was found to be greatest among the high-elevation wetland sites. The quantification of hydrologic function was largely derived from scores pertaining to questions regarding depth of ponding and whether there was an inlet or outlet. None of the wetlands were influenced by inlets or outlets, and therefore depth of ponding was the key factor in determining difference in hydrologic function, primarily reflecting how a wetland potentially could reduce flooding and erosion through water retention (Hruby, 2004).

Results indicate that high-elevation wetlands scored the highest in hydrologic function (Figure 13). This occurred because high-elevation wetland sites have greater ponding depths (Figure 14). Depth of floodwater storage is greatest at high-elevations in the study area, likely resulting from variations in precipitation, snow accumulation, and/or landslide geomorphology. Precipitation is known to increase with elevation, especially in a mountainous setting where the spatial distribution of moisture is influenced by the associated topography (Anders, Roe, Durran, & Minder, 2006; Clark, Campbell, Grizzle, Acosta-Martinez, & Zak, 2009; Lavoie & Bradley, 2003). These results support conclusions made by Bauder (2005) that precipitation is one of the most important factors to influence ponding characteristics, based on correlating yearly precipitation with the total number of days water stands in wetland basins. This study found the depth of ponding correlated with elevation, where mid- and low-elevation wetlands generally had lower ponding depth, likely resulting from lower precipitation amounts.

Snow is the second factor that influences wetland ponding depth, which is dependent on topography, precipitation, and wind (Wahren, Williams, & Papst, 2001) and tends to accumulate in depressions (Billings & Mooney, 1968). Higher-elevation wetlands likely receive more snowfall than the mid- and low-elevation wetland sites and perhaps contribute to deepening of depressions. Thorn (1976) concluded in a study conducted in the Colorado Front Range that snow is a modifying force to basin morphology. Mechanical transport in terms of snow creep, mass moving events, and fluvial processes directly related to snow melt all contribute to basin alterations by removing sediment from the wetland basin (Thorn, 1976). Wetland basins may be deeper at higher elevations because of higher amounts of snow accumulation, resulting in more mechanical transport (Thorn, 1976; Price, 1981).

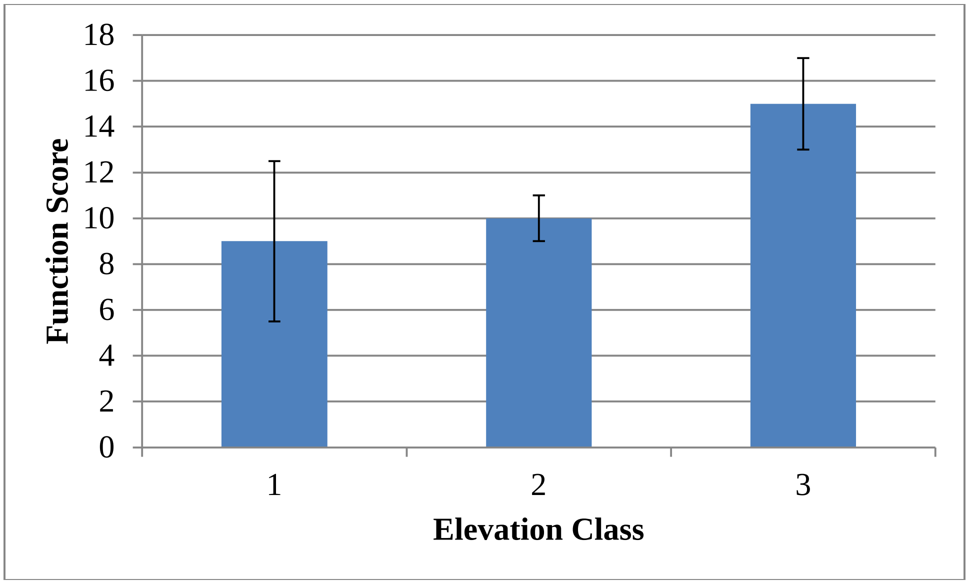


*Figure 13*. Significant median hydrologic function scores for the three elevation classes. *Note*. Error bars represent the interquartile range.

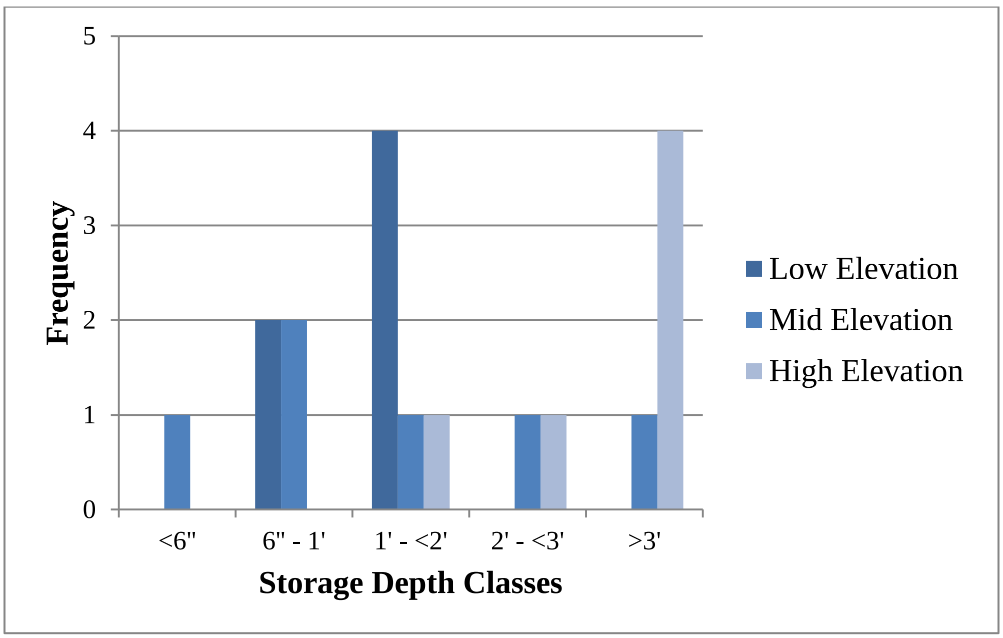


*Figure 14*. Storage depths associated with wetland sites.

Landslide morphology may also alter wetland basin depth. Higher-elevation wetlands that occur as a result of landslides are typically closer to the head scarp area of the landslide. Given this situation, steeper slopes above these wetland sites promote high energy sheet wash events resulting from the already higher levels of precipitation and snow melt (Cruden & Varnes, 1996; Price, 1981; Thorn, 1976). Sheet wash is one of the factors described by Thorn (1976) that mechanically transports sediment out of a basin in terms of fluvial processes.

Habitat function was found to be greatest among high-elevation wetland sites (Figure 15). Total function was found statistically different among elevation classes and consists of water quality, hydrologic, and habitat function scores combined. Significant differences in hydrologic and habitat function scores drive the total function score when added together. Similarly to hydrologic and habitat function, total function was found greatest at high-elevation wetlands (Figure 16). Mid-elevation wetlands score lowest in terms of total function.

*Vegetation*

Vegetation characteristics relating to elevation gradients pertain mainly to adaptations to precipitation gradients common with montane and subalpine environments (Bauder, 2005; Lopez, Davis, & Fennessy, 2002). Specifically, few studies have analyzed subalpine wetland vegetation associated with the Cascade Range; however, ties can be made relating precipitation gradients of the Sierra Nevada Mountains. Bauder (2005) found strong correlations between precipitation amounts and persistent wetland ponding.

In terms of percent cover, woolly sedge was greatest in the high-elevation wetlands (Figure 17). Sedges (*Carex* spp.) are well adapted to wetland environments and perform well in terms of soil stabilization because of their extensive root systems (Steed & DeWald, 2003). With regard to the woolly sedge, it is listed as a wetland obligate species and thrives in wetlands with the least amount of groundwater fluctuation (Steed, DeWald, & Kolb, 2002). High-elevation wetlands likely have the highest percent cover

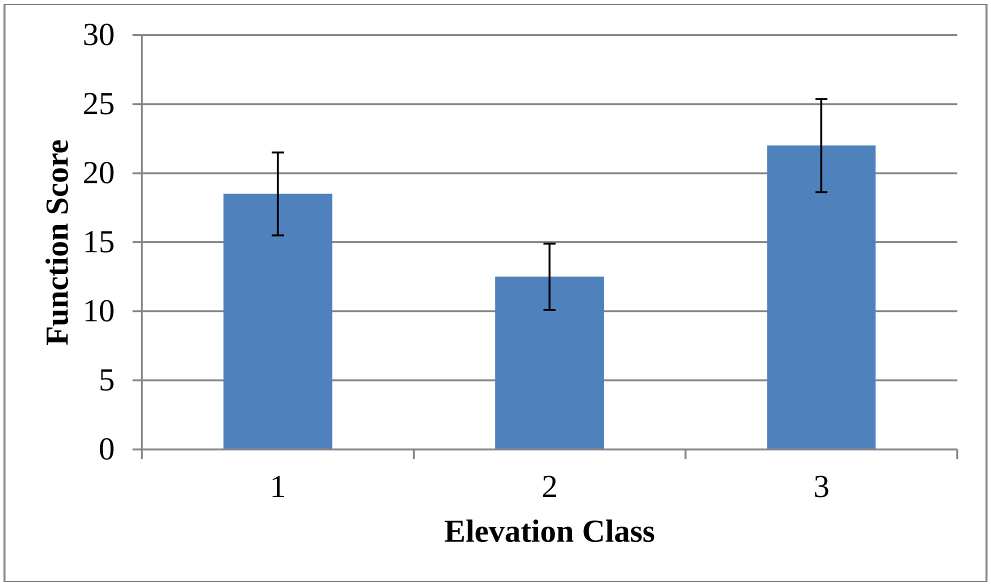


*Figure 15*. Significant median habitat function scores by elevation class. *Note.* Error bars represent the interquartile range.

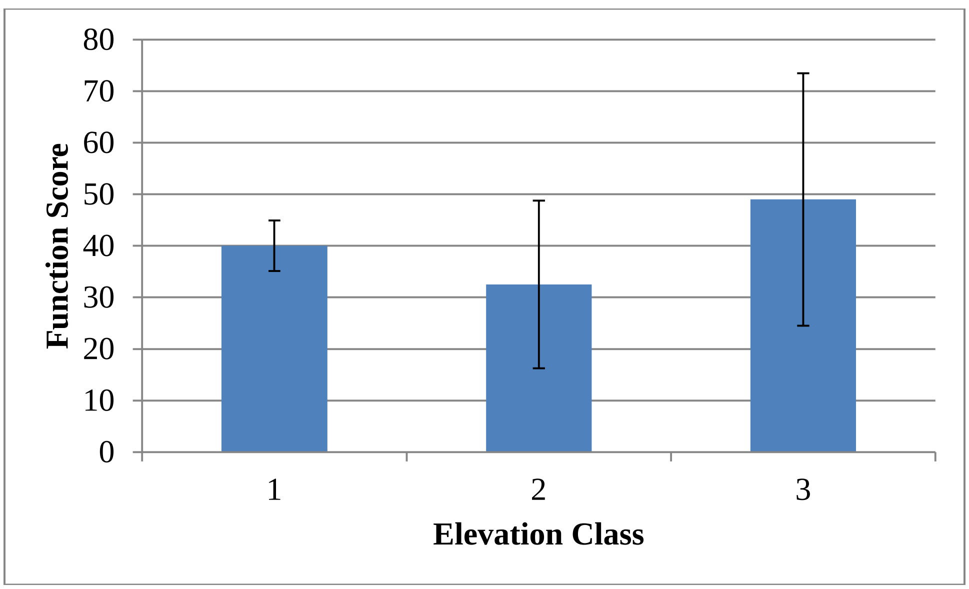


*Figure 16*. Significant median total function scores by elevation class. *Note*. Error bars represent the interquartile range

of woolly sedge because higher amounts of ponding, which provides more consistent water levels and a favorable environment for the woolly sedge.

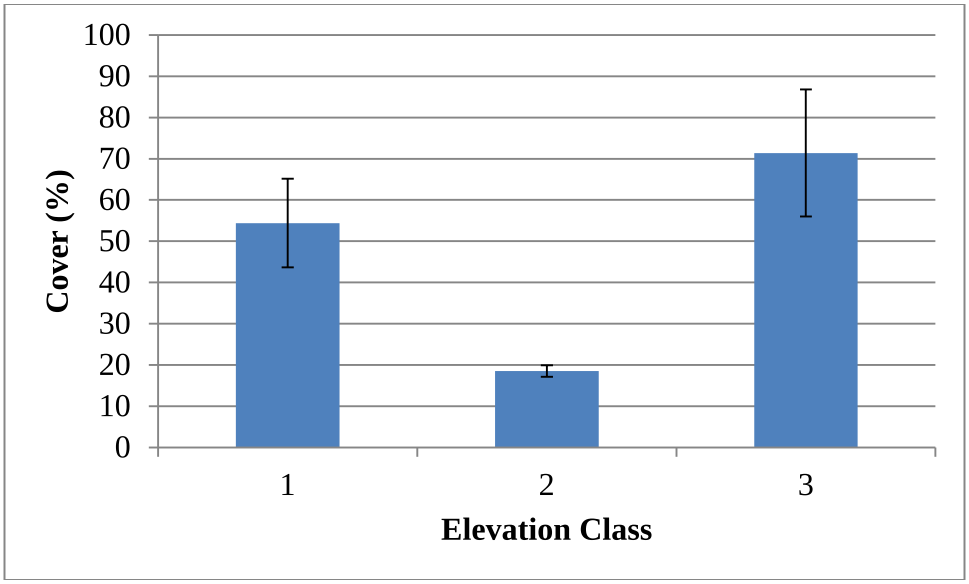

*Figure 17*. Significant median percent cover of woolly sedge (*Carex pellita*) by elevation class. *Note.* Error bars represent the interquartile range.

Wool grass (*Scirpus cyperinu*) was found only in the low-elevation wetlands and was negatively correlated with elevation. Wool grass is classified as a wetland obligate species for the region and is characterized by growing in colonies and tolerating shallow water (Atkinson, Perry, Noe, Daniels, & Cairns, 2010). As low-elevation wetlands have the lowest ponding depths, they may provide a more favorable environment for wool grass.

Brewer's rush (*Juncus breweri*) was negatively correlated with elevation. Brewer's rush is characterized by favoring transitional areas of wetlands along the wetland and upland boundary. It is classified as a FACW species in the region and tolerates moist to slightly wet soils (Tiner, 1998). Again, Brewer's rush is more likely to inhabit low-elevation wetlands because of lower ponding depths and limited open water. Kentucky bluegrass (*Poa pratensis*) was also found negatively correlated with elevation based on a Spearman Rank correlation Test. This species was primarily found in the transition area favoring more upland environments. Kentucky bluegrass is known to be an upland species in the region and favors dry to moist soils, which support findings that it is more likely to inhabit low-elevation wetlands because of less depth of ponding and drier soil conditions (Tiner, 1998).

Vegetation species richness was found to be significantly different among elevation classes (Figure 18). Species richness was higher at low-elevation wetlands and decreased respectively at mid- and high-elevation wetlands. Species richness is directly related to hydrology in terms of how it can limit or promote diversity in a wetland (Mitsch & Gosselink, 2007). Hydrology can limit diversity by allowing only water tolerant (hydrophytic) vegetation to grow in wetlands that have the presence of ponding most of the year, such as the high-elevation wetlands in this study. Hydrology can

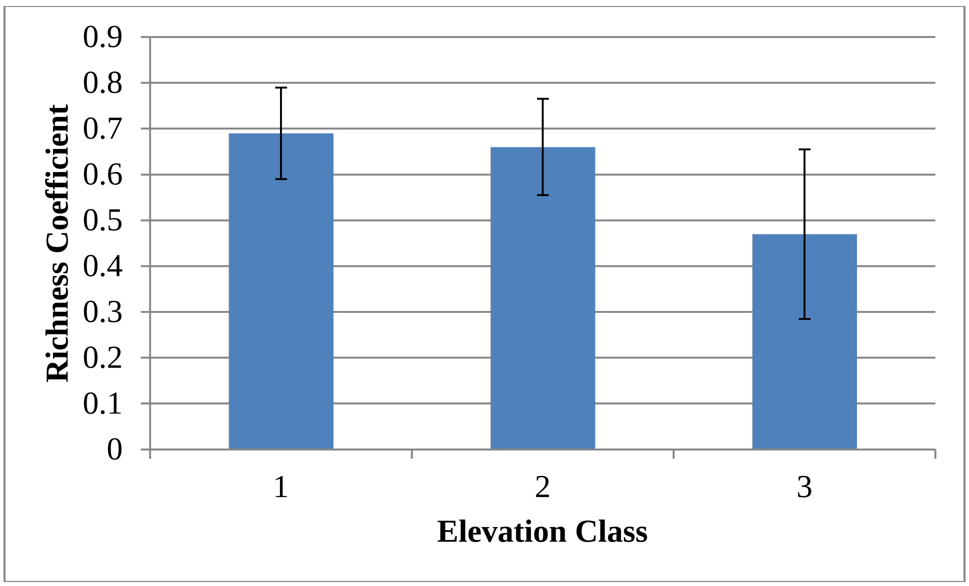


*Figure 18*. Significant median species richness by elevation class. *Note.* Error bars represent the interquartile range.

promote diversity by occasionally inundating wetlands, allowing for facultative vegetation to inhabit the wetland and creating more diversity (Tiner, 1998; Mitsch & Gosselink, 2007). High-elevation wetlands have deeper basins, and greater ponding levels, resulting in lower species richness than low-elevation wetlands with shallow basins and less inundation. In addition, other studies have found that species richness increases when water decreases (Cooper, 1990; Cooper & Andrus, 1994). Cooper (1990) found that number of vegetation species generally decreases with inundation. Cooper and Andrus (1994) concluded that wetland ponding duration directly influences vegetation community structure; specifically, lower moisture content increasing species richness in peatland communities located in the Wind-River Range, Wyoming.  In addition to hydrology, temperature and growing season duration also influence species richness. Scherrer and Körner (2011) found that temperature strongly correlated with plant distribution and abundance in alpine plant communities between 2200 – 2800 m elevation ranges in the Swiss Alps, likely reducing species richness at higher elevations.

*Soil*

With regard to macronutrients, potassium was found to be significantly different between elevation classes using a Kruskal-Wallis Test (Figure 19). Potassium concentrations were found to be highest among mid-elevation, lower in high-elevation, and lowest in low-elevation wetlands. This is supported by studies conducted by Venterink, Davidsson, Kiehl, and Leonardson (2002) and Venterink, Pieterse, Belgers, Wessen, and De Ruiter (2002), where they found that wetting and drying of wetland soil potentially controls levels of potassium: the more wetland soil dries and re-wets, higher amounts of potassium become available in the soil resulting from the physical adsorption of clay particles during the draining process. Low-elevation wetlands exhibit a shorter period of inundation, with longer dry periods resulting from lower levels of precipitation and snowmelt compared to the mid- and high-elevation wetlands. The mid-elevation wetlands have the highest amount of potassium concentration because they likely

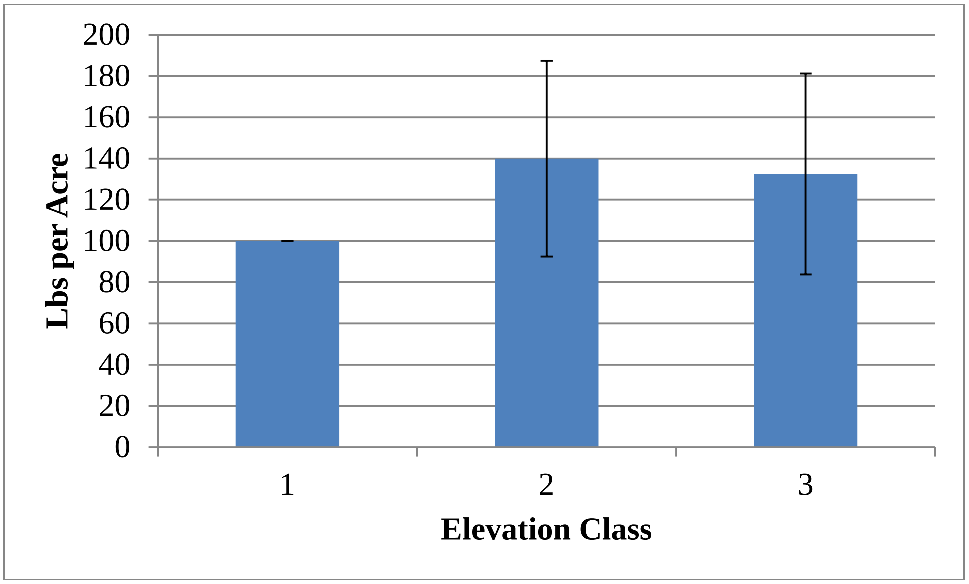

*Figure 19*. Significant median potassium concentrations by elevation class. *Note.* Error bars represent the interquartile range

experience the most pronounced drying and re-wetting cycles, while the high-elevation wetlands have more constant inundation, reducing the amount of potassium concentration. This is likely explained by mid-elevation wetlands experiencing more precipitation events than lower-elevation wetlands, but having warmer temperatures and more shallow storage basins allowing for more frequent drying and re-wetting cycles.

## Aspect

Nine wetlands were found to be north-facing and the remaining nine were determined as south-facing. There were no significant results pertaining to aspect. This is contrary to studies that have linked aspect to wetland function, including Bliss (1963), Coop and Givinish (2007), and Miller and Halpern (1998), who have linked aspect to differences in plant communities, water availability, and soil conditions.

## WESPUS Variables

The WESPUS is similar to the WSWRS in terms of the method of using a list of indicators to determine a functional score (Adamus et al., 2010). However, the WESPUS is an alternative version of the WET, also developed by Adamus (1983), that uses more indicators than the WSWRS, including elevation and wetland position on the landscape.

All variables were tested for significant differences with WESPUS variables for more detailed analysis. Wetlands with higher habitat function scores had several, rather than few or none, downed woody debris pieces; median score for several = 22 and few = 15.5. This supports wetlands with more downed woody debris will provide more species habitat. This is especially true for migratory bird species and species that utilize downed wood for nesting (Tiner, 1998).

Wetlands with several, rather than few or none, downed woody debris pieces have a higher total function score; median score for several = 47 and few = 34.5. Wetlands with more downed wood will score higher in terms of habitat function increasing total function. In addition, the larger the wetland's surface area also correlates with high habitat function because larger wetlands tend to have more open water which scores highly in habitat function criteria. Also, larger wetlands are more likely to accumulate larger woody debris from fluvial processes because of their size (Hruby, 2004). Kraus et al. (2005) describe the importance of downed woody debris in mangrove ecosystems as pertaining to erosion control, facilitating soil formation, increasing water retention, providing a nursery bed for seed germination, and providing aquatic habitat.

Wetlands with several, rather than few or none, downed wood pieces greater than four inches in diameter have a higher total function score; median score for several = 46 and few = 35. This significant result is supported again by the previous habitat discussions regarding downed woody debris. Large downed woody debris is considered a special habitat consideration in the WSWRS and provides a higher habitat score. Large woody debris offers habitat for decomposers, such as bacteria and fungi, and invertebrates. In addition, it also provides habitat for amphibians and other vertebrates (Hruby, 2004; Hruby et al., 2000).

Wetlands with higher amounts of coarse sand have more herbaceous cover and uniform vegetation height (Figure 20 & 21). This finding is similar to a study conducted

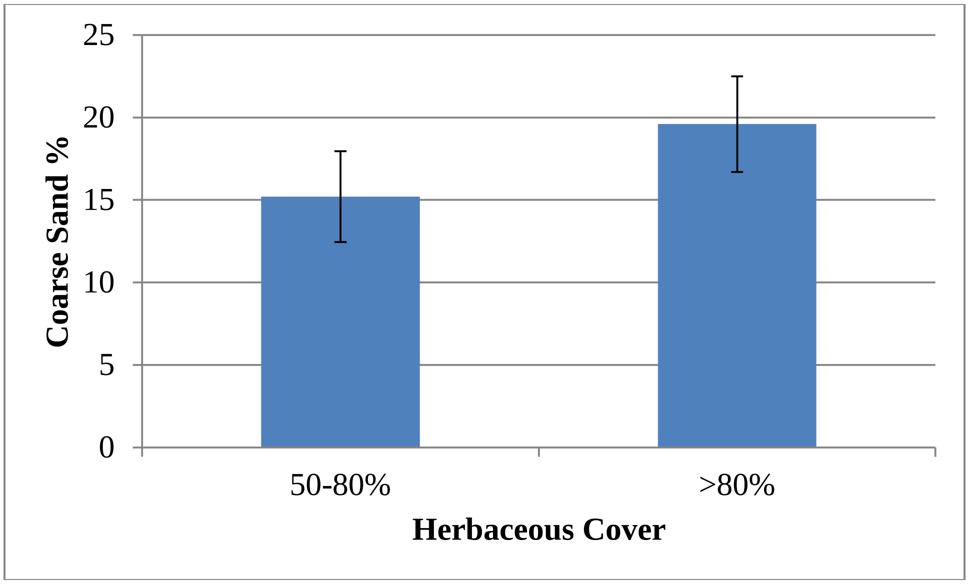


*Figure 20*. Significant median percent of coarse sand for WESPUS herbaceous cover classes. *Note.* Error bars represent the interquartile range.

by Dunaway, Swanson, Wendel, and Clary (1994) where they found nearly 50% of herbaceous plants sampled comprised of rushes, sedges, and mixed grasses, were found in a sandy loam soil. This also indicates a higher potential for mechanical transport, wind erosion, with wetlands that contain higher amounts of coarse sand (Thorn, 1976). Herbaceous plants also tend to have more uniform heights than those with a diversity of plant forms.

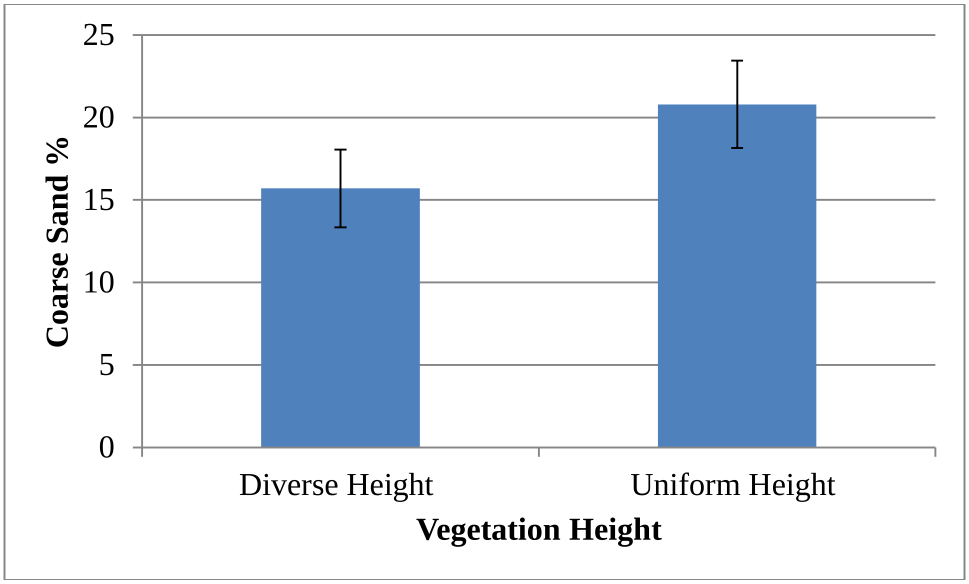


*Figure 21*. Significant median percent of coarse sand for WESPUS vegetation height classes. *Note.* Error bars represent the interquartile range.

The final WESPUS variable to discuss is downed woody debris compared to silt content. Figure 22 illustrates that wetlands containing several downed woody debris pieces have soils with higher amounts of silt. This likely indicates that wetlands with higher amounts of downed woody debris result in slower flows through the wetland, allowing more silt deposition (Tiner, 1998). In addition, the downed wood may trap silt as water flows through wetlands. Other theories state that more downed woody debris could indicate higher amounts of runoff and erosion in and around the wetland. Also, wetlands that have more downed wood pieces are higher-elevation wetlands that experience more precipitation (Figures 23 & 24). The higher amounts of precipitation would typically create more runoff allowing wetlands to trap more silt (Thorn, 1976: Tiner, 1998).

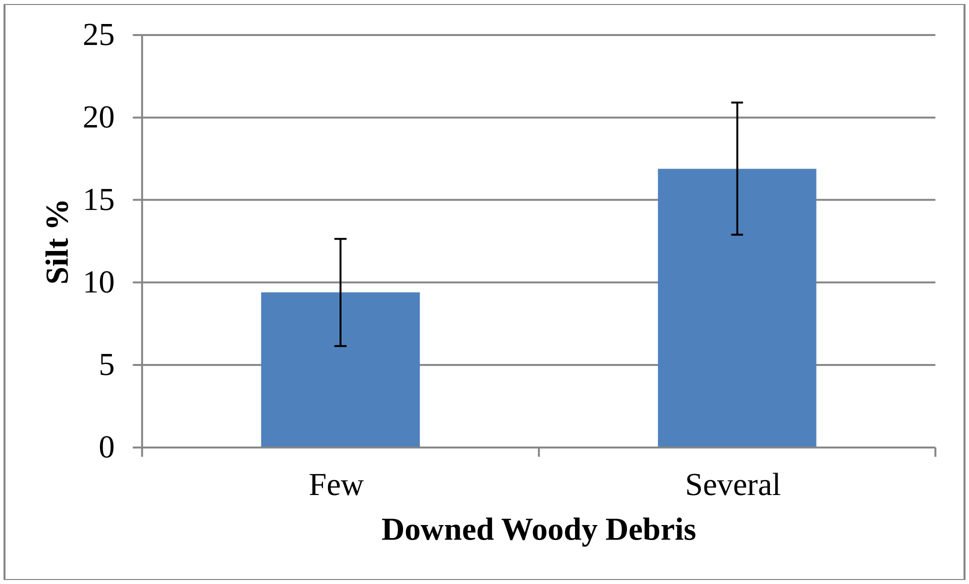


*Figure 22*. Significant median percent of silt for WESPUS downed woody debris classes. *Note.* Error bars represent the interquartile range.

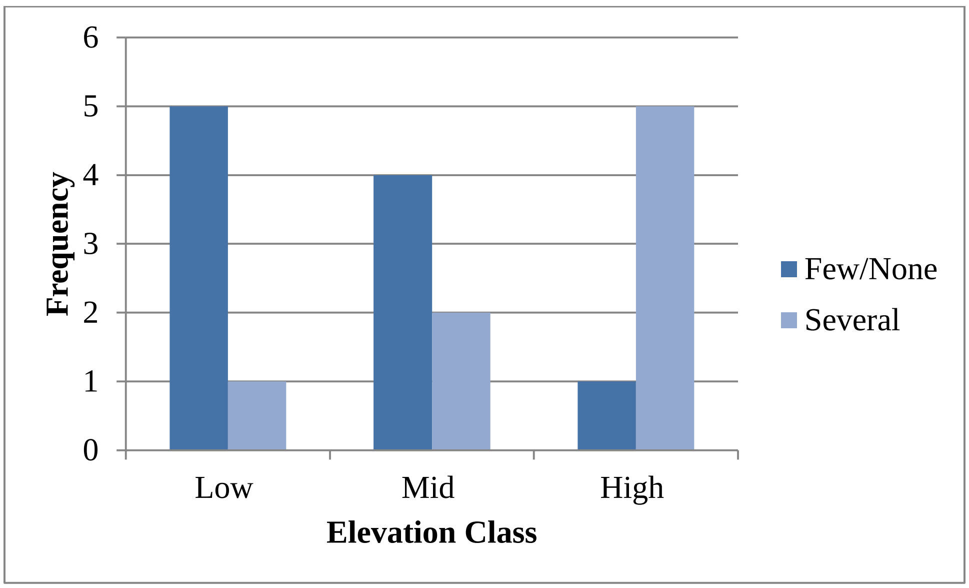


*Figure 23*. Downed woody debris greater than four inches in diameter by elevation class

Soil Characteristics

Wetland soil characteristics are mainly influenced by external inputs, including various forms of runoff transporting sediments; both suspended and dissolved (Prusty, Chandra, & Azeez, 2010). Studies analyzing specific wetland soil macronutrients throughout the Cascade Range are rare. A basic understanding of soil characteristics,

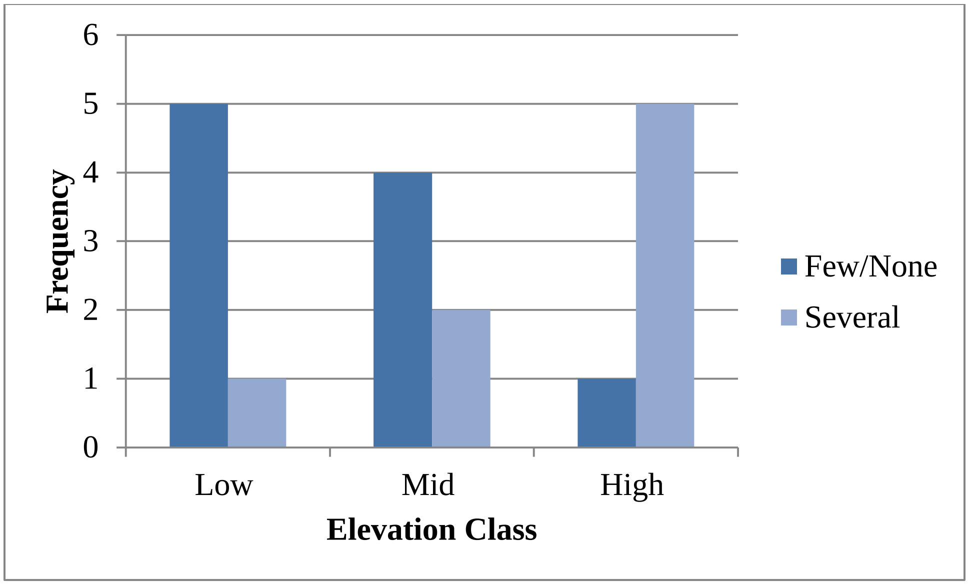

*Figure 24*. General downed wood pieces by elevation class

including macronutrients, is important for wetland management because these factors are the driving forces behind wetland productivity (Mitsch & Gosselink, 2007; Prusty et al., 2010).

*Macronutrients*

Calcium was found to be negatively correlated with habitat function, likely driven by corresponding differences in organic matter. Highly organic soils usually have more insoluble minerals in organic form, making them unusable for vegetation (Mitsch & Gosselink, 2007). Ferric iron and potassium were both found to negatively correlate with organic matter. As organic matter is reduced, this allows for more minerals and nutrients to become available for plant uptake (Mitsch & Gosselink, 2007). Previous discussion on potassium revealed that Venternik et al. (2002a) and Venternik et al. (2002b) found that potassium concentrations are also higher when wetland soils go through wetting and drying cycles. In addition, ferric iron and potassium are both primary nutrients contributing to wetland plant growth and can be limiting factors for species richness in nutrient deficient environments (Venternik et al., 2002a).

### *Texture*

Soil texture was compared to wetland function variables and soil characteristics using the Spearman Rank Correlation test. Results indicate that habitat function is negatively correlated with very coarse sand. This finding is likely related to the fact that increased permeability that will likely result in less ponding and shallower water depths ultimately leading to lower habitat function scores (Saxton, Rawls, Romberger, & Papendick, 1986). Total function was also found to negatively correlate with very coarse sand and likely has the same driving force as noted above for habitat function.

pH was found to be negatively correlated with very fine sand, fine sand, and medium sand, while positively correlated with very coarse sand. As finer sediment concentrations decrease, soil pH increases, likely resulting from variations in saturation levels, leaching, and organic matter concentrations. As finer sediments decrease, this implies an increase in coarser sediments, likely increasing permeability and leaching, allowing for less hydrogen cation accumulation, ultimately increasing soil pH (Tiner, 1998). A high concentration of coarse sand was found in lower elevation wetlands, similarly, increasing leaching rates allowing for decreased soil pH levels (Tiner, 1998).

### *Organic Matter*

Fine sand, medium sand, and very coarse sand were found to have statistically significant correlations with organic matter. Fine and medium sand were negatively correlated with organic matter, while very coarse sand was positively correlated with organic matter. The relationship between organic matter and texture pertains to leaching rates and organic matter accumulation (Townsend, Vitousek, & Trumbore, 1995). An expected result would have been the opposite based on differences in ponding and leaching. More specifically, higher amounts of coarse sand would facilitate higher leaching rates, decreasing organic matter while higher amounts of fine sand would facilitate lower leaching rates, increasing organic matter. The actual findings are contrary to Townsend et al. (1995) and Megonigal, Patrick, and Faulkner (1993). A potential explanation is supported by Campbell, Cole, and Brooks (2002) relating to shallow soil samples (< 10 cm). Organic matter was found to accrete near the soil surface in naturally occurring depressional wetlands in Pennsylvania (Campbell, Cole, & Brooks, 2002).

# CHAPTER VII

# SUMMARY AND MANAGEMENT IMPLICATIONS

## Summary

Results from this study show that elevation is the dominant force behind wetland function over aspect. Elevation influences precipitation and snowpack which changes wetland function most by altering basin size and hydrology in turn increasing ecological function. This section will briefly outline important findings and offer potential management implications of this study.

Habitat, hydrologic, and total function were all found to be significantly different with elevation. Habitat function was highest in high-elevation wetlands and this is thought to be influenced by variations in precipitation and snowpack. Variations in precipitation and snowpack alter basin surface area and depth in turn increasing wetland habitat. Hydrologic function was also greater in high-elevation wetlands. Depth of ponding was the driving force behind hydrologic function. High-elevation wetlands have deeper basins likely resulting from higher amounts of precipitation, deeper snowpack, and are situated higher on the landslide. Wetland site situation on the landslide may have played a more significant role in wetland ponding depth than precipitation. Topographic analysis reveals high-elevation wetlands having steeper uphill slopes, likely increasing sheet wash velocity, perhaps deepening wetland basin morphology. The resulting deeper basins allow for more flood water retention resulting in higher hydrological function. Finally, total function was found to be greatest in high-elevation wetlands. Total function is the sum of water quality, habitat, and hydrologic function, and therefore explanations directly tie to previous conclusions on habitat and hydrologic function.

Three vegetation species were found to be significantly related with elevation including woolly sedge, Brewer's rush, and Kentucky bluegrass. Woolly sedge had the greatest median percent cover in high-elevation wetlands because of characteristics associated with the species. Woolly sedge thrives in areas with the least amount of groundwater fluctuation, which occurs in high-elevation wetlands because of high amounts of precipitation and snow melt. Brewer's rush was found negatively correlated with elevation because it favors areas with less ponding and more transitional areas between wet and upland soils. Kentucky bluegrass was also found to be negatively correlated with elevation. Kentucky bluegrass favors more upland and drier soils more characteristic of low-elevation wetlands. Finally, species richness was found to be significantly different with elevation. The highest species richness was found in mid-elevation wetlands, likely driven by variations in soil wetting and drying cycles. The last significant result related to elevation was soil potassium concentrations, which were highest at mid-elevation wetlands. This occurs presumably because of wetting and drying of the wetland soil, which allows for more potassium to become available for plant uptake.

No significant results were found with regard to aspect, although species richness and diversity were both found to be higher in north-facing wetlands. This finding is supported by studies conducted in the Rocky Mountains in terms of higher soil moisture and better temperatures for seed germination, which make for higher amounts of species richness and diversity compared to south-facing wetlands. In terms of limitations, a small sample size may have been the reason for insignificant differences with regard to aspect. A more detailed analysis, including a larger sample size, could be conducted to strengthen this study to check this result by examining wetlands watershed-wide based on aspect. Results could be compared based on significant differences at other wetland sites.

Several significant results were found comparing variables to WESPUS including habitat function, total function, coarse sand, and silt. Habitat function was higher in wetlands with several downed woody debris pieces. Similarly, total function was higher in wetlands with more downed woody debris and several pieces or downed wood greater than 4 inches in diameter. This is logical because more downed wood will result in higher habitat function scores because WSWRS considers downed wood special habitat features. Coarse sand concentrations were found to be higher in wetlands with more than 80% herbaceous cover and wetlands with more uniform vegetation heights. Finally, silt concentrations were found to be higher in wetlands with more downed woody debris.

Soil characteristics include macronutrients, texture, and organic content. Several significant results were found comparing soil characteristics to all other variables. Variations in macronutrients, calcium, ferric iron, and potassium, were all found to be statistically significant. Calcium was negatively correlated with habitat function. Ferric iron and potassium were both negatively correlated with organic matter. In terms of soil texture, very coarse sand was negatively correlated with habitat and total function. Very fine, fine, and medium sand were all negatively correlated with pH. Very coarse sand was the only positive correlation with pH. Finally, organic matter was negatively correlated with fine and medium sand, while a positive correlation was found with very coarse sand.

## Management Implications

Subalpine wetlands perform a variety of beneficial functions for the surrounding landscape. Important management implications involve public use, grazing, timber, and roads. As stated in Chapter II, the Wenatchee National Forest (1990) manages "areas that are inundated by surface or ground water with a frequency sufficient enough to support prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Under normal circumstances the areas does or would support prevalence of vegetative or aquatic life."

Despite the WSWRS being developed for wetlands under 1000 m in elevation, the findings of this study indicate that it is effective for subalpine wetlands. When coupled with a hybrid of the WESPUS, quantifying subalpine wetland function becomes strengthened in terms of effectiveness by increasing the number of measurable variables. Given the results of this thesis, priority for management should be given to wetland elevation in terms of quantifying subalpine wetland function because no statistically significant results were found when comparing variables with aspect. A subalpine wetland management program could be developed to concentrate restoration and conservation efforts on higher elevation wetlands. For example, placing downed wood pieces in subalpine wetlands will provide more habitat, ultimately increasing wetland function. Furthermore, statistically significant soil characteristics directly tied to wetland function include calcium and very coarse sand concentrations. In terms of management, a wetland monitoring program could be developed to document soil characteristic fluctuations focusing on macronutrient concentrations and substrate textures to infer overall wetland function and ecological health.

Additionally, changes could be made to the WSWRS to incorporate more measureable variables to make it more applicable to wetlands located higher than 1000 m in elevation. Additional variables could be added to classify wetlands further, such as adding scoring categories based on elevation and soil characteristics. To maintain the rapid nature of the WSWRS, elevation can be measured by a GPS unit or remotely via computer mapping software, and based on the significance of very coarse sand, a general soil texture category could be added containing a feel test with two classes to infer functional scores (e.g., feels more like sand or feels more like silt).

With regard to further research, a comparative analysis could be done in terms of conducting similar research at a different location within the Swauk Watershed on a different landslide deposit to measure function based on underlying geology. In addition, more subalpine function data could be compiled to develop modeling techniques to measure function remotely. Finally, over time wetland function could be measured in the Swuak Watershed to assess impacts associated with climate change. The 18 wetlands assessed in this thesis could provide baseline data that may be used to monitor general wetland function throughout the Swauk Watershed. Finally, a more detailed precipitation analysis could be conducted to measure actual precipitation totals among wetland elevational classes and compare the finding to wetland basin depth.

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# APPENDIX

## Washington State Wetland Rating System – Eastern Washington Field Form

The following wetland rating form was originally published in 2008 and has been updated to a 2014 edition since. The 2008 form was used for this research and is not readily available.

Wetland name or number: ___________

# WETLAND RATING FORM –EASTERN WASHINGTON

Version 2 – Updated July 2006 to increase accuracy and reproducibility among users – Updated Oct. 2008 with the new WDFW definitions for priority habitats

Name of wetland (if known): _____ Date of site visit: _____

Rated by: _____ Trained by Ecology? ☐ Yes ☐ No Date of training: _____

SEC: _____ TWNSHP: _____ RNGE: _____ Is S/T/R in Appendix D? ☐ Yes ☐ No

**Map of wetland unit: Figure _____ Estimated size _____**

## SUMMARY OF RATING

**Category based on FUNCTIONS provided by wetland:** ☐ I ☐ II ☐ III ☐ IV

| | |
|---|---|
| Category I = | Score > 70 |
| Category II = | Score 51 - 69 |
| Category III = | Score 30 - 50 |
| Category IV = | Score < 30 |

| | |
|---|---|
| Score for "Water Quality" Functions | |
| Score for Hydrologic Functions | |
| Score for Habitat Functions | |
| TOTAL score for Functions | |

**Category based on SPECIAL CHARACTERISTCS of Wetland:** ☐ I ☐ II ☐ III ☐ Does not Apply

**Final Category** (choose the "highest" category from above") ☐

**Summary of basic information about the wetland unit.**

| Wetland Type | |
|---|---|
| **Vernal Pool** | ☐ |
| **Alkali** | ☐ |
| **Natural Heritage Wetland** | ☐ |
| **Bog** | ☐ |
| **Forest** | ☐ |
| **None of the above** | ☐ |

| Wetland Class | |
|---|---|
| **Depressional** | ☐ |
| **Riverine** | ☐ |
| **Lake-fringe** | ☐ |
| **Slope** | ☐ |
| Check if unit has multiple HGM classes present | ☐ |

**Does the wetland being rated meet any of the criteria below?**

If you answer YES to any of the questions below you will need to protect the wetland according to the regulations regarding the special characteristics found in the wetland.

| Check List for Wetlands that Need Special and that are Not Included in the Rating | YES | NO |
|---|---|---|
| SP1. *Has the wetland unit been documented as a habitat for any Federally listed Threatened or Endangered **animal or plant** species (T/E species)?* For the purposes of this rating system, "documented" means the wetland is on the appropriate state or federal database. | ☐ | ☐ |
| SP2. *Has the wetland unit been documented as habitat for any State listed Threatened or Endangered **animal** species?* For the purposes of this rating system, "documented" means the wetland is on the appropriate state database. Note: Wetlands with State listed plant species are categorized as Category 1 Natural Heritage Wetlands (see p. 19 of data form). | ☐ | ☐ |
| SP3. *Does the wetland unit contain individuals of Priority species listed by the WDFW for the state?* | ☐ | ☐ |
| SP4. *Does the wetland unit have a local significance in addition to its functions?* For example, the wetland has been identified in the Shoreline Master Program, the Critical Areas Ordinance, or in a local management plan as having special significance. | ☐ | ☐ |

**To complete the next part of the data sheet you will need to determine the Hydrogeomorphic Class of the wetland being rated.**

The hydrogeomorphic classification groups wetlands into those that function in similar ways. Classifying the wetland first simplifies the questions needed to answer how it functions. The Hydrogeomorphic Class of a wetland can be determined using the key below. See p. 20 for more detailed instructions on classifying wetlands.

Wetland name or number: ____________

**Classification of Vegetated Wetlands for Eastern Washington**

If the hydrologic criteria listed in each question do not apply to the entire unit being rated, you probably have a unit with multiple HGM classes. In this case, identify which hydrologic criteria in questions 1-7 apply, and go to Question 8.

1. Does the entire wetland unit **meet both** of the following criteria?

   ☐ The vegetated part of the wetland is on the shores of a body of open water (without any vegetation on the surface) where at least 20 acres (8 ha) in size;
   ☐ At least 30% of the open water area is deeper than 3 m (10 ft)?

   ☐ NO – go to Step 2 ☐ **YES** – The wetland class is **Lake-fringe (lacustrine fringe)**

2. Does the wetland unit **meet all** of the following criteria?

   ☐ The wetland is on a slope *(slope can be very gradual).*
   ☐ The water flows through the wetland in one direction (unidirectional) and usually comes from seeps. It may flow subsurface, as sheetflow, or in a swale without distinct banks.
   ☐ The water leaves the wetland **without being impounded**?
   NOTE: *Surface water does not pond in these types of wetlands except occasionally in very small and shallow depressions or behind hummocks (depressions are usually <3 ft diameter and less than a foot deep).*

   ☐ NO – go to Step 3 ☐ **YES** – The wetland class is **Slope**

3. Is the wetland unit in a valley or stream channel where it gets inundated by overbank flooding from that stream or river? In general, the flooding should occur at least once every ten years to answer "yes". *The wetland can contain depressions that are filled with water when the river is not flooding.*

   ☐ NO – go to Step 4 ☐ **YES** – The wetland class is **Riverine**

4. Is the wetland unit in a topographic depression, outside areas that are inundated by overbank flooding, in which water ponds, or is saturated to the surface, at some time of the year. *This means that any outlet, if present is higher than the interior of the wetland.*

   ☐ NO – go to Step 5 ☐ **YES** – The wetland class is **Depressional**

5. Your wetland unit seems to be difficult to classify and probably contains several different HGM classes. For example, seeps at the base of a slope may grade into a riverine floodplain, or a small stream within a depressional wetland has a zone of flooding along its sides. GO BACK AND IDENTIFY WHICH OF THE HYDROLOGIC REGIMES DESCRIBED IN QUESTIONS 1-7 APPLY TO DIFFERENT AREAS IN THE UNIT (make a rough sketch to help you decide). Use the following table to identify the appropriate class to use for the rating system if you have several HGM classes present within your wetland. NOTE: Use this table only if the class that is recommended in the second column represents 10% or more of the total area of the wetland unit being rated. If the area of the class listed in column 2 is less than 10% of the unit, classify the wetland using the class that represents more than 90% of the total area.

| *HGM Classes Within One Delineated Wetland Boundary* | *Class to Use for Rating* |
|---|---|
| Slope + Riverine | Riverine |
| Slope + Depressional | Depressional |
| Slope + Lake-fringe | Lake-fringe |
| Depressional + Riverine (riverine is within boundary of depression) | Depressional |
| Depressional + Lake-fringe | Depressional |

If you are unable still to determine which of the above criteria apply to your wetland, or you have more than 2 HGM classes within a wetland boundary, classify the wetland as **Depressional** for the rating.

Wetland name or number: ____________

| D | Depressional and Flat Wetlands | Points |
|---|---|---|
| | WATER QUALITY FUNCTIONS – Indicators that wetland functions to improve water quality. | (only 1 score per box) |
| **D 1** | **Does the wetland unit have the <u>potential</u> to improve water quality?** | *(see p.38)* |
| | D 1.1 Characteristics of surface water flows out of the wetland unit:<br>• Wetland has no surface water outlet ........ points = 5 ☐<br>• Wetland has an intermittently flowing outlet ........ points = 3 ☐<br>• Wetland has a highly constricted permanently flowing outlet........ points = 3 ☐<br>• Wetland has a permanently flowing surface outlet........ points = 1 ☐ | |
| | D 1.2 The soil 2 inches below the surface (or duff layer) is clay or organic *(use NRCS definition of soil types).*<br>☐ **YES** points = 3 ☐ **NO** points = 0 | |
| | D 1.3 Characteristics of persistent vegetation (emergent, shrub, and/or forest Cowardin class):<br>• Wetland has persistent, ungrazed vegetation for > = 2/3 of area........ points = 5 ☐<br>• Wetland has persistent, ungrazed vegetation from 1/3 to 2/3 of area........ points = 3 ☐<br>• Wetland has persistent, ungrazed vegetation from 1/10 to < 1/3 of area........ points = 1 ☐<br>• Wetland has persistent, ungrazed vegetation < 1/10 of area........ points = 0 ☐<br>**Map of Cowardin vegetation classes** | **Figure** ☐ |
| | D 1.4 Characteristics of seasonal ponding or inundation: *This is the area of ponding that fluctuates every year. Do not count the area that is permanently ponded.*<br>• Area seasonally ponded is > 1/2 total area of wetland........ points = 3 ☐<br>• Area seasonally ponded is 1/4 to 1/2 total area of wetland........ points = 1 ☐<br>• Area seasonally ponded is < 1/4 total area of wetland........ points = 0 ☐<br>NOTE: *See text for indicators of seasonal and permanent inundation/flooding..........* **Map of Hydroperiods** | **Figure** ☐ |
| | **Total for D 1** *Add the points in the boxes above* | |
| **D 2** | **Does the wetland unit have the <u>opportunity</u> to improve water quality?**<br>Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland? *Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.*<br>☐ Grazing in the wetland or within 150 ft<br>☐ Untreated stormwater discharges to wetland<br>☐ Tilled fields or orchards within 150 ft. of wetland<br>☐ A stream or culvert discharges into wetland that drains developed areas, residential areas, farmed fields, roads, or clear-cut logging<br>☐ Residential, urban areas, golf courses are within 150 ft. of wetland<br>☐ Wetland is fed by groundwater high in phosphorus or nitrogen<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | Multiplier |
| ◆ | **<u>TOTAL</u> – Water Quality Functions** Multiply the score from D1 by D2. ***Record score on p. 1 of field form*** | _____ |
| | HYDROLOGIC FUNCTIONS – Indicators that wetland functions to reduce flooding and stream erosion. | |
| **D 3** | **Does the wetland unit have the <u>potential</u> to reduce flooding and stream erosion?** | *(see p.39)* |
| | D 3.1 Characteristics of surface water flows out of the wetland unit:<br>• Wetland has no surface water outlet........ points = 8 ☐<br>• Wetland has an intermittently flowing outlet........ points – 4 ☐<br>• Wetland has a highly constricted permanently flowing outlet........ points = 4 ☐<br>• Wetland has a permanently flowing surface outlet........ points = 0 ☐ | |
| | D 3.2 Depth of storage during wet periods. *Estimate the height of ponding above the surface of the wetland (see text for description of measuring height). In wetlands with permanent ponding, the surface is the lowest elevation of "permanent" water).*<br>• Marks of ponding are at least 3 ft. above the surface........ points = 8 ☐<br>• The wetland is a "headwater" wetland *(see p. 39)*........ points = 6 ☐<br>• Marks are 2 ft. to < 3 ft. from surface........ points = 6 ☐<br>• Marks are 1 ft. to < 2 ft. from surface........ points = 4 ☐<br>• Marks are 6 in. to < 1 ft. from surface........ points = 2 ☐<br>• No marks above 6 in. or wetland has only saturated soils........ points = 0 ☐ | |
| | **Total for D 3** *Add the points in the boxes above* | |
| **D 4** | **Does the wetland unit have the <u>opportunity</u> to reduce flooding and erosion?**<br>*Answer NO if the major source of water is groundwater, irrigation return flow, or water levels in the wetland are controlled by a reservoir.* Answer YES if the wetland is in a location in the watershed where the flood storage, or reduction in water velocity it provides helps protect downstream property and aquatic resources from flooding or excessive and/or erosive flows. *Note which of the following conditions apply.*<br>☐ Wetland is in a headwater of a river or stream that has flooding problems.<br>☐ Wetland drains to a river or stream that has flooding problems<br>☐ Wetland has no outlet and impounds surface runoff water that might otherwise flow into a river or stream that has flooding problems<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p. 42)*<br><br>Multiplier |
| ◆ | **<u>TOTAL</u> – Hydrologic Functions** Multiply the score from D3 by D4; then ***record score on p.1 of field form.*** | _____ |

Wetland name or number: ___________

| R | Riverine Wetlands | Points |
|---|---|---|
| | WATER QUALITY FUNCTIONS – Indicators that wetland functions to improve water quality. | (only 1 score per box) |
| **R 1** | **Does the wetland unit have the <u>potential</u> to improve water quality?** | *(see p.45)* |
| | R 1.1 Area of surface depressions within the riverine wetland that can trap sediments during a flooding event:<br>• Depressions cover > 1/3 area of wetland........ points = 6 ☐<br>• Depressions cover > 1/10 area of wetland........ points = 3 ☐<br>**If depressions > 1/10th of area of unit draw polygons on aerial photo or map.**<br>• Depressions present but cover < 1/10 area of wetland........ points = 1 ☐<br>• No depressions present........ points = 0 ☐ | **Figure** ☐ |
| | R 1.2 Characteristics (cover) of the vegetation in the unit *(area of polygons with > 90% cover at person height. This is **not** Cowardin vegetation classes)*:<br>• Forest or shrub > 2/3 the area of the wetland........ points =10 ☐<br>• Forest or shrub 1/3 – 2/3 area of the wetland........ points = 5 ☐<br>• Ungrazed, herbaceous plants > 2/3 area of wetland........ points = 5 ☐<br>• Ungrazed herbaceous plants 1/3 – 2/3 area of wetland........ points = 2 ☐<br>• Forest, shrub, and ungrazed herbaceous < 1/3 area of wetland........ points = 0 ☐<br>**Arial photo or map showing polygons of different vegetation cover** | **Figure** ☐ |
| | Total for R1 — Add the points in the boxes above | |
| **R 2** | **Does the wetland have the <u>opportunity</u> to improve water quality?**<br>Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland. *Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.*<br>☐ Grazing in the wetland or within 150 ft<br>☐ Wetland intercepts groundwater within the Reclamation Area<br>☐ Untreated stormwater flows into wetland<br>☐ Tilled fields or orchards within 150 ft. of wetland<br>☐ Water flows into wetland from a stream or culvert that drains developed areas, residential areas, farmed fields, roads, or clear-cut logging<br>☐ Residential or urban areas are within 150 ft. of wetland<br>☐ The river or stream that floods the wetland has a contributing basin where human activities have raised levels of sediment, toxic compounds or nutrients in the river water above water quality standards.<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p. 46)*<br>Multiplier |
| ◆ | **<u>TOTAL</u> – Water Quality Functions**<br>Multiply the score from R1 by the multiplier in R2; then ***record score on p.1 of field form.*** | ____ |
| | HYDROLOGIC FUNCTIONS – Indicators that wetland functions to reduce flooding and stream degradation. | |
| **R 3** | **Does the wetland have the <u>potential</u> to reduce flooding and erosion?** | *(see p.47)* |
| | R 3.1 Amount overbank storage the wetland provides: *Estimate the average width of the wetland perpendicular to the direction of the flow of water and the width of the stream or river channel (distance between banks). Calculate the ratio: width of wetland / width of stream.*<br>• If the ratio is 2 or more........ points =10 ☐<br>• If the ratio is between 1 and < 2........ points = 8 ☐<br>• If the ratio is 1/2 to < 1........ points = 4 ☐<br>• If the ratio is 1/4 to < 1/2........ points = 2 ☐<br>• If the ratio is < 1/4........ points = 1 ☐<br>**Aerial photo or map showing average widths** | **Figure** ☐ |
| | R 3.2 Characteristics of vegetation that slow down water velocities during floods: *Treat large woody debris as "forest or shrub" (areas of polygons with > 90% cover at person height. This is **not** Cowardin vegetation classes):*<br>• Forest or shrub for more than 2/3 the area of the wetland........ points = 6 ☐<br>• Forest or shrub for > 1/3 area OR herbaceous plants > 2/3 area........ points = 4 ☐<br>• Forest or shrub for > 1/10 area OR herbaceous plants > 1/3 area........ points = 2 ☐<br>• Vegetation does not meet above criteria........ points = 0 ☐<br>**Aerial photo or map showing polygons of different vegetation types** | **Figure** ☐ |
| | Total for R3 — *Add the points in the boxes above* | |
| **R 4** | **Does the wetland have the <u>opportunity</u> to reduce flooding and erosion?**<br>*Answer NO if the major source of water is irrigation return flow or water levels are controlled by a reservoir.* Answer YES if the wetland is in a location in the watershed where the flood storage, or reduction in water velocity it provides helps protect downstream property and aquatic resources from flooding or excessive and/or erosive flows. *Note which of the following conditions apply.*<br>☐ There are human structures and activities downstream (roads, buildings, bridges, farms) that can be damaged by flooding.<br>☐ There are natural resources downstream (e.g. salmon redds) that can be damaged by flooding<br>☐ Other ______<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p.50)*<br>Multiplier |
| ◆ | **<u>TOTAL</u> – Hydrologic Functions** — Multiply the score from R3 by the multiplier in R4. ***Record score on p.1 of field form.*** | ____ |

Wetland name or number: ____________

| L | Lake-fringe Wetlands | Points (only 1 score per box) |
|---|---|---|
| | WATER QUALITY FUNCTIONS – Indicators that wetland functions to improve water quality. | |
| **L 1** | **Does the wetland have the <u>potential</u> to improve water quality?** | *(see p.52)* |
| | L 1.1 Average width of vegetation along the lakeshore:<br>• Vegetation is more than 33 ft. (10m) wide ........ points = 6 ☐<br>• Vegetation is more than 16 ft.(5m) wide and < 33 ft wide........ points = 3 ☐<br>• Vegetation is 6 ft. (2m) wide to < 16 ft wide ........ points = 1 ☐<br>**Map of Cowardin classes with widths marked** | **Figure** ☐ |
| | L 1.2 Characteristics of the vegetation in the wetland: *Choose the appropriate description that results in the highest points, and do not include any open water in your estimate of coverage. The herbaceous plants can be either the dominant form or as an understory in a shrub or forest community. These are not Cowardin classes. Area of Cover is total cover in the unit, but it can be in patches. NOTE: Herbaceous does not include aquatic bed.*<br>• Herbaceous plants cover > 90% of the vegetated area........ points = 6 ☐<br>• Herbaceous plants cover > 2/3 of the vegetated area........ points = 4 ☐<br>• Herbaceous plants cover > 1/3 of the vegetated area........ points = 3 ☐<br>• Other vegetation that is not aquatic bed in > 2/3 vegetated area........ points = 3 ☐<br>• Other vegetation that is not aquatic bed in > 1/3 vegetated area........ points = 1 ☐<br>• Aquatic bed cover > 2/3 of the vegetated area........ points = 0 ☐<br>**Map with polygons of different vegetation types** | **Figure** ☐ |
| | Total for L1 *Add the points in the boxes above* | |
| **L 2** | **Does the wetland have the <u>opportunity</u> to improve water quality?**<br>Answer YES if you know or believe there are pollutants in the lake water, or surface water flowing through the wetland to the lake is polluted. *Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.*<br>☐ Wetland is along the shores of a lake or reservoir that does not meet water quality standards<br>☐ Grazing in the wetland or within 150 ft<br>☐ Untreated stormwater flows into the wetland<br>☐ Tilled fields or orchards within 150 ft. of wetland<br>☐ Residential or urban areas are within 150 ft. of wetland<br>☐ Powerboats with gasoline or diesel engines use the lake<br>☐ Parks with grassy areas that are maintained, ballfields, golf courses (all within 150 ft. of shore of lake)<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p.53)*<br>Multiplier |
| ◆ | **<u>TOTAL</u> – Water Quality Functions** Multiply the score from L1 by the multiplier in L2.<br>***Record score on p.1 of field form.*** | ____ |
| | HYDROLOGIC FUNCTIONS – Indicators that wetland functions to reduce shoreline erosion. | |
| **L 3** | **Does the wetland have the <u>potential</u> to reduce shoreline erosion?** | *(see p.54)* |
| | L 3.1 Average width and characteristics of vegetation along the lakeshore ***(do not** include aquatic bed):*<br>*(choose the highest scoring description that matches conditions in the wetland)*<br>• > 3/4 of vegetation is shrubs or trees at least 33 ft. (10m) wide........ points = 6 ☐<br>• > 3/4 of vegetation is shrubs or trees at least 6 ft. (2m) wide. ........ points = 4 ☐<br>• > 1/4 of vegetation is shrubs or trees at least 33 ft. (10m) wide........ points = 4 ☐<br>• Vegetation is at least 6 ft. (2m) wide ........ points = 2 ☐<br>• Vegetation is less than 6 ft. (2m) wide........ points = 0 ☐<br>**Aerial photo or map with Cowardin vegetation classes** | **Figure** ☐ |
| **L 4** | **Does the wetland have the <u>opportunity</u> to reduce erosion?**<br>Are there features along the shore that will be impacted if the shoreline erodes? *Note which of the following conditions apply.*<br>☐ There are human structures and activities along the shore behind the wetland (buildings, fields) that can be damaged by erosion.<br>☐ There are undisturbed natural resources along the shore (e.g. mature forests, other classes of wetland) behind the wetland that can be damaged by shoreline erosion.<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p. 55)*<br>Multiplier |
| ◆ | **<u>TOTAL</u> – Hydrologic Functions** Multiply the score from L3 by the multiplier L4.<br>***Record score on p.1 of field form.*** | ____ |

Comments:

Wetland name or number: ____________

| S | Slope Wetlands | Points |
|---|---|---|
| | WATER QUALITY FUNCTIONS – Indicators that wetland functions to improve water quality. | (only 1 score per box) |
| **S 1** | **Does the wetland have the <u>potential</u> to improve water quality?** | *(see p.56)* |
| | S 1.1 Characteristics of average slope of wetland:<br>• Slope is 1% or less *(a 1% slope has a 1 ft. vertical drop in elevation for every 100 ft. horizontal distance)* ....points = 3<br>• Slope is between 1% and 2% ....points = 2<br>• Slope is more than 2% but less than 5% ....points = 1<br>• Slope is 5% or greater ....points = 0 | |
| | S 1.2 The soil 2 inches below the surface is clay or organic, or smells anoxic *(use NRCS definitions of soil types)*.<br>**YES** = 3 points **NO** = 0 points | |
| | S 1.3 Characteristics of the vegetation in the wetland that trap sediments and pollutants: *Choose the points appropriate for the description that best fits the vegetation in the wetland.* ***Dense*** *vegetation means you have trouble seeing the soil surface (> 75% cover), and* ***uncut*** *means not grazed or mowed and plants are higher than 6 inches.*<br>• Dense, ungrazed, herbaceous vegetation > 90% of the wetland unit ....points = 6<br>• Dense, ungrazed, herbaceous vegetation > 1/2 of unit ....points = 3<br>• Dense, woody, vegetation > 1/2 of unit ....points = 2<br>• Dense, ungrazed, herbaceous vegetation > 1/4 of unit ....points = 1<br>• Does not meet any of the criteria above for herbaceous vegetation ....points = 0<br>**Aerial photo or map with vegetation polygons** | **Figure** ☐ |
| | Total for S 1 *Add the points in the boxes above* | |
| **S 2** | **Does the wetland have the <u>opportunity</u> to improve water quality?**<br>Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland? *Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.*<br>☐ Grazing in the wetland or within 150 ft<br>☐ Wetland is a groundwater seep within the Reclamation Area<br>☐ Untreated stormwater flows through the wetland<br>☐ Tilled fields, logging, or orchards within 150 ft. of wetland<br>☐ Residential, urban areas, golf courses are within 150 ft. upslope of wetland<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | *(see p. 58)*<br><br>Multiplier |
| ◆ | **<u>TOTAL</u> – Water Quality Functions** Multiply the score from S1 by the multiplier in S2. ***Record score on p.1 of field form.*** | _____ |
| | HYDROLOGIC FUNCTIONS – Indicators that wetland functions to reduce flooding and stream erosion. | |
| **S 3** | **Does the wetland unit have the <u>potential</u> to reduce flooding and stream erosion?** | *(see p.59)* |
| | S 3.1 Characteristics of vegetation that reduce the velocity of surface flows during storms: *Choose the points appropriate for the description that best fits conditions in the wetland. See questions S 1.3 for definition of dense and uncut.* ***Rigid*** *means that the stems of plants should be thick enough (usually > 1/8 in), or dense enough to remain erect during surface flows.*<br>• Dense, uncut, **rigid** vegetation covers > 90% of the area of the unit.... points = 6 ☐<br>• Dense, uncut, **rigid** vegetation> 1/2 – 90% area of unit .... points = 3 ☐<br>• Dense, uncut, **rigid** vegetation > 1/4 – 1/2 of unit.... points = 1 ☐<br>• More than 1/4 of area is grazed, mowed, tilled, or vegetation is not rigid.... points = 0 ☐ | |
| | S 3.2 Characteristics of slope wetland that holds back small amounts of flood flows.<br>The slope has small surface depressions that can retain water over at least 10% of its area.<br>☐ **YES** = 2 points ☐ **NO** = 0 points | |
| | Total for S3 Add the points in the boxes above | |
| **S 4** | **Does the wetland unit have the <u>opportunity</u> to reduce flooding and erosion?** *(see p. 61)*<br>Answer NO if the major source of water is irrigation return flow (e.g. a seep that is on the downstream side of a dam or at the base of an irrigated field. Answer YES if the wetland is in a landscape position where the reduction in water velocity it provides helps protect downstream property and aquatic resources fro flooding or excessive and/or erosive flows. *Note which of the following conditions apply.*<br>☐ Wetland has surface runoff that can cause flooding problems downgradient<br>☐ Other _____<br>☐ **YES** multiplier is 2 ☐ **NO** multiplier is 1 | Multiplier |
| ◆ | **<u>TOTAL</u> – Hydrologic Functions** Multiply the score from S3 by S4. ***Record score on p.1 of field form.*** | _____ |

Comments: _____

Wetland name or number: ____________

| *These questions apply to wetlands of all HGM classes.*<br>HABITAT FUNCTIONS – Indicators that wetland functions to provide important habitat. | **Points**<br>(only 1 score per box) |
|---|---|

**H 1 Does the wetland have the <u>potential</u> to provide habitat for many species?** *(see P. 62)*

**H 1.1** <u>Categories of Vegetation structure</u>: **Figure** ☐

*Check the vegetarian classes (as defined by Cowardin) and heights of emergents present. Size threshold for each class or height category is 1/4 acre or more than 10% of the area if unit is < 2.5 acres.*

- ☐ Aquatic bed
- ☐ Emergent plants 0-12 inches (0-30cm) high are the highest layer and have > 30% cover
- ☐ Emergent plants >12 – 40 inches (30 – 100cm) high are the highest layer with > 30% cover
- ☐ Emergent plants > 40 inches (>100cm) high are the highest layer with > 30% cover
- ☐ Scrub/shrub (areas where shrubs have > 30% cover)
- ☐ Forested (areas where trees have > 30% cover)

*Add the number of vegetation types that qualify. If you have:*

4 –6 types .......... points = 3 ☐ 2 types ..... points = 1 ☐
3 types ............... points = 2 ☐ 1 type....... points = 0 ☐

**Map of Cowardin vegetation classes and areas with different heights of emergents**

**H 1.2** Is one of the vegetation types "aquatic bed?" *(see p.64)*

☐ **YES** = 1 point ☐ **NO** = 0 points

**H 1.3** <u>Surface Water</u> *(see p. 65)* **Figure** ☐

H1.3.1 Does the unit have areas of "open" water (without emergent or shrub plants) over at least 1/4 acre or 10% of its area during the spring (March – early June) OR in early fall (August – end of September)? *Note: answer YES for Lake-fringe wetlands.*

☐ YES = 3 points & **go to H 1.4** ☐ NO = go to H 1.3.2

H 1.3.2 Does the unit have an intermittent or permanent stream within its boundaries, or along one side, over at least 1/4 acre or 10% of its area, AND that has an unvegetated bottom (answer yes only if H 1.3.1 is NO)?

☐ YES = 3 points ☐ NO = 0 points

**Map showing areas of open water**

**H 1.4** <u>Richness of Plant Species</u> *(see p. 66)*

Count the number of plant species in the wetland that cover at least 10 $ft^2$ *(different patches of the same species can be combined to meet the size threshold)*

*You do not have to name the species. Do not include Eurasian Milfoil, reed canarygrass, purple loosestrife, Russian Olive, Phragmites, Canadian Thistle, Yellow-flag Iris, and Salt Cedar (Tamarisk)*

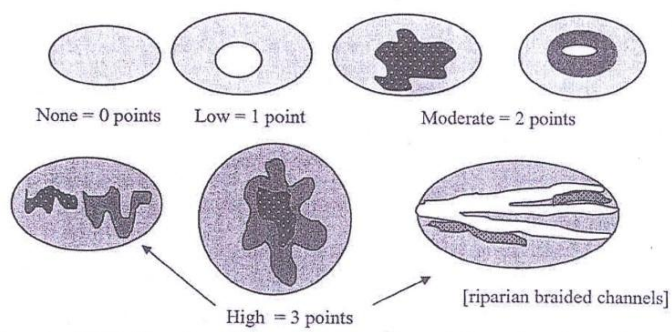
If you counted:
- > 9 species points = 2 ☐
- 4 – 9 species points = 1 ☐
- < 4 species points = 0 ☐

\# of species _____

*List species below if you wish:* _____

**H 1.5** Interspersion of Habitats *(see p. 67)* **Figure** ☐

Decided from the diagrams below whether interspersion between types of vegetation (described in H1.1), or categories and unvegetated areas (can include open water or mudflats) is high, medium, low, or none.




Note: If you have 4 or more vegetation categories or 3 vegetation categories and open water, the rating is always "high".

**Use maps from H 1.1 and H 1.3**

Comments: _____

Wetland name or number: ____________

| | | |
|---|---|---|
| | H 1.6 Special Habitat Features *(see p. 68)*<br>*Check the habitat features that are present in the wetland unit. The number of checks is the number of points you put into the next column.*<br>☐ Loose rocks larger than 4" **or** large, downed, woody debris (> 4 in. diameter) within the area of surface ponding or in stream<br>☐ Cattails or bulrushes are present within the unit<br>☐ Standing snags (diameter at the bottom > 4 inches) in the wetland unit or within 30m (100 ft) of the edge<br>☐ Emergent or shrub vegetation in areas that are permanently inundated/ponded. *The presence of "yellow flag" Iris is a good indicator of vegetation in areas permanently ponded.*<br>☐ Stable steep banks of fine material that might be used by beaver or muskrat for denning (> 45 degree slope) OR signs of recent beaver activity<br>☐ Invasive species cover less than 20% in each stratum of vegetation *(canopy, sub-canopy, shrubs, herbaceous, moss/ground cover)*<br>*Maximum score possible = 6* | |
| | **H 1 TOTAL Score** – potential to provide habitat *Add the scores in the column above* | |
| **H 2** | **Does the wetland have the opportunity to provide habitat for many species?** | (only 1 score per box) |
| | H 2.1 Buffers *(see P. 71)*:<br>*Choose the description that best represents condition of buffer of wetland unit. The highest scoring criterion that applies to the wetland is to be used in the rating. See text for definition of "undisturbed". Relatively undisturbed also means no grazing, no landscaping, no daily human use, and no structures or paving within undisturbed part of buffer.*<br>☐ 330 ft (100m) of relatively undisturbed vegetated areas, rocky areas, or open water > 95% of circumference. .......... **points = 5**<br>☐ 330 ft (100m) of relatively undisturbed vegetated areas, rocky areas, or open water > 50% circumference .......... **points = 4**<br>☐ 170 ft (50m) of relatively undisturbed vegetated areas, rocky areas, or open water > 95% circumference .......... **points = 4**<br>☐ 330 ft (100m) of relatively undisturbed vegetated areas, rocky areas, or open water > 25% circumference.......... **points = 3**<br>☐ 170 ft (50m) of relatively undisturbed vegetated areas, rocky areas, or open water for > 50% circumference .......... **points = 3**<br>**If buffer does not meet any of the three criteria above:**<br>☐ No paved areas (except paved trails) or buildings within 80 ft (25m) of wetland > 95% circumference. Light to moderate grazing or lawns are OK .......... **points = 2**<br>☐ No paved areas of buildings within 170 ft (50m) of wetland for > 50% circumference. Light to moderate grazing or lawns are OK .......... **points = 2**<br>☐ Heavy grazing in buffer.......... **points = 1**<br>☐ Vegetated buffers are < 6.6 ft wide (2m) for more than 95% of the circumference (e.g. tilled fields, paving, basalt bedrock extend to edge of wetland) .......... **points = 0**<br>☐ Buffer does not meet any of the criteria above.......... **points = 1** | **Figure** ☐ |
| | H 2.2 Wet Corridors *(see p. 72)*<br>H 2.2.1 Is the wetland part of a relatively undisturbed and unbroken, > 30 ft. wide, vegetated corridor at least 1/4 mile long with surface water or water flowing water throughout most of the year (> 9 months/yr?) (dams, heavily used gravel roads, paved roads, fields tilled to edge of stream, or pasture to edge of stream are considered breaks in the corridor).<br>☐ **YES** = **4 points** (go to H 2.3) ☐ **NO** = go to H 2.2.2<br>H. 2.2.2 Is the unit part of a relatively undisturbed and unbroken, > 30 ft. wide, vegetated corridor, at least 1/4 mile long with water flowing seasonally, **OR** a lake-fringe wetland without a "wet" corridor, **OR** a riverine wetland without a surface channel connecting to the stream?<br>☐ **YES** = **2 points** (go to H 2.3) ☐ **NO** = go to H 2.2.3<br>H. 2.2.3 Is the wetland within 1/2 mile of any permanent stream, seasonal stream, or lake (*do not include man-made ditches*)?<br>☐ **YES** = 1 point ☐ **NO** = 0 points | |

Comments: _____

H 2.3 Near or adjacent to other priority habitats listed by WDFW *(see new and complete descriptions of WDFW priority habitats, and the counties in which they can be found, in the PHS report http://wdfw.wa.gov/hab/phslist.htm)*.
Which of the following priority habitats are within 330ft (100m) of the wetland unit?
*NOTE: the connections to the habitats can be disturbed.*

- ☐ **Aspen Stands:** Pure or mixed stands of aspen greater than 0.4 ha (1 acre).
- ☐ **Biodiversity Areas and Corridors**: Areas of habitat that are relatively important to various species of native fish and wildlife (may include urban or urban growth areas) (*full descriptions in WDFW PHS report p. 152*).
- ☐ **Eastside Steppe:** Non-forested vegetation type dominated by broadleaf herbaceous flora(i.e., forbs), perennial bunchgrasses, or a combination of both (*full description of species found here in WDFW PHS report p. 153*).
- ☐ **Old-growth/Mature forests (east of Cascade crest):** (*full descriptions in WDFW PHS report p. 157*). Old-growth: Stands are > 150 yrs in age; may be variable in tree species composition and structural characteristics due to the influence of fire, climate, and soils. Mature: Stands 80 – 160 yrs old. Decay, decadence, numbers of snags, and quantity of large downed material is generally less than that found in old-growth.
- ☐ **Oregon white Oak:** Woodlands Stands of pure oak or oak/conifer associations where canopy coverage of the oak component is important (*full descriptions in WDFW PHS report p. 158*).
- ☐ **Juniper Savannah**: All juniper woodlands (*SE part of state only; check map*)
- ☐ **Shrub-steppe**: A nonforested vegetation type consisting of one or more layers of perennial bunchgrasses and a conspicuous but discontinuous layer of shrubs (see Eastside Steppe for sites with little or no shrub cover).
- ☐ **Riparian**: The area adjacent to aquatic systems with flowing water that contains elements of both aquatic and terrestrial ecosystems which mutually influence each other.
- ☐ Inland Dunes This placeholder is for a new priority habitat that will capture areas known as Inland Dunes. A definition will be developed later in Fall 2008. *(check WDFW web site)*
- ☐ **Instream:** The combination of physical, biological, and chemical processes and conditions that interact to provide functional life history requirements for instream fish and wildlife resources.
- ☐ **Caves:** A naturally occurring cavity, recess, void, or system of interconnected passages under the earth in soils, rock, ice, or other geological formations and is large enough to contain a human.
- ☐ **Cliffs:** Greater than 7.6 m (25 ft) high and occurring below 5000 ft.
- ☐ **Talus:** Homogenous areas of rock rubble ranging in average size 0.15 - 2.0 m (0.5 - 6.5 ft), composed of basalt, andesite, and/or sedimentary rock, including riprap slides and mine tailings. May be associated with cliffs.
- ☐ **Snags and Logs:** Trees are considered snags if they are dead or dying and exhibit sufficient decay characteristics to enable cavity excavation/use by wildlife. Priority snags have a diameter at breast height of > 30 cm (12 in) in eastern Washington and are > 2 m (6.5 ft) in height. Priority logs are > 30 cm (12 in) in diameter at the largest end, and > 6 m (20 ft) long.

If wetland has **2 or more** Priority Habitats = **4 points**
If wetland has **1** Priority Habitat = **2 points**
No Priority habitats = **0 points**

*Note: All vegetated wetlands are by definition a priority habitat but are not included in this list. Nearby wetlands are addressed in H 2.4)*

H 2.4 Landscape: *Choose the **one** description of the landscape around the wetland that best fits. (see p. 76)*

- The wetland unit is in an area where annual rainfall is less than 12 inches, and its water regime is not influenced by irrigation practices, dams, or water control structures. (*Generally, this means outside boundaries of reclamation areas, irritation district, or reservoirs.*) .......... points = 5 ☐
- There are at least 3 other wetlands within 1/2 mile, and the connections between them are relatively undisturbed (light grazing in the connection or an open water connection along a lake shore without heavy boat traffic are OK, but connections should NOT be bisected by paved roads, fill, fields, heavy boat traffic or other development. .......... points = 5 ☐
- There are at least 3 other wetlands within 1/2 mile, BUT the connections between them are disturbed. .......... points = 2 ☐
- There is at least 1 wetland within 1/2 mile .......... points = 1 ☐
- Does not meet any of the four criteria above .......... points = 0 ☐

**H 2** TOTAL Score – opportunity for providing habitat — *Add the scores in the columns above* [ ]

**H 3 Does the wetland unit have indicators that its ability to provide habitat is reduced?**

H 3.1 Indicator of reduced habitat functions *(see p. 75)* — *Points will be subtracted*
Do the areas of open water in the wetland unit have a resident population of carp (see text for indicators of the presence of carp)? Note: *This question does not apply to reservoirs with water levels controlled by dams, such as the reservoirs on the Columbia and Snake Rivers.*
☐ **YES** = 5 points ☐ **NO** = 0 points

◆ **Total Score for Habitat Functions** — Add the points for H 1, H 2 and H 3; and ***record the result on p. 1*** _____

Comments: _____

Wetland name or number: ____________

## CATEGORIZATION BASED ON SPECIAL CHARACTERISTICS

***Please determine if the wetland meets the attributes described below and circle the appropriate Category. NOTE: A wetland may meet the criteria for more than one set of special characteristics. Record all those that apply. NOTE: All units should also be characterized based on their functions.***

| | **Wetland Type** – *Check off any criteria that apply to the wetland. Circle the Category when the appropriate criteria are met.* | |
|---|---|---|
| **SC1** | **Vernal pools** *(see p.79)*<br>Is the wetland unit **less than 4,000 ft²**, and does it meet at least **two** of the following criteria?<br>☐ Its only source of water is rainfall or snowmelt from a small contributing basin and has no groundwater input.<br>☐ Wetland plants are typically present only in the spring; the summer vegetation is typically upland annuals. *NOTE: If you find perennial, "obligate", wetland plants the wetland is probably NOT a vernal pool.*<br>☐ The soil in the wetland are shallow (<1 ft. deep (30cm) and is underlain by an impermeable layer such as basalt or clay.<br>☐ Surface water is present for less than 120 days during the "wet" season.<br>☐ **YES** = Go to SC 1.1 ☐ **NO** *not a vernal pool* | |
| | SC 1.1 Is the vernal pool relatively undisturbed in February and March?<br>☐ **YES** = Go to SC 1.2 ☐ **NO** = *not a vernal pool with special characteristics* | |
| | SC 1.2 Is the vernal pool in an area where there are at least 3 separate aquatic resources within 0.5 miles (other wetlands, rivers, lakes etc.)?<br>☐ **YES** = Category II ☐ **NO** = Category III | ☐ **Cat. II**<br>☐ **Cat. III** |
| **SC2** | **Alkali wetlands** *(see p.81)*<br>Does the wetland unit meet **one** of the following two criteria?<br>☐ The wetland has a conductivity > 3.0 mS/cm.<br>☐ The wetland has a conductivity between 2.0 – 3.0 mS, and more than 50% of the plant cover in the wetland can be classified as "alkali" species (see Table 2 for list of plants found in alkali systems).<br>☐ If the wetland is dry at the time of your field visit, the central part of the area is covered with a layer of salt.<br>**OR** does the wetland meet **two** of the following three sub-criteria?<br>☐ Salt encrustations around more than 80% of the edge of the wetland.<br>☐ More than 3/4 of the plant cover consists of species listed on Table 2.<br>☐ A pH above 9.0. All alkali wetlands have a high pH, but please note that some freshwater wetlands may also have a high pH. Thus, pH alone is not a good indicator of alkali wetlands.<br>☐ **YES** = Category I ☐ **NO** – not an alkali wetland | **Cat. I**<br>☐ |
| **SC3** | **Natural Heritage Wetlands** *(see p. 82)*<br>Natural Heritage wetlands have been identified by the Washington Natural Heritage Program/DNR as either high quality undisturbed wetlands or wetlands that support state Threatened, Endangered, or Sensitive plant species.<br>SC 3.1 Is the wetland unit being rated in a Section/Township/Range that contains a natural heritage wetland? *(This question is used to screen out most sites before you need to contact WNHP/DNR.)*<br>S/T/R information from Appendix D ☐ or accessed from WNHP/DNR web site ☐<br>**YES** ☐ Contact WNHP/DNR (see p. 79) and go to SC 3.2 **NO** ☐<br>SC 3.2 Has DNR identified the wetland unit as a high quality undisturbed wetland or as a site with state threatened or endangered plant species?<br>☐ **YES** = Category 1 ☐ **NO** – not a natural heritage wetland | **Cat. I**<br>☐ |

Wetland name or number: ____________

| | | |
|---|---|---|
| **SC4** | **<u>Bogs</u>** *(see p. 82)*<br>Does the wetland unit **(or any part of the wetland unit)** meet both the criteria for soils and vegetation in bogs? Use the key below to identify if the wetland is a bog. *If you answer yes you will still need to rate the wetland based on its functions.*<br>SC 4.1 Does the wetland have organic soil horizons (i.e. layers of organic soil), either peats or mucks, that compose 16 inches or more of the first 32 inches of the soil profile? (See Appendix B for a field key to identify organic soils.)<br>☐ **YES** = go to SC 4.3 ☐ **NO** = go to SC 4.2<br>SC 4.2 Does the wetland have organic soils, either peats or mucks that are less than 16 inches deep over bedrock or an impermeable hardpan such as clay or volcanic ash, or that are floating on top of a lake or pond? ☐ **YES** = go to 4.3 ☐ **NO** = Is not a bog for rating<br>SC 4.3 Does the wetland have more than 70% cover of mosses at ground level in any area within its boundaries, AND other plants, if present, consist of the "bog" species listed in Table 3 as a significant component of the vegetation (more than 30% of the total shrub and herbaceous cover consists of species in Table 3)?<br>☐ **YES** = Category I bog ☐ **NO** = go to question 4.4<br>NOTE: *If you are uncertain about the extent of mosses in the understory you may substitute that criterion by measuring the pH of the water that seeps into a hole dug at least 16" deep. If the pH is less than 5.0 and the "bog" plant species in Table 3 are present, the wetland is a bog.*<br>SC 4.4 Is the unit, or any part of it, forested (> 30% cover) with sitka spruce, subalpine fir, western red cedar, western hemlock, lodgepole pine, quaking aspen, Englemann's spruce, or western white pine, WITH any of the species (or combination of species) on the bog species plant list in Table 3 as a significant component of the ground cover (> *30% coverage of the total shrub/herbaceous cover*)?<br>☐ **YES** = Category 1 bog ☐ **NO** | **Cat. I**<br>☐ |
| **SC5** | **<u>Forested Wetlands</u>** *(see p. 85)*<br>Does the wetland unit have an area of forest *(you should have identified a forested class, if present, in question H 1.1)* rooted within its boundary that meet **at least one** of the following three criteria?<br>☐ The wetland is within the "100 year" floodplain of a river or stream.<br>☐ Aspen (*Populus tremuloides*) are a dominant or co-dominant of the "woody" vegetation. (*Dominants means it represents at least 50% of the cover of woody species, co-dominant means it represents at least 20% of the total cover of woody species.*)<br>☐ There is at least 1/4 acre of trees (even in wetlands smaller than 2.5 acres) that are "mature" or "old-growth" according to the definitions for these priority habitats developed by WDFW *(see p. 83)*.<br>☐ **YES** = got o SC 5.1 ☐ **NO** – *not a forested wetland with special characteristics* | |
| | SC 5.1 Does the wetland unit have a forest canopy where more than 50% of the tree species (by cover) are slow growing native trees? Slow growing trees are: western red cedar (*Thuja plicata*), Alaska yellow cedar (*Chamaecyparis nootkatensis*), pine spp. mostly "white" pine (Pinus monticola), western hemlock (*Tsuga heterophylla*), Englemann spruce (*Picea engelmannii*)?<br>☐ **YES** = Category I ☐ **NO** = go to SC 5.2 | **Cat. I**<br>☐ |
| | SC 5.2 Does the unit have areas where aspen (*Populus tremuloides*) as a dominant or co-dominant species?<br>☐ **YES** = Category I ☐ **NO** = go to SC 5.3 | **Cat. I**<br>☐ |
| | SC 5.3 Does the wetland unit have a forest canopy where more than 50% of the tree species (by cover) are fast growing species? Fast growing species are: Alders – red (*alnus rubra*), thin-leaf (A. *tenuifolia*); Cottonwoods – narrow-leaf (*Populus angustifolia*), black (*P. balsamifera*); Willows – peach-leaf (Salix *amygdaloides*), Sitka (S. *sitchensis*), Pacific (*S. lasiandra*), Aspen – *Populus tremuloides*), Water Birch (*Betula occidentalis*)<br>☐ **YES** = Category II ☐ **NO** = go to SC 5.5 | **Cat. II**<br>☐ |
| | SC 5.5 Is the forested component of the wetland within the "100 year floodplain" of a river or stream?<br>☐ **YES** = Category II | **Cat. II**<br>☐ |
| ◆ | **Category of wetland based on Special Characteristics**<br>*Choose the "highest" rating if wetland falls into several categories.*<br>If you answered **NO** for all types enter "Not Applicable" on p. 1 | ______ |