A comparison of water table dynamics and soil texture under black cottonwood recent alluvial bar, beaked sedge, and Geyser's/Drummond's willow communities
by Darin Jay Law

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
Although riparian ecosystems comprise only two percent of the western United State's land area (Kovalchilc and Elmore, 1995), these areas are extensively used for wildlife (Thomas, 1979), fish habitat (Duff, 1979), and livestock forage (Reid and Pickford, 1946). They are also important in maintaining water quality and quantity (Horton and Campbell, 1974). Since cottonwood, willow, and sedge riparian areas are important, more needs to be known about the natural factors that control the occurrence of riparian community types. Managers need to know how water table fluctuations influence riparian vegetation (Fenner et al, 1985), and how soil texture relates to both riparian vegetation (Hansen et al, 1995) and the water table (Friedman et al., 1997).

Such knowledge will enable managers to develop restoration plans for degraded riparian community types.

I compared water table fluctuation and depth, soil texture, coarse fragment percentage and streamside and hillside slope degrees under beaked sedge, Geyer's willow, and black cottonwood recent alluvial bar communities. Six sites representing each community type were monitored. Two sites were west and four sites were east of the Continental Divide. Each community type was monitored for water table fluctuation and depth on a bimonthly basis. Soil texture, slope and species composition were analyzed at all monitoring sites.

There were no significant differences in water table fluctuation between the three community types ($p = 0.6702$). On the other hand, water table depths between community types were significantly different ($p = 0.0035$). Cottonwood communities had deeper water tables than willow communities, which had deeper water tables than sedge communities. Particle size percentages were significantly different between community types. Sand percentages ranged successively higher from willow (36%) to sedge (47%) to cottonwood (78%; $p = 0.0004$). Silt and clay percentages mirror the sand, willow (39%, 25%), sedge 35%, 18%) and cottonwood (15%, 7%; p=0.0002, 0.0031) and are significantly different. Coarse fragment percentages of 46% in cottonwood, 22% in willow and 15% in sedge soils are statistically different (p value = 0.0108). There were no significant differences in streamside and hillside slope degrees between cottonwood (0.6°, 0.6°; 0.6%), sedge (1,° 1°; 1.1%), and willow (1°, 1.6°; 1.1%, 1.7%) community types with p values of 0.7622 and 0.2850 respectively.

A COMPARISON OF WATER TABLE DYNAMICS AND SOIL TEXTURE UNDER BLACK COTTONWOOD RECENT ALLUVIAL BAR, BEAKED SEDGE, AND GEYER'S/DRUMMOND'S WILLOW COMMUNITIES

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Darin Jay Law

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APPROVAL

of a thesis submitted by

Darin Jay Law

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Signature Darin J. Laird

Date April 19, 1999

This work is dedicated to the success of Range Management and all natural resource management. It is our responsibility to treat natural resources as a valuable gift. A gift such as grandpa's old hunting knife or bamboo flyrod from which satisfaction is received when properly used and cared for. This will ensure their legacy in our lives and in the lives of our children's children and beyond.

VITA

Darin J. Law was born February 11, 1972 in Brigham City, Utah to Verl and Evelyn Law. He graduated from Emmett High School in Emmett, Idaho in 1990. In 1996 he received a Bachelor of Science degree in Range Resources from the University of Idaho. Shortly after finishing his undergraduate studies, he married Tiffany G. Hanks on June 4, 1997. They are currently the parents of a beautiful baby girl, Caitlyn.

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Dr. Clayton Marlow has been more than kind and helpful in allowing me the opportunity to work under him in the capacity of a graduate student and employee. I am extremely indebted and grateful to him. He has been a wonderful resource and friend. The other members of my committee have also been very willing to impart of their vast experience and expertise in my behalf; to them, I am grateful.

I entered graduate school and marriage near the same time. My wife Tiffany has been my full support and has often listened to the successes and failures that I experienced while producing this work. She has unselfishly given of her time in working to supplement our income. She has also been a wonderful mother to our daughter, Caitlyn, of whom I am also thankful. Tiffany, thank you so very much, you're my inspiration.

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ABSTRACT

Although riparian ecosystems comprise only two percent of the western United State's land area (Kovalchik and Elmore, 1995), these areas are extensively used for wildlife (Thomas, 1979), fish habitat (Duff, 1979), and livestock forage (Reid and Pickford, 1946). They are also important in maintaining water quality and quantity (Horton and Campbell, 1974). Since cottonwood, willow, and sedge riparian areas are important, more needs to be known about the natural factors that control the occurrence of riparian community types. Managers need to know how water table fluctuations influence riparian vegetation (Fenner *et al.*, 1985), and how soil texture relates to both riparian vegetation (Hansen *et al.*, 1995) and the water table (Friedman *et al.*, 1997). Such knowledge will enable managers to develop restoration plans for degraded riparian community types.

I compared water table fluctuation and depth, soil texture, coarse fragment percentage and streamside and hillside slope degrees under beaked sedge, Geyer's willow, and black cottonwood recent alluvial bar communities. Six sites representing each community type were monitored. Two sites were west and four sites were east of the Continental Divide. Each community type was monitored for water table fluctuation and depth on a bimonthly basis. Soil texture, slope and species composition were analyzed at all monitoring sites.

There were no significant differences in water table fluctuation between the three community types ($p = 0.6702$). On the other hand, water table depths between community types were significantly different ($p = 0.0035$). Cottonwood communities had deeper water tables than willow communities, which had deeper water tables than sedge communities. Particle size percentages were significantly different between community types. Sand percentages ranged successively higher from willow (36%) to sedge (47%) to cottonwood (78%; $p = 0.0004$). Silt and clay percentages mirror the sand, willow (39%, 25%), sedge 35%, 18%) and cottonwood (15%, 7%; p=0.0002, 0.0031) and are significantly different. Coarse fragment percentages of 46% in cottonwood, 22% in willow and 15% in sedge soils are statistically different (p value = 0.0108). There were no significant differences in streamside and hillside slope degrees between cottonwood (0.6°, 0.6°; 0.6%), sedge (1°, 1°; 1.1%), and willow (1°, 1.6°; 1.1%, 1.7%) community types with p values of 0.7622 and 0.2850 respectively.

Chapter 1

INTRODUCTION

Riparian Areas

Riparian ecosystems are those lands adjacent to water where plants dependent on a continuous water source exist (Kovalchik, 1987). These ecosystems comprise only about 2 percent of the total western United States land area (Kovalchik and Elmore, 1991), but contribute many important functions and values. Riparian ecosystems: are important wildlife habitat (Ames, 1977; Patton, 1977; Thomas, 1979; Johnson *et al.*, 1977), modify aquatic environments and fish habitat (Duff, 1979; Meehan *et al.*, 1977), help maintain water quality and quantity (Horton and Campbell, 1974; Brinson *et al.*1981), and are valuable for livestock forage (Reid and Pickford, 1946). For managers to better understand riparian community types, information is needed regarding which factors naturally control their extent. Such information will help reclamation activities in the riparian area and would provide much needed perspective regarding factors that control the presence or absence of riparian community types.

Many authors have studied the relationship between vegetation and various influencing factors. Dyksterhuis (1949) reported that climax vegetation is a product of soil and climate and present rangeland vegetation is a product of soil, climate and grazing disturbance. Nearly 20 years later, Daubenmire (1970) reported that individual ecosystems are distinguished by abiotic and biotic characteristics. Riparian areas are very dynamic (Padgett *et. al.*, 1989) due to: constant reworking of substrates, the presence of side channels, topographic variability as well as flooding. Nevertheless, biotic characteristics such as climate, water availability, topography, and chemical and physical properties of the soil determine riparian communities (USDA, 1998). Therefore, more research is needed on the relationship between biotic and abiotic factors that might control the distribution of riparian communities.

As a first attempt, several riparian vegetation classification systems have been created to aid managers in the western states: eastern Idaho and western Wyoming (Youngblood *et. al.*, 1985), southern Oregon forests (Kovalchik, 1987), Utah and southeastern Idaho (Padgett *et. al.*, 1989), Nevada and eastern California (Manning and Padgett, 1995) and Montana (Hansen *et. al.*, 1995). These classification systems contain valuable information about succession, soil pedon descriptions and management. However, they provide little quantitative information regarding soil texture and water tables, which largely determine community type (Brady, 1990). According to Hansen *et al.* (1995), soils are generally thought to influence riparian species composition, species coverage, and growth form. Groundwater may affect riparian vegetation more than soil characteristics (Hansen *et al.*, 1995) and effects of water table declines are related to soil textures (Friedman *et al.*, 1997). However, most of the classification field methods only classified soil pedons to the family level (USDA-SCS, 1975). Equally common was that depth to water table was only recorded when it appeared in the soil pit, and was considered to be at the soil surface in moist organic soils. Water table fluctuations were not recorded. As a result, the above classifications do not adequately address those factors that determine riparian communities.

To begin to fill in the gaps in data about possible abiotic/biotic riparian community classification, this study tests reported riparian vegetation, soil texture, slope and water table relationships against those actually measured in three riparian communities. These communities are dominated by either black cottonwood (*Populus trichocarpa* T. & G. ex Hook), beaked sedge (*Carex rostrata* Stokes), or Geyer's (*Salix geyeriana* Anderss.) and Drummond's willow (*Salix drummondiana* Barratt).

These three species were chosen because of their abundance and common occurrence throughout the northern Rocky Mountains (Hansen *et. al.*, 1988). By comparing the descriptions of these riparian communities with actual field conditions managers will be more capable of interpreting the ability of a specific riparian area to support a certain community type.

Chapter 2

LITERATURE REVIEW

Black Cottonwood (*Populus trichocarpa* Torr. & Gray ex Hook)

Black cottonwood communities: provide food and cover for livestock and big game, help stabilize stream banks for erosion control and fish habitat (Hansen *et al.*, 1995) and provide nesting sites for birds (Dittberner and Olson, 1983). Native plains cottonwood (*Populus deltoides* Marsh.) stands provide habitat for 82% of all bird species breeding in northeastern Colorado (Knopf, 1985). Beidleman (1978) recorded 245 vertebrate species and subspecies in cottonwood stands in Colorado. Eastern Colorado cottonwoods also provide nearly all the native tree cover (Crouch, 1979)

Cottonwoods are fast growing pioneer species that do not have a long lifespan (150 – 200 years), in comparison with other tree species. During their first year, cottonwoods invest a lot of their energy seeking water. Below ground growth far exceeds above ground growth during their first year. The greater the contact with the ground water table, the more successful the tree becomes. After contact is made with ground water, growth shifts from roots to above ground biomass, leaves, branches, and stems. Once established, the trees respond poorly to permanent changes or fluctuations in ground water depths. In many agricultural settings permanent changes in ground-water level result in death of mature cottonwoods. Thus, human storage and use of water can change cottonwood communities (Scott, 1991).

Boggs and Weaver (1992) found cottonwood communities eventually became grassland communities with declining water availability. Along those lines, flood suppression and water development since the 1800s caused cottonwood communities to become dominated by exotic trees like Russian-olive (*Elaeagnus anugstifolia* L.) and trees from the eastern Plains (Olson and Knopf, 1986; Johnson, 1992; Shafroth *et. al.*, 1995). Without measurements of ground-water fluctuations, it is difficult to understand how much change causes mortality. Rood *et al.* (1994) in southwestern Alberta found that there exists a close relationship between river stage and depth to water table in a permeable substrate. Rood *et al.* (1994), also noted that riparian substrates consist of a mixture of sand, gravel, and cobble, which allows free water movement (Mahoney and Rood, 1992). Catherine Creek in northeastern Oregon displays soil characteristics similar to those reported in Canada; well-drained loamy soils with sand, gravel, and cobbles 1 m below the soil surface (Kauffman *et al.* 1985). Hansen *et al.* (1995) described the soils that cottonwoods inhabit as silt loams with sand and cobble layers and a water table existing within 1 m of the soil surface during the growing season. These types of soil are very significant to black cottonwood community development. The coarse sands and cobbles provide aerated, well-drained horizons favored by black cottonwood (Anderson as cited by Kauffman *et al.*, 1985).

Beaked Sedge (*Carex rostrata* Stokes)

Beaked sedge is an important dominant type in Montana and other temperate climates (Hansen *et al.* 1988; Kovalchik 1987). This species is used to restore degraded riparian areas because it provides high value for erosion control (USDA, 1986). Dominating the understory of many willow communities throughout the northern Rocky Mountains, beaked sedge is very productive. Clippings in northwestern Montana produced 5376 kilograms per hectare (Winward, 1998). Although its value rating for cattle and wildlife forage is low to moderate (Manning and Padgett, 1995) beaked sedge is moderately palatable and tolerant to cattle grazing (Hermann, 1970; Ratliff, 1983). Its thick dense sod also forms streambank undercuts providing excellent fish habitat (Hansen *et al.* 1988).

High water tables determine and influence beaked sedge distribution more than the substrate properties (Youngblood *et al.* 1985), water tables generally rest at about 23 cm below the soil surface and are seasonal (Manning and Padgett, 1995). Sjoberb and Danell (1983) found that shoot densities of beaked sedge were higher on seasonally flooded soils, and that with continual flooding, shoot densities decreased although beaked sedge does colonize permanently flooded sites (Manning and Padgett, 1995). Soils are usually anaerobic (Hansen *et al.* 1988) and consist of clay and clay loam to sandy loam (Hansen *et al.* 1995; Manning and Padgett, 1995). Kauffman (1985) described soils of sedge communities as having fine-textured A-horizons above a coarse-textured horizon, which forms a water restrictive horizon. When beaked sedge communities experience a drop in the water table, willow species begin to increase (Hansen *et al.* 1988), with

Nebraska sedge (*Carex nebrascensis* Dewey) and tufted hairgrass (*Deschampsia cespitosa* (L.) Beauv.) increasing in the understory (Manning and Padgett, 1995) and becoming codominants with high grazing use (Kovalchik 1987). Thus, high relatively stable water tables are necessary to maintain stable beaked sedge communities (Hansen *et al.* 1988).

Willow (*Salix* sp.)

Being very common in many riparian communities (Kovalchik, 1987) willows are important in maintaining stream bank characteristics and biological diversity in riparian areas (Smith, 1980). Willows also hinder erosion in riparian areas. Stems and leaves help slow water velocity dissipating energy while roots provide bank stability (Crouch and Honeyman 1986; Elmore and Beschta, 1987; Platts *et al.*, 1987; Skinner *et al.*, 1986). Willows trap sediment in overland flow, (Platts *et al.*, 1987) that can pollute streams. Because of these beneficial effects, willows are considered valuable to "proper riparian function" (Kovalchik and Elmore, 1991).

Willow species, as a whole, are generally adapted to various soil textures (Winward, 1998). Soils under a Wolf willow (*Salix wolfii*) stand near Stanley, Idaho were moderate to rapidly permeable with a gravelly loam of 25% cobbles in the upper 38 cm. Immediately below this layer is a gravelly sandy clay loam with 30% cobbles (Clary, 1995). Hansen *et al.* (1995) found coarse-textured soils under Geyer's willow stands in Montana while Winward (1998) stated that Geyer's willow does well on fine textures and Drummond's willow will flourish on coarse textures. Youngblood *et. al.* (1985) discovered that most Geyer's willow communities occupied fine-textured soils. The only community with abundant coarse fragments was the Geyer's willow /Mesic forb community type. Manning and Padgett (1995) found soils to be fine, loamy-textured under Geyer's and booth (*Salix boothii*) willow stands in Nevada. Kauffman *et al.* (1985) also noted soils along Catherine Creek in northeastern Oregon to be well drained and shallow beneath shrub-dominated communities. Water tables remained within 1 m (39 cm) during the spring and available water is texture dependent in Montana sites described by Hansen *et al.* (1995). Water tables commonly remain within 1 m of the soil surface throughout the growing season. These characteristics (e.g. well drained soils) provide aerated water in the rooting zone (Hansen *et al.* 1995).

Summary

Rood *et al.* (1994) described Alberta riparian soils textures as mixtures of sand, gravel, and cobbles. Kauffman *et. al.* (1985) in northeastern Oregon described cottonwood soil textures as loamy with sand gravel, and cobbles 1 m below the soil surface. Hansen *et. al.* (1995) in Montana described cottonwood soil textures to be silt loams with sand and cobble layers. Hansen *et. al.* (1995) also stated that water tables were within 1 m of the soil surface during the growing season.

Beaked sedge soils are very different than cottonwood soils in that they are fine textured (Kauffman, 1985) and consist of clay and clay loam to sandy loam (Hansen *et. al.*, 1995). Water tables are similar to cottonwood water tables in that they are high

(Youngblood *et. al.*, 1985) usually resting 23 cm below the soil surface (Manning and Padgett, 1995).

Willow soils are more variable and intermediate between cottonwood and sedge soils. They are permeable with gravelly loams of 25% cobbles above gravelly sandy clay loams with 30% cobbles near Stanley, Idaho (Clary, 1995) they are also coarse textured (Hansen *et. al.*, 1995) and fine textured (Winward, 1998; Youngblood *et. al.*, 1985). Manning and Padgett (1995) noted willow soils to be fine loamy textured. Water tables beneath willow communities were within 1 m (39 cm) of the soil surface in Montana (Hansen *et. al.*, 1995).

It can be seen that there is overlap and inconsistencies between the soils and water tables described in cottonwood, sedge and willow communities. There is reference to sand and loam in every one of the community types with gravels and cobbles noted in cottonwood and willow communities. Water tables are only generally described in cottonwood communities (within 1 m) to quite narrow in sedge (23 cm) and willow (39 cm) communities. But, there is reference to "within 1 m" of the soil surface in all of the community types. Therefore, given the above information, cottonwood soils are probably coarse textured made up of sand, gravels and cobbles with deeper water tables than sedge and willow water tables. Sedge soils are probably fine textured with the highest water tables. Willow soils are probably fine textured containing some gravels and cobbles with water tables intermediate in depth between cottonwood and sedge water tables.

Chapter 3

WEST VERSUS EAST OF THE CONTINENTAL DIVIDE

Introduction

Due to the overlap and inconsistency in soils and water tables between cottonwood, sedge and willow communities the primary objectives of the study were to describe and compare: water table depth and fluctuation, soil texture, coarse fragment percentages and streamside and hillside slope across the three community types. Streamside slopes are those slopes parallel to the contour, adjacent to the stream while hillside slopes are perpendicular to the stream. The community types were located in two groups, the west group and the east group. One group of the three community types was located west of the continental divide while a second group of the three community types was located east of the continental divide (Fig. 3.1). The continental divide forms a natural boundary between two primary climates in Montana. A maritime climate with relatively uniform temperatures and higher precipitation dominates west of the divide. East of the divide a true continental climate causes more extreme temperatures and lower precipitation (Southard, 1967). Thus, climate may have an overriding effect on the community type: water table depth and fluctuation, soil texture, coarse fragment percentage and streamside and hillside slope degrees attributed to their location east or west of the Continental Divide. As a result, I compared water table fluctuation and depth, soil texture, coarse fragments and slope between the two groups of community types to test whether or not there were differences between the two groups that would bias the individual community type comparisons.

Objectives

A. To compare/contrast water table fluctuation and depth, soil texture, coarse fragments and slopes between the west group of communities and the east group of communities.

Hypotheses

1. Ho: There is no difference in mean water table fluctuation between west and east groups.

   Ha: There is a difference in mean water table fluctuation between west and east groups.

2. Ho: There is no difference in mean water table depth between west and east groups.

   Ha: There is a difference in mean water table depth between west and east groups.

3. Ho: There is no difference in soil texture between west and east groups.

   Ha: There is a difference in soil texture between west and east groups.

4. Ho: There is no difference in mean coarse fragment percentages between west and east groups.

Ha: There is a difference in mean coarse fragment percentages between west and east groups.

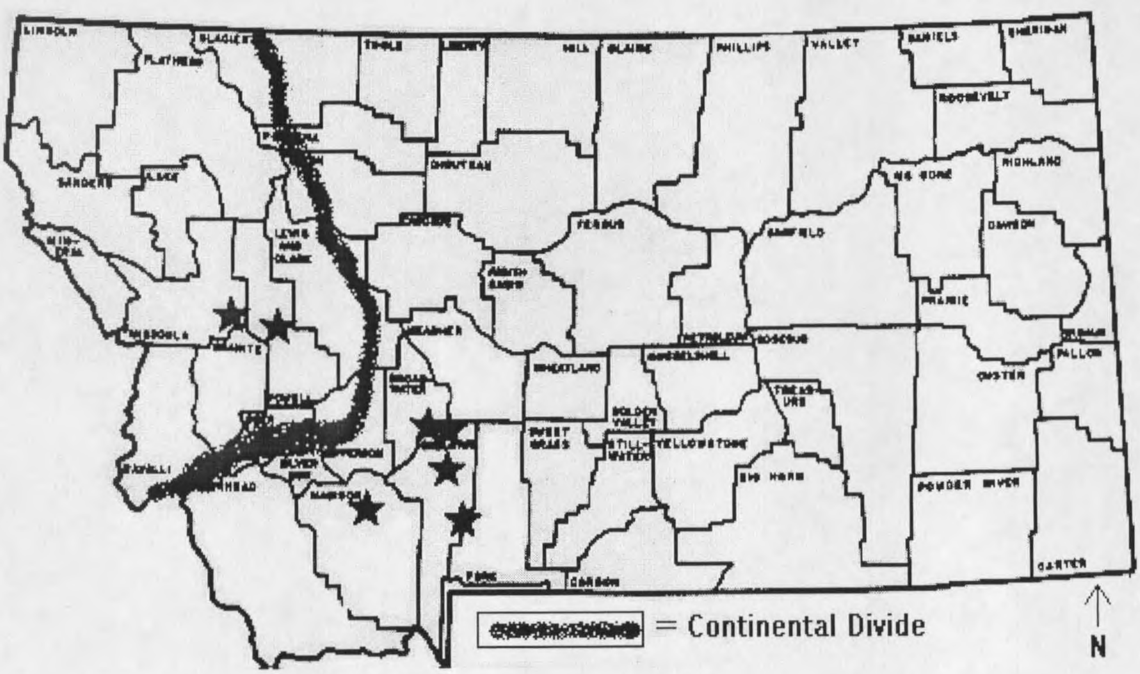
5. Ho: There is no difference in mean slope degrees between west and east groups.

   Ha: There is a difference in mean slope degrees between west and east groups.

Study Area

Study sites (Fig. 3.1) covered a broad range of Montana, mountain valleys at elevations between 1000 m and 1462 m. Cattle and wildlife have grazed all study sites.

Figure 3.1. Map of Montana. Stars represent study locations, not individual sampling units.



Black Cottonwood Recent Alluvial Bar Communities (Fig. 3.2)

Two black cottonwood sites west of the Continental Divide are on the Blackfoot River in a narrow mountain valley (46.975° latitude, 113.325° longitude). These two sites are found on a sandy to cobbly alluvium arising from glacial outwash of argillites, quartzites and subordinate carbonate rocks from the Precambrian Belt Series (MAES, 1980). The remaining black cottonwood sites are east of the Continental Divide adjacent

Figure 3.2. An example of a recent alluvial bar black cottonwood site along the Blackfoot River near Clearwater Junction, Montana.

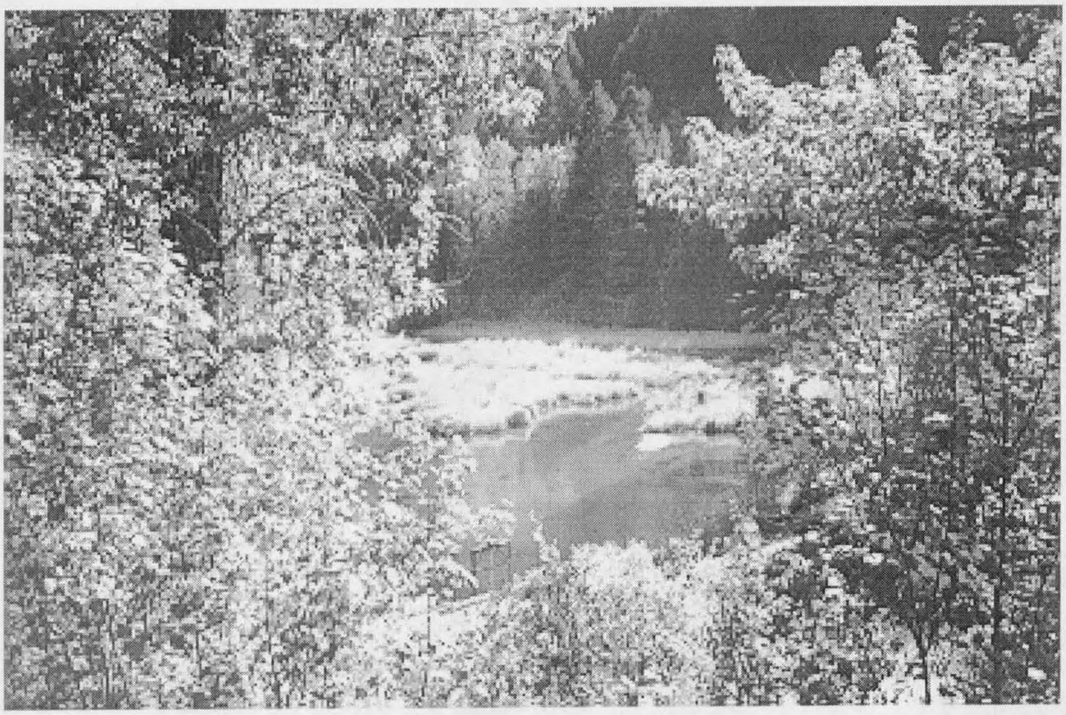
to the Gallatin River, which drains the wide Gallatin Valley, Bozeman and Three Forks, Montana (45.675° latitude, 111.225° longitude; 45.875° latitude, 111.375° longitude).

Alluvial fill at the Gallatin sites ranges from a cobble to boulder soil mix from soft Tertiary valley-fill sediment originating from the Late Cretaceous-Early Tertiary Period (MAES, 1980).

Beaked Sedge Communities (Fig. 3.3)

Two beaked sedge sites west of the Continental Divide were adjacent to Shanley and Lynn Creek (meandering meadow streams) near Ovando, Montana (47.12° latitude, 113.22° longitude). These two streams drain a rolling landform of glacial outwash and lateral morains. Soils contain various mixtures of sand, pebbles, gravels, cobbles and boulders weathered from argillites, quartzites and subordinate carbonate rocks originating from the Precambrian Belt Series (MAES, 1980). The next two beaked sedge sites were located east of the Continental Divide adjacent to Railroad Creek (meandering meadow stream) near Norris, Montana (45.52° latitude, 111.77° longitude). The creek drains a finely sorted gravel/cobble colluvium. Soft Tertiary valley-fill sediment is the primary parent material originating from the Late Cretaceous-Early Tertiary Period (MAES, 1980). The remaining beaked sedge types were located east of the Continental Divide adjacent to Hyalite Creek, (mountain stream) 10 miles south of Bozeman, Montana (45.42° latitude, 111.08° longitude). Volcanic ejecta, lava flows and volcanic deposits mixed by debris flow and fluvial processes formed the parent material during the mid-Cretaceous to Quaternary Periods. Cobbles and gravel dominate the soil mix (MAES, 1980).

Figure 3.3. An example of a beaked sedge community type adjacent to Hyalite Creek, Bozeman, Montana.



Willow Communities (Fig. 3.4)

The willow sites occurred adjacent to a variety of stream types and soils. Two willow sites were located west of the Continental Divide adjacent to Cottonwood Creek (meandering meadow stream) near Ovando, Montana (47.12° latitude, 113.22° longitude). Cottonwood Creek drains a rolling landform of glacial outwash and lateral morains. Soils contain various mixtures of sand, pebbles, gravels, cobbles and boulders weathered from argillites, quartzites and subordinate carbonate rocks originating from the

Figure 3.4. An example of a Geyer's willow community type adjacent to Cottonwood Creek, Ovando, Montana.

Precambrian Belt Series (MAES, 1980). The next two willow sites east of the Continental Divide were adjacent to Brackett Creek (mountain stream) 22 miles northeast of Bozeman, Montana (45.88° latitude, 110.93° longitude). These two sites were formed over hard sandstones and soft gray shales originating from the Cretaceous Montana Group (MAES, 1980). The remaining willow sites were located east of the Continental Divide adjacent to Hyalite Creek, a mountain stream near Bozeman, Montana (45.42° latitude, 111.08° longitude). Volcanic ejecta, lava flows and volcanic deposits mixed by debris flow and fluvial processes formed the parent material during the mid-Cretaceous to Quaternary Periods (MAES, 1980).

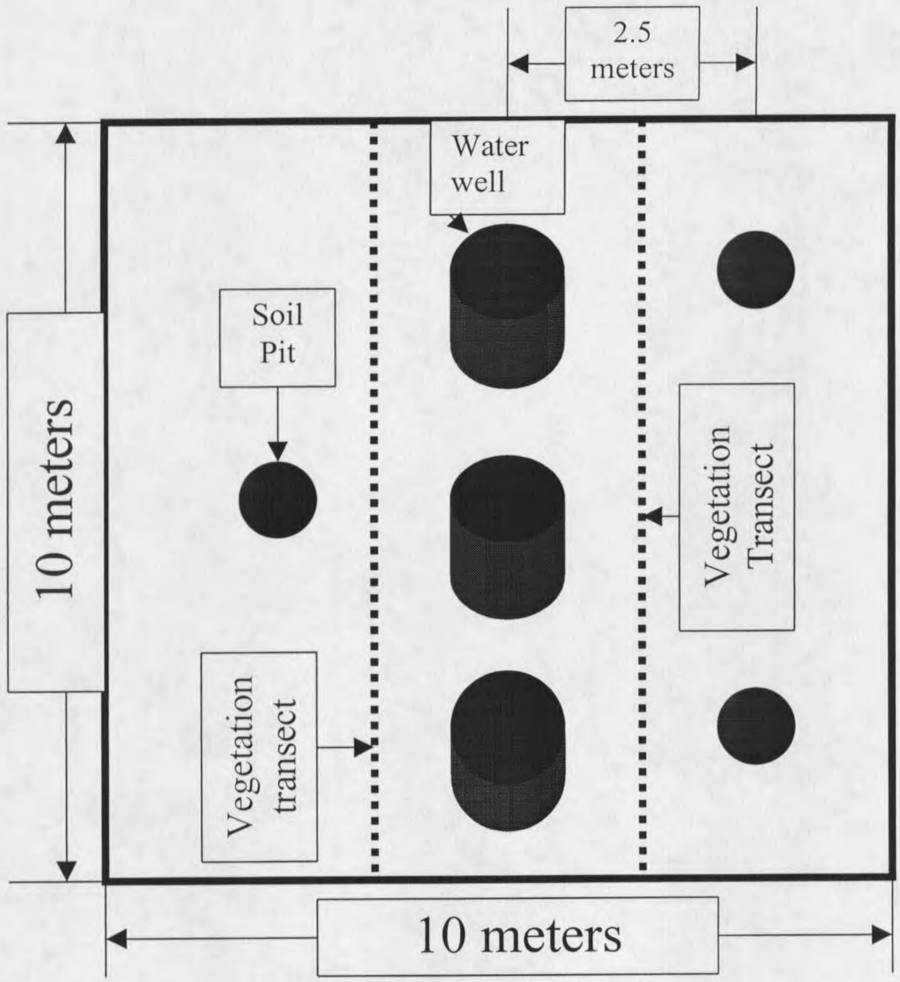
Methods

Six sites of each of the targeted community types were chosen based on the Hansen *et al.* (1995) riparian classification system (cover type and dominant species). All sampling localities were 100 m^2 and each site was considered random. Percent cover, of species and life forms (Appendix A, B, C) was obtained by sampling two 10 m transects at 1 m intervals using a 25 x 50 Daubenmire cover frame (Daubenmire, 1959) (Fig. 3.5).

Water tables were measured by driving three, 1.9 cm x 1.5 m schedule 40 perforated steel pipes into the soil to a depth of 1 m. These wells were spaced along an upslope gradient perpendicular to the stream at 3 m intervals. All three wells were placed in the middle of the 100 m^2 site (Fig. 3.5) and were considered random experimental units. Water table depths were measured every two weeks from June through October 1997 and 1998. Water table fluctuation was measured by subtracting each 2-week measurement from the one previous to it.

Four stratified soil samples (0-13 cm, 13 – 25 cm, 25 – 38 cm, 38 - 51 cm) were taken from three 51 cm deep pits on each site. Pits were dug 1 m away from and on alternate sides of the water wells (Fig. 3.5). The pits were considered random for this study. Texture was analyzed for each soil sample by drying and sieving each sample

Figure 3.5. A schematic of a study site layout.



Stream is located adjacent to the site, perpendicular to the water wells and soil pits

with a 2 mm sieve. Then, the hydrometer method (Day, 1965; Bouyoucos, 1963; Gee and Bauder, 1979) was used to separate percent sand, silt and clay particle sizes from the

0 – 2-mm portion of each sample. The > 2-mm fraction was weighed to estimate percentage of coarse fragments.

Streamside and hillside slopes were measured within each site using a stadia rod and abney level over a distance of 6 meters. Streamside slope was considered to be parallel to the contour while hillside slope was considered to be perpendicular to the contour regardless of stream meanders.

Statistical Models

To statistically compare all water table, soil and slope data between the west and east groups, the data was pooled separately for each group. For example, west group water table depths were compared to east group water table depths without regard to community type. Doing this allowed me to compare west group physical characteristics with east group physical characteristics. I used $p > 0.1$ as the level of significance for all of the statistical tests. The alpha of 0.1 was used to maintain accuracy in detecting differences in the face of extreme riparian variation although the actual power of the test is somewhat reduced. This reduces the probability of not detecting differences when differences in fact exist.

A 3-stage nested repeated measures ANOVA was used to compare water table fluctuation and depths between the west and east groups. The repeated measures design was used because multiple observations were taken on each well over time. Because multiple observations were taken on each well over time, the observations were not independent from each other. Independent observations is an assumption that must be met in ANOVA. Therefore, the repeated measures design was used to create independence among observations. A square root transformation was performed on the water table fluctuation data to achieve a homogeneous variance for the ANOVA analysis, also an assumption that must be met in ANOVA.

A 3-stage nested ANOVA was used to compare soil texture (particle sizes < 2 mm) and coarse fragment (> 2 mm) percentages between west and east groups. A square root transformation was also performed on the coarse fragment data to achieve a homogeneous variance for the ANOVA analysis.

Differences in slope between west and east groups were analyzed using a nested ANOVA. A square root transformation was also performed on the slope data to achieve a homogeneous variance for the ANOVA analysis.

Results

Water Table Fluctuation

There were no significant differences between west and east group water table fluctuation. The water table hypothesis test (Table 3.1) shows that with an F value of 2.0643 and a p value of 0.1713 (Table 3.2) the null hypothesis cannot be rejected at an alpha of 0.1. Thus, there are no significant differences in mean water table fluctuation between west and east groups.

Table 3.1. Hypothesis test for water table fluctuation between the west and east groups.

Ho: west = east vs. Ha: not all water table fluctuation means are equal between the west and east groups.
Test Statistic: F* = 2.0643
Decision Rule: Reject Ho if F* = 2.0643 > F(1- 0.1, 1, 15.02) = 3.07
Conclusion: Fail to reject Ho and conclude no significant mean water table fluctuation differences between the west and east groups.

Table 3.2. ANOVA table of water table fluctuation between the west and east groups.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	67	278.29	4.15	2.75	0.0001
Error	257	388.76	1.51		
Corrected Total	324	667.05			
	R-Square	C.V.	Root MSE	CHGE MEAN	
	0.4172	50.7512	1.2299	2.42	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location(east/west)	1	9.05	9.05	5.99	0.0151
Type(Location)	4	52.89	13.22	8.74	0.0001
Site(Location*Type)	12	68.00	5.67	3.75	0.0001
III(Location*Type*Site)	36	73.75	2.05	1.35	0.0948
Measure	7	25.02	3.57	2.36	0.0235
Location*Measure	7	37.15	5.31	3.51	0.0013
Source: Location(east/west)					
Error: 0.6917*MS(site(location*type))+ 0.3083*MS(error)					
DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
1	9.05	15.02	4.39	**2.0643**	**0.1713**

Water Table Depth

There were no significant differences between west and east group water table depths. The water table depth hypothesis test (Table 3.3) shows that with an F value of 2.1674 and a p value of 0.1666 (Table 3.4) the null hypothesis cannot be rejected at an alpha of 0.1. Therefore, there are no significant mean water table depth differences between the west and east groups.

Table 3.3. Hypothesis test for water table depth between the west and east groups.

Ho: west = east vs. Ha: not all water table depth means are equal between the west and east groups.
Test Statistic: F* = 2.1647
Decision Rule: Reject Ho if F* = 2.1647 > F(1- 0.1, 1, 12.04) = 3.18
Conclusion: Fail to reject Ho and conclude no significant differences in mean water table depth between the west and east groups.

Table 3.4. ANOVA table of water table depths between the west and east groups

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	67	215467.87	3215.94	50.17	0.0001
Error	278	17818.68	64.10		
Corrected Total	345	233286.55			
	R-Square	C.V.	Root MSE	CHGE MEAN	
	0.9236	23.7079	8.0060	33.77	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location(east/west)	1	11603.56	11603.56	181.03	0.0001
Type(Location)	4	117134.92	29283.73	456.87	0.0001
Site(Location*Type)	12	74008.54	6167.38	96.22	0.0001
Ill(Location*Type*Site)	36	14548.15	404.12	6.3	0.0001
Measure	7	16705.18	2386.45	37.23	0.0001
Location*Measure	7	4209.37	601.34	9.38	0.0001
Source: Location(east/west)					
Error: 0.8667*MS(site(location*type))+ 0.1333*MS(error)					
DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
1	11603.56	12.04	5353.58	**2.1674**	**0.1666**

Soil Particle Size Analysis

Sand. There were no significant differences in sand, silt, clay or coarse fragment percentages between the west and east groups. The sand hypothesis test (Table 3.5) shows that with an F value of 0.0140 and a p value of 0.9078 (Table 3.6) the null hypothesis cannot be rejected at an alpha of 0.1. As a result, there are no significant mean sand percentage differences between the west and east groups.

Table 3.5. Hypothesis test for sand percentages between the west and east groups.

Ho: west = east vs. Ha: not all sand means are equal between the west and east groups.
Test Statistic: F* = 0.0140
Decision Rule: Reject Ho if F* = 0.0140 > F(1- 0.1, 1, 11.94) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean sand percentage differences between the west and east groups.

Table 3.6. ANOVA table of sand percentages between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	112434.51	2121.41	7.07	0.0001
Error	168	50402.77	300.02		
Corrected Total	221	162837.28			
	R-Square	C.V.	Root MSE	Percent Mean	
	0.6905	32.5272	17.3210	53.2508	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/ west)	1	41.77	41.77	0.14	0.7095
Type(Location)	4	70892.11	17723.03	59.07	0.0001
Site (Location*Type)	12	35017.53	2918.13	9.73	0.0001
Pit (Location*Type*Site)	36	5822.17	161.73	0.54	0.9846
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) - 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	41.77	11.94	2987.39	**0.014**	**0.9078**

Silt. The silt hypothesis test (Table 3.7) shows that with an F value of 0.1471 and a p value of 0.9961 (Table 3.8) null hypothesis cannot be rejected at an alpha of 0.1. Thus, there are no significant mean silt percentage differences between the west and east groups.

Table 3.7. Hypothesis test for silt percentages between the west and east groups.

Ho: west = east vs. Ha: not all silt means are equal between the west and east groups.
Test Statistic: F* = 0.1471
Decision Rule: Reject Ho if F* = 0.1471 > F(1- 0.1, 1, 11.89) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean silt percentages differences between the west and east groups.

Table 3.8. ANOVA table of silt percentages between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	38296.31	722.57	4.5	0.0001
Error	168	26984.87	160.62		
Corrected Total	221	65281.17			
	R-Square	C.V.	Root MSE	Percent Mean	
	0.5866	42.1979	12.6738	30.0341	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/west)	1	139.72	139.72	0.87	0.3523
Type(Location)	4	24040.35	6010.09	37.42	0.0001
Site (Location*Type)	12	11152.09	929.34	5.79	0.0001
Pit (Location*Type*Site)	36	2672.97	74.25	0.46	0.9961
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) – 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	139.72	11.89	160.62	**0.1471**	**0.9961**

Clay. The clay hypothesis test (Table 3.9) shows that with an F value of 0.0321 and a p value of 0.8608 (Table 3.10) the null hypothesis cannot be rejected at an alpha of 0.1. Consequently, there are no significant mean clay percentage differences between the west and east groups.

Table 3.9. Hypothesis test for clay percentages between the west and east groups.

Ho: west = east vs. Ha: not all clay means are equal between the west and east groups.
Test Statistic: F* = 0.0321
Decision Rule: Reject Ho if F* = 0.0321 > F(1- 0.1, 1, 11.96) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean clay percentage differences between the west and east groups.

Table 3.10. ANOVA table of clay percentages between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	23970.61	452.28	8.22	0.0001
Error	168	9238.98	54.99		
Corrected Total	221	33209.59			
	R-Square	C.V.	Root MSE	Percent Mean	
	0.5866	43.9174	7.4158	16.8858	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/ west)	1	26.14	26.14	0.48	0.4915
Type(Location)	4	12446.21	3111.55	56.58	0.0001
Site (Location*Type)	12	9536.80	794.73	14.45	0.0001
Pit (Location*Type*Site)	36	1871.04	51.97	0.95	0.5633
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) – 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	26.14	11.96	814.30	**0.0321**	**0.8608**

Coarse Fragments. The coarse fragment hypothesis test (Table 3.11) shows that with an F value of 0.2073 and a p value of 0.6571 (Table 3.12) the null hypothesis cannot be rejected at an alpha of 0.1. Hence, there are no significant mean coarse fragment percentage differences between the west and east groups.

Table 3.11. Hypothesis test for coarse fragments between the west and east groups.

Ho: west = east vs. Ha: not all coarse fragment means are equal between the west and east groups.
Test Statistic: F* = 0.2073
Decision Rule: Reject Ho if F* = 0.2073 > F(1- 0.1, 1, 11.89) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean coarse fragment percentage differences between the west and east groups.

Table 3.12. ANOVA table of coarse fragment percentages between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	961.37	18.14	4.92	0.0001
Error	168	619.54	3.69		
Corrected Total	221	1580.90			
	R-Square	C.V.	Root MSE	Percent Mean	
	0.6081	37.6208	1.9203	5.1045	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/ west)	1	4.57	4.57	1.24	0.2671
Type(Location)	4	477.14	119.28	32.35	0.0001
Site (Location*Type)	12	258.94	21.58	5.85	0.0001
Pit (Location*Type*Site)	36	216.97	6.03	1.63	0.0207
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) – 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	4.57	11.89	22.05	**0.2073**	**0.6571**

Slope

Streamside Slope. There were no significant differences in streamside and hillside slope degrees between the west and east groups. The streamside slope hypothesis test (Table 3.13) shows that with an F value of 0.6476 and a p value of 0.4366 (Table 3.14) the null hypothesis cannot be rejected at an alpha of 0.1. Wherefore, there are no significant mean streamside slope differences between the west and east groups.

Table 3.13. Hypothesis test for streamside slope between the west and east groups.

Ho: west = east vs. Ha: not all streamside slope means are equal between the east and west groups.
Test Statistic: F* = 0.6476
Decision Rule: Reject Ho if F* = 0.6476 > F(1- 0.1, 1, 12) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean streamside slope differences between the west and east groups.

Table 3.14. ANOVA table of streamside slope between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	9.36	0.55	4.81	0.0009
Error	18	2.06	0.11		
Corrected Total	35	11.42			
	R-Square	C.V.	Root MSE	Slope Mean	
	0.819647	36.41294	0.34	0.93	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/ west)	1	0.44	0.44	3.82	0.0662
Type(Location)	4	0.81	0.20	1.78	0.1773
Site (Location*Type)	12	8.11	0.68	5.91	0.0004
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) – 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	0.44	12	0.68	**0.6476**	**0.4366**

Hillside Slope. The hillside slope hypothesis test (Table 3.15) shows that with an F value of 2.3990 and a p value of 0.1474 (Table 3.16) the null hypothesis cannot be rejected at an alpha of 0.1. Thence, there are no significant mean hillside slope differences between the west and east groups.

Table 3.15. Hypothesis test for hillside slope between the west and east groups.

Ho: east = west vs. Ha: not all hillside slope means are equal between the west and east groups.
Test Statistic: F* = 2.3990
Decision Rule: Reject Ho if F* = 2.3990 > F(1- 0.1, 1, 12) = 3.18
Conclusion: Fail to reject Ho and conclude no significant mean hillside slope differences between the west and east groups.

Table 3.16. ANOVA table of hillside slope between the west and east groups.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	9.36	0.55	4.81	0.0009
Error	18	2.06	0.11		
Corrected Total	35	11.42			
	R-Square	C.V.	Root MSE	Slope Mean	
	0.867078	36.41294	0.34	0.93	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Location (east/ west)	1	0.44	0.44	3.82	0.0662
Type(Location)	4	0.81	0.20	1.78	0.1773
Site (Location*Type)	12	8.11	0.68	5.91	0.0004
Source : Location (east/west)					
Error:					
1.0265*MS(Site(Location*Type)) – 0.0265*MS(Error)		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
1	1.05	12	0.4372	**2.3990**	**0.1474**

Summary

Water tables on the west of the Continental Divide fluctuated a mean of 6.6 cm around a depth of 32.7 cm. Soils on the west of the Continental Divide contained a man of 52% sand, 31% silt 17% clay, and 24% coarse fragments. Thus, soils on the west of the Continental Divide are gravelly loams to gravelly sandy loams (Buol, 1989). Streamside and uphill slopes are 0.6° (0.7%) and 0.5° (0.6%) respectively. These results are not statistically different from sites on the east of the continental divide. Water tables on the east of the Continental Divide fluctuated a mean of 5.4 cm around a depth of 34.5 cm. Soils contained a mean of 54% sand, 29% silt, 17% clay and 27% coarse fragments. Thus, soils on the east are gravelly loams to gravelly sandy loams (Buol, 1989). Streamside and hillside slopes are 1° (1.1%) and 1° (1.1%) respectively.

The previous tests indicate that there are no significant water table (fluctuation and depth), soil particle size, coarse fragment percentages, or slope differences between the west and east groups. With these results I can conclude that it is reasonable to compare recent alluvial bar black cottonwood, beaked sedge, and Geyer's/Drummond's willow communities without respect to their location west or east of the Continental Divide. According to Southard (1967), the Continental Divide separates the two primary climates in Montana (maritime on the west and continental on the east). It is conceivable that these different climates would have an affect on riparian water tables, soils, and slopes. But, the above tests indicate that no significant differences exist among the measured physical characteristics between the group west of the Continental Divide and the group east of the Continental Divide.

Chapter 4

COMMUNITY TYPE COMPARISONS

Objectives

A. To test whether there were differences between cottonwood, sedge and willow community type (C. T.) water table depths, fluctuation, soil textures and coarse fragments.

B. To test whether there were differences between cottonwood, sedge and willow C. T. stream and hillside slope degrees.

C. To begin to fill in riparian classification data gaps by quantifying part of the ecological range of black cottonwood, beaked sedge and Geyer's/Drummond's willow C. T.

Hypotheses

1. Ho: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy sites with no difference in mean water table fluctuation.

   Ha: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities differ in mean water table fluctuation.

2. Ho: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy sites with no difference in mean water table depths.

   Ha: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy sites with differing mean water table depths.

3. Ho: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy only silt loam soils.

   Ha: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities, and beaked sedge communities occur on different soil textures.

4. Ho: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy sites with no difference in coarse fragment percentage.

   Ha: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occupy sites with different coarse fragment percentages.

5. Ho: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities have no difference in mean streamside or hillside slope degrees.

   Ha: Alluvial bar black cottonwood communities, Geyer's/Drummond's willow communities and beaked sedge communities occur on different mean streamside and hillside slope degrees.

Methods

The methods and sites, described in the previous chapter, used to compare west versus east of the continental divide physical factors were used for the community type comparisons. The data from the west and east groups were poled since the west and east groups were not significantly different in any measured factor.

Statistical Models

A 3-stage nested repeated measures ANOVA was used to compare water table fluctuation and depth between the 3 communities at an alpha of 0.1. A square root transformation was performed on the water table fluctuation data to achieve a homogeneous variance for ANOVA analysis.

A 3-stage nested ANOVA was used to compare particle size and coarse fragment percentages between the 3 communities at an alpha of 0.1. A square root transformation was performed on the coarse fragment data to achieve a homogeneous variance for ANOVA analysis.

Differences in slope were analyzed using a nested ANOVA also at an alpha of 0.1. A square root transformation was also performed on the slope data to achieve a homogeneous variance for ANOVA analysis.

Results

Water Table Fluctuation

There were significant mean water table fluctuation differences between the three community types. The water table fluctuation hypothesis test (Table 4.1) shows that with an F value of 0.4089 and a p value of 0.6702 (Table 4.2) the null hypothesis cannot be rejected at an alpha of 0.1. Thus, there are no significant mean water table fluctuation differences between the community types.

Table 4.1. Hypothesis test for water table fluctuation between the community types.

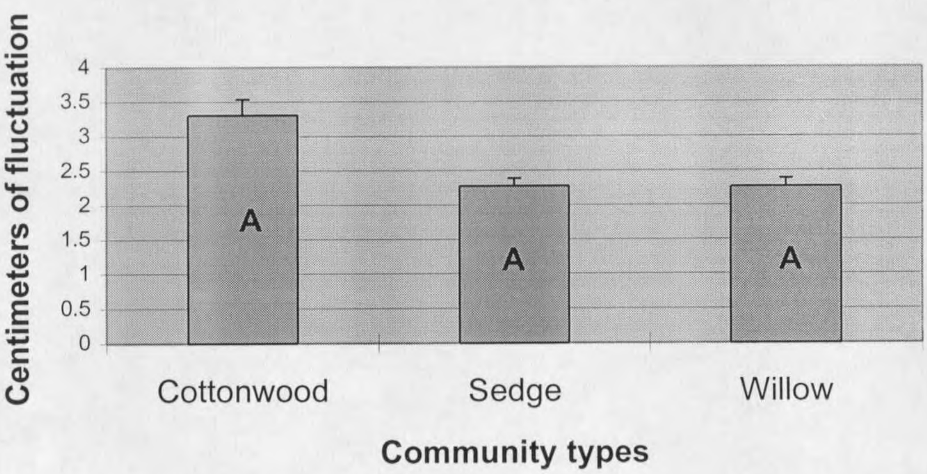
Ho: cottonwood = sedge = willow vs. Ha: not all water table fluctuation means are equal.
Test Statistic: F* = 0.4089
Decision Rule: Reject Ho if F* = 0.4089 > F(1- 0.1, 2, 18.63) = 2.59
Conclusion: Fail to reject Ho and conclude no significant mean water table fluctuation differences.

Hence, mean water table fluctuation beneath all communities is not statistically different. Cottonwood communities fluctuated a mean of 10.9 cm while sedge and willow communities fluctuated a mean of 5.2 cm and 4.9 cm respectively (Fig. 4.1).

Table 4.2. ANOVA table of water table fluctuation between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	74	314.66	4.25	2.75	0.0001
Error	250	352.39	1.41		
Corrected Total	324	667.05			
	R-Square	C.V.	Root MSE	CHGE MEAN	
	0.471719	50.7512	1.1872	2.42	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	4.14	2.07	1.47	0.2326
Site(Type)	15	107.96	7.20	5.11	0.0001
Ill(Type*Site)	36	68.01	1.89	1.34	0.1031
Measure	7	35.01	5.00	3.55	0.0012
Type*Measure	14	73.52	5.25	3.73	0.0001
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	2.0678	18.63	5.06	**0.4089**	**0.6702**

Figure 4.1. Square root mean water table fluctuation for each community Type. The p value of 0.6702 indicates no difference between community types represented by the letters.



Water Table Depth

There were significant mean water table depth differences between the three community types. The water table depth hypothesis test (Table 4.3) shows that with an F* value of 8.4025 and a p value of 0.0035 (Table 4.4) the null hypothesis is rejected at an alpha of 0.1. Thus, there are significant mean water table depth differences between the community types.

Table 4.3. Hypothesis test for water table depth between the three communities.

Ho: cottonwood = sedge = willow vs. Ha: not all water table depth means are equal.
Test Statistic: F* = 8.4025
Decision Rule: Reject Ho if F* = 8.4025 > F(1- 0.1, 2, 15.11) = 2.70
Conclusion: Reject Ho and conclude that not all mean water table depths are equal.

Although the formal hypothesis test indicates significant mean water table depth differences between community types, there is a significant interaction between community type and measurement period that must not be overlooked (Table 4.4). This interaction may indicate that there are not significant differences between community types at some measurement periods. This may confound the results of the main effect (community type comparison). Therefore, I have constructed a table showing the least squares mean p values between each measurement period and the community types (Table 4.5). Table 4.5 shows that the p values between each community for each measurement period are all 0.0001. These p values are all significant ($p < 0.1$). Thus, the

Table 4.4. ANOVA table of water table depth between communities.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	74	216392.65	2924.23	46.91	0.0001
Error	271	16893.90	62.34		
Corrected Total	345	233286.55			
	R-Square	C.V.	Root MSE	Depth MEAN	
	0.927583	23.38	7.90	33.77	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	76148.73	38074.37	610.76	0.0001
Site(Type)	15	91895.45	6126.36	98.27	0.0001
III(Type*Site)	36	14808.27	411.34	6.60	0.0001
Measure	7	14814.61	2116.37	33.95	0.0001
Type*Measure	14	5134.15	366.73	5.88	0.0001
1. Source: Type					
1. Error: Site(Type)					
2. Source: Type*Measure					
2. Error: MS(Error)					
DF	Type III MS	Denominator DF	Denominator MS	F Value	Pr > F
1. 2	38074.37	15.11	4531.33	**8.4025**	**0.0035**
2. 14	366.73	271	62.34	**5.8827**	**0.0001**

eight measurement periods are all significantly different between the three community types. For example, sedge measurement period 1 is significantly different from willow and cottonwood measurement period 1. Measurement period 1 is also significant between willow and cottonwood. Therefore, the main effect of the model (community type comparison) is not confounded and the null hypothesis is rejected. The least square mean and Bonferroni multiple comparison tests between the three community types (Fig. 4.6, 4.7) both indicate that water table depth means are significantly different between the three communities.

Table 4.5. Type x Measure p values.

Measurement		Cottonwood	Sedge	Measurement		Cottonwood	Sedge
1	Cottonwood			5	Cottonwood		
	Sedge	0.0001			Sedge	0.0001	
	Willow	0.0001	0.0001		Willow	0.0001	0.0001
2	Cottonwood			6	Cottonwood	0.0001	
	Sedge	0.0001			Sedge		
	Willow	0.0001	0.0001		Willow	0.0001	0.0001
3	Cottonwood			7	Cottonwood		
	Sedge	0.0001			Sedge	0.0001	
	Willow	0.0001	0.0001		Willow	0.0001	0.0001
4	Cottonwood			8	Cottonwood		
	Sedge	0.0001			Sedge	0.0001	
	Willow	0.0001	0.0001		Willow	0.0001	0.0001

Table 4.6. Least squares mean p values between the community types.

	Cottonwood	Sedge	Willow
Cottonwood		0.0001	0.0001
Sedge	0.0001		0.0001
Willow	0.0001	0.0001	

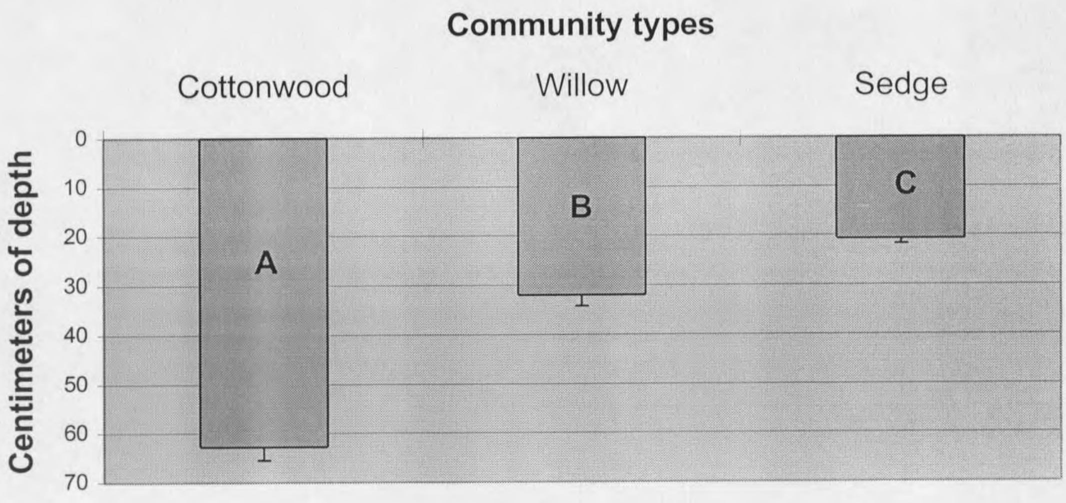
Therefore, cottonwood communities have significantly deeper mean water tables (62.8 cm) than mean willow community water tables (32.0 cm) which are significantly deeper than mean sedge community water tables (20.7 cm) (Fig. 4.2).

Table 4.7. Bonferroni multiple comparison test for water table depths.

Bonferroni (Dunn) T tests for variable: Depth
Alpha = 0.1 Confidence = 0.9 df = 271 MSE = 62.3391
Critical Value of T = 2.13895
Comparisons significant at the0.1 level are indicated by '***'

	Simultaneous Lolr Confidence Limit	Difference Betlen Means	Simultaneous Upper Confidence Limit	
Cotton – Willow	28.3340	30.8074	33.2809	***
Cotton – sedge	39.6729	42.0994	44.5258	***
Willow – Cotton	-33.2809	-30.8074	-28.3340	***
Willow – Sedge	9.2446	11.2919	13.3392	***
Sedge – Cotton	-44.5258	-42.0994	-39.6729	***
Sedge – Willow	-13.3392	-11.2919	-9.2446	***

Figure 4.2. A bar graph representing the depth to water table for each community type. The p value of 0.0035 indicates that not all community types are equal. A least squares mean and Bonferroni multiple comparison tests indicate that mean water table depths are significantly different between the three communities at an alpha of 0.1. The different letters represent significance.



Soil Particle Size

Sand. There were significant soil particle size and coarse fragment percentage differences between the three community types. The sand percentage hypothesis test (Table 4.8) shows that with an F value of 13.8235 and a p value of 0.0004 (Table 4.9) the null hypothesis is rejected at an alpha of 0.1. As a result, there are significant mean sand percentage differences between the community types.

Table 4.8. Hypothesis test for sand percentage between the three community types.

Ho: cottonwood = sedge = willow vs. Ha: not all sand percentage means are equal.
Test Statistic: F* = 13.8235
Decision Rule: Reject Ho if F* = 13.8235 > F(1- 0.1, 2, 15.01) = 2.70
Conclusion: Reject Ho and conclude that not all sand percentages mean are equal.

Table 4.9. ANOVA table of sand percentages between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	53	112434.51138905	2121.4058753	7.07	0.0001
Error	168	50402.77146500	300.01649682		
Corrected Total	221	162837.28285405			
	R-Square	C.V.	Root MSE	Sand MEAN	
	0.690427	32.52717	17.32098429	53.25081081	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	69137.20079930	34568.60031	115.22	0.0001
Site(Type)	15	37597.99122932	2506.5327486	8.35	0.0001
Pitl(Type*Site)	36	5822.16739707	161.72687214	0.54	0.9846
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	34568.6004	15.01	2500.7077483	**13.8235**	**0.0004**

Silt. The silt percentage hypothesis test (Table 4.10) shows that with an F value of 15.2319 and a p value of 0.0002 (Table 4.11) the null hypothesis is rejected at an alpha of 0.1. As a result, there are significant mean silt percentage differences between the community types.

Table 4.10. Hypothesis test for silt percentage between the three community types.

Ho: cottonwood = sedge = willow vs. Ha: not all silt percentage mean are equal.
Test Statistic: F* = 15.2319
Decision Rule: Reject Ho if F* = 15.2319 > F(1- 0.1, 2, 15.02) = 2.70
Conclusion: Reject Ho and conclude that not all mean silt percentages are equal.

Table 4.11. ANOVA table of silt percentages between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	53	38296.30616482	722.57181443	4.50	0.0001
Error	168	26984.86720500	160.62420955		
Corrected Total	221	65281.17336982			
	R-Square	C.V.	Root MSE	Silt MEAN	
	0.586636	42.19791	12.67376067	30.03409910	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	23775.16859450	11887.584297	74.01	0.0001
Site(Type)	15	11731.17159801	782.07810653	4.87	0.0001
Pitl(Type*Site)	36	2672.97033183	74.24917588	0.46	0.9961
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	11887.5843	15.02	780.4375253	**15.2319**	**0.0002**

Clay. The clay percentage hypothesis test (Table 4.12) shows that with an F value of 8.6797 and a p value of 0.0031 (Table 4.13) the null hypothesis is rejected at an alpha of 0.1. Hence, there are significant mean clay percentage differences between the community types.

Table 4.12. Hypothesis test for mean clay percentages between the three community types.

Ho: cottonwood = sedge = willow vs. Ha: not all mean clay percentages are equal.
Test Statistic: F* = 8.6797
Decision Rule: Reject Ho if F* = 8.6797 > F(1- 0.1, 2, 15.01) = 2.70
Conclusion: Reject Ho and conclude that not all clay percentages are equal.

Table 4.13. ANOVA table of clay percentages between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	53	23970.61306982	452.27571830	8.22	0.0001
Error	168	9238.97895000	54.99392232		
Corrected Total	221	33209.59201982			
	R-Square	C.V.	Root MSE	Clay MEAN	
	0.721798	32.52717	7.41578872	16.88576577	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	11883.99494145	5941.9974707	108.05	0.0001
Site(Type)	15	10293.77552600	686.25170173	12.48	0.0001
Pitl(Type*Site)	36	1871.04028542	51.97334126	0.95	0.5633
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	5941.99747	15.01	684.58523915	**8.6797**	**0.0031**

Coarse Fragments. The coarse fragment percentage hypothesis test (Table 4.14) shows that with an F value of 6.2140 and a p value of 0.0108 (Table 4.15) the null hypothesis is rejected at an alpha of 0.1. Therefore, there are significant mean coarse fragment percentage differences between the community types.

Table 4.14. Hypothesis test for coarse fragment percentages between the three community types.

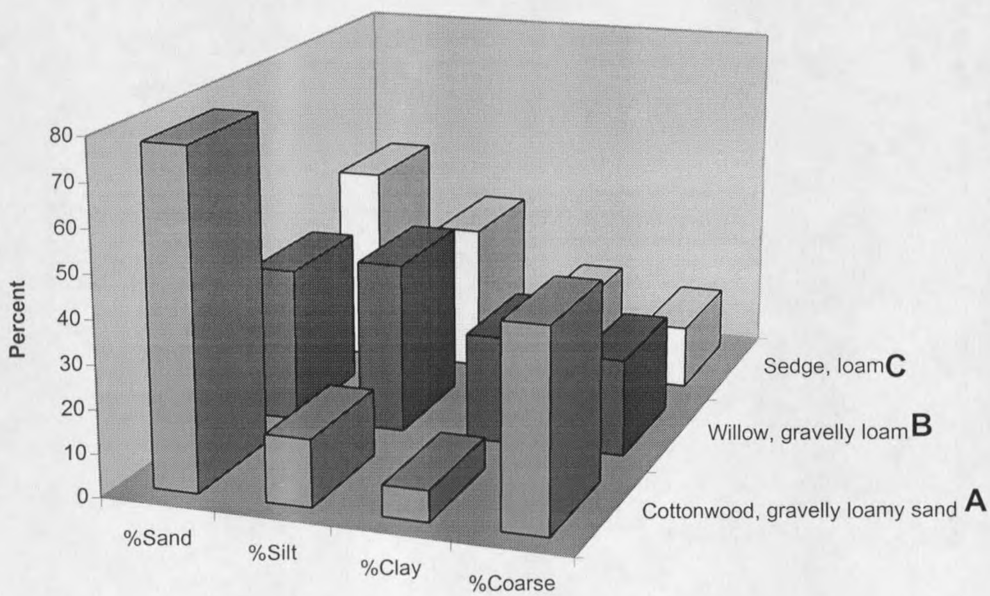
Ho: cottonwood = sedge = willow vs. Ha: not all coarse fragment percentages are equal.
Test Statistic: F* = 6.2140
Decision Rule: Reject Ho if F* = 6.2140 > F(1- 0.1, 2, 15.01) = 2.70
Conclusion: Reject Ho and conclude that not all mean coarse fragment percentages are equal.

Table 4.15. ANOVA table of coarse fragment percentages between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	53	961.36731261	18.13900590	4.92	0.0001
Error	168	619.53759634	3.68772379		
Corrected Total	221	1580.90490894			
	R-Square	C.V.	Root MSE	Coarse MEAN	
	0.608112	37.62080	1.92034471	5.10447613	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	336.34779715	168.17389857	45.60	0.0001
Site(Type)	15	406.88206136	27.12547076	7.36	0.0001
Pitl(Type*Site)	36	216.97371836	6.02704773	1.63	0.0207
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	168.173899	15.01	27.063597257	**6.2140**	**0.0108**

Consequently, cottonwood soils were sandier (78%) than sedge soils, which were sandier (47%) than willow (36%) soils at the 0.1 alpha level (Fig. 4.3). Cottonwood soils also contained less clay (7%) and silt (15%) than sedge soils, which contained less clay (18%) and silt (35%) than willow soils which contained 25% clay and 39% silt (Fig. 8). Sampled coarse fragments measured 2.1 mm to 11 cm and mean coarse fragment percentages were significantly different between the three community types (Fig. 8). Cottonwood soils contained the most mean coarse fragment percentages (49%), willow soils intermediate (22%) and sedge soils the least (15%) (fig 8).

Figure 4.3. Soil particle size and coarse fragment percentages graphed by community type. All particle sizes and coarse fragment percentages are statistically different among the community types as indicated by the letters.



Slopes

Streamside Slope. There were no significant differences in streamside and uphill slope degrees. The hypothesis test for streamside slopes (Table 4.16) indicates that with an F value of 0.2766 and a p value of 0.7622 (Table 4.17) the null hypothesis cannot be rejected at an alpha of 0.1. Therefore, cottonwood, willow and sedge community streamside slope means are not significantly different from one another.

Table 4.16. Hypothesis test for streamside slope degrees between the three community types.

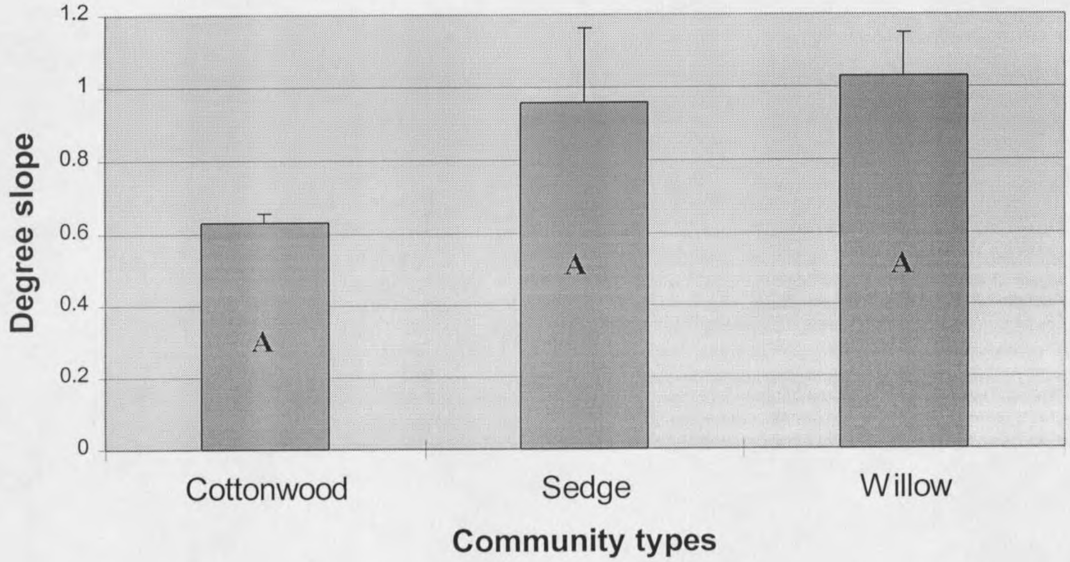
Ho: cottonwood = sedge = willow vs. Ha: not all mean streamside slope degrees are equal.
Test Statistic: F* = 0.2766
Decision Rule: Reject Ho if F* = 0.2766 > F(1- 0.1, 2, 15) = 2.70
Conclusion: Fail to reject Ho and conclude that all mean streamside slope degrees are equal.

Table 4.17. ANOVA table of streamside slope degrees between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	17	9.36312728	0.55077219	4.81	0.0009
Error	18	2.06023430	0.11445746		
Corrected Total	35	11.42336159			
	R-Square	C.V.	Root MSE	Slope MEAN	
	0.819647	36.41294	0.33831562	0.92910833	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	0.33301329	0.16650664	1.45	0.2596
Site(Type)	15	9.03011400	0.60200760	5.26	0.0006
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	0.16650664	15	0.6020075997	**0.2766**	**0.7622**

Thus, streamside slopes were not significantly different (Fig. 4.4). Mean streamside slopes measured 0.6° (0.7%) in cottonwood communities, 1° (1.1%) in sedge communities, and 1° (1.1%) in willow communities.

Figure 4.4. Streamside degree slope graphed by community type. Bars with the same letter are statistically not statistically different.



Hillside Slope. The hypothesis test for hillside slope (Table 4.17) indicates that with an F value of 1.3662 and a p value of 0.2850 (Table 4.18) the null hypothesis cannot be rejected at an alpha of 0.1. Therefore, no significant differences in hillside slope means exist among the community types.

Table 4.18. Hypothesis test for hillside slope degrees between community types.

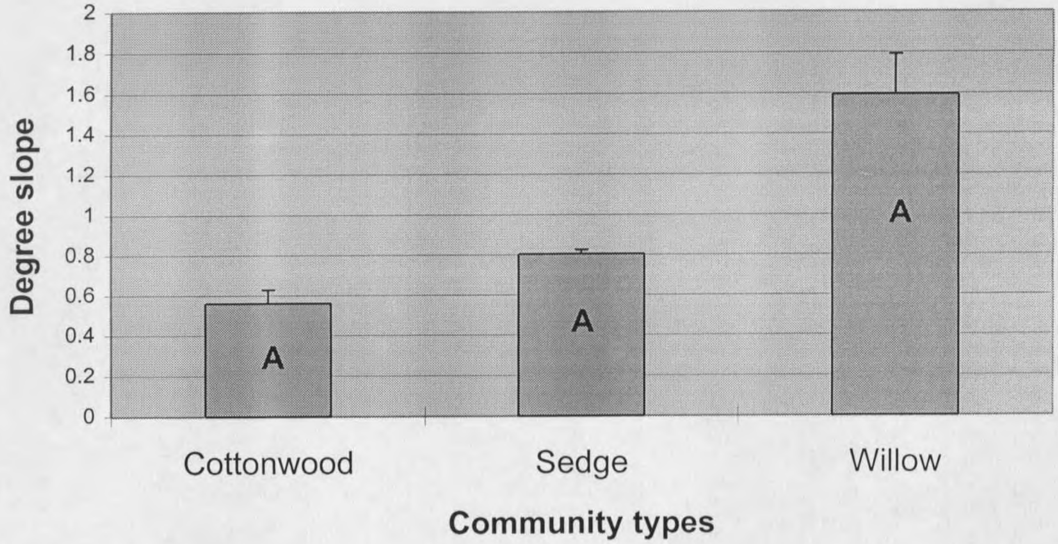
Ho: cottonwood = sedge = willow vs. Ha: not all mean hillside slope degrees are equal.
Test Statistic: F* = 1.3662
Decision Rule: Reject Ho if F* = 1.3662 > F(1- 0.1, 2, 15) = 2.70
Conclusion: Fail to reject Ho and conclude no differences in mean hillside slope degrees.

Table 4.19. ANOVA table of hillside slope degrees between community types.

Source	DF	Sum of squares	Mean Square	F Value	Pr > F
Model	17	10.86127077	0.63889828	6.91	0.0001
Error	18	1.66501904	0.09250106		
Corrected Total	35	12.52628981			
	R-Square	C.V.	Root MSE	Slope MEAN	
	0.819647	31.36576	0.03413987	0.96965556	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Type	2	1.67365662	0.83682831	9.05	0.0019
Site(Type)	15	9.18761415	0.61250761	6.62	0.0001
Source: Type					
Error: Site(Type)					
		Denominator	Denominator		
DF	Type III MS	DF	MS	F Value	Pr > F
2	0.83682831	15	0.6125076102	**1.3662**	**0.2850**

Wherefore, hillside slopes were not significantly different (Fig. 4.5). Mean hillside slopes were 0.6° (0.7%) in cottonwood communities, 0.8° (0.9%) in sedge communities and 1.6° (1.8%) in willow communities.

Figure 4.5. Hillside degree slope graphed by community type. Bars with the same letter are statistically similar.



Percent Cover

The results of the Daubenmire cover analysis to determine community type are located in appendix A through C. The black cottonwood recent alluvial bar communities had and average of 30% black cottonwood cover with a range of 9.8 – 54.65% and 70% non-vegetative cover. Geyer's willow communities had an average of 35% Geyer's willow cover with a range of 16.05 – 52.9%. Beaked sedge communities had an average of 44% beaked sedge cover with a range of 36.5 – 59.25%. These results clearly show that black cottonwood, Geyer's willow and beaked sedge are the dominant tree, shrub and graminoid species respectively and more or less equal the percent cover represented by these species in the community types described and classified by Hansen *et al.* (1995).

Summary

Ecological Amplitude

There does seem to be an ecological range of black cottonwood, beaked sedge and Geyer's/Drummond's willow communities which, considering the measured factors of this study, is controlled by texture and depth to the water table. All three community types fall within a water table fluctuation range of 0.05 – 0.1 m and a streamside and hillside slope range of 0.5° - 1.6° (0.6% - 1.8%).

Black Cottonwood Recent Alluvial Bar. Young black cottonwood communities occupy gravelly loamy sand soils (46% coarse fragments). Groundwater within these communities has a mean depth of 0.6 m.

Beaked Sedge. Beaked sedge communities appear on sites with loam soils (15% coarse fragments). Mean depth to water is 0.2 m in beaked sedge communities.

Geyer's Willow. Mean depth to water table is 3.2 m in Geyer's willow communities. Geyer's willow communities also occur on sites with gravelly loam soils (22% coarse fragments).

Chapter 5

DISCUSSION AND CONCLUSION

Water Table Fluctuation

Ground-water losses through wells, springs and evapotranspiration are recharged by stream loss, snow melt and precipitation infiltration. The interaction between draw down and recharge rates can cause considerable daily and seasonal water table fluctuation (Hackett *et al.*, 1960). One might assume that, given different soil textures, coarse fragment percentages, depth to water table and a difference in climate between the west and east groups that water table fluctuation would also be significantly different between the community types. Yet, water table fluctuation to a depth of 1 m was not different among the community types. Therefore more research needs to be conducted on topics such as recharge/discharge patterns. Also, cottonwood transpiration rates (Hackett *et al.*, 1960) may not cause a water table fluctuation difference as black cottonwood recent alluvial bar sites do not have a high transpiring leaf area. Transpiring leaf area was assumed to be proportional to foliage volume which was proportional to percent cover according to a phreatophyte study performed in Nevada (Robinson, 1970). A small cover percentage equals little foliage volume and thus, less transpiring leaf area. Our data shows cottonwood sites had an average of only 30% cottonwood cover and an average of

70% non-vegetative cover (Appendix A). This indirectly indicates that the measured black cottonwood recent alluvial bar sites have low transpiration rates. Even though mean water table fluctuation did not differ among the communities, significantly different mean water table depths, soil particle sizes and coarse fragment percentages may have dictated whether cottonwoods, willows or sedges occupied a site.

Water Table Depth and Soil Texture

Soil texture and water table depth likely play a significant role in regulating soil Eh (aeration) and water availability which in turn determines plant community type (Brady, 1990). Oxygen is essential for plant root growth (Yamasaki, 1952). Woody species are particularly dependent on well-watered, well-aerated and well-drained substrates (Pezeshki *et al.*, 1998). Soil texture and water table depth help to provide the appropriate water and oxygen levels for willows and cottonwoods. Pezeshki *et al.* (1998) found black willow (*Salix nigra*) net carbon fixation to be highest in well-watered and well-drained conditions. Also, total black willow root biomass, at a variety of depths, decreased significantly under low soil aeration. Black willow posts exposed to continuously flooded conditions next to creeks had an 80% mortality rate and 78.8% of live root biomass was within 15 cm of the soil surface in continuously flooded treatments. Baldcypress (*Taxodium distichum*) and oaks (*Quercas* spp.) follow this trend as well (Pezeshki, 1991). The limited root growth under reduced conditions (low Eh) may be a result of a variety of factors. Anaerobic microbial respiration and chemical reactions may cause nutrients to become unavailable or toxic to plants (Gambrell *et. al.*, 1991; Mitsch and Gosselink, 1993; DeLaune and Pezeshki, 1991). Root respiration is also constrained under reduced conditions, which limits the energy necessary for roots to absorb nutrients and water (Brady, 1990). This information explains why both cottonwood and willows would occupy sandy and gravelly sites with relatively high water tables (Hansen *et. al.*, 1995). Sandy and gravelly soils provide well-drained conditions (high root zone aeration) while high water tables provide the well-watered conditions favored by these woody species.

Unlike woody species, beaked sedge seems to be tolerant of root zone saturation. This may be due to the fact that beaked sedge has aerenchyma tissue which allows roots to take oxygen from above the ground (Svejcar, 1997). High water tables determine and influence beaked sedge distribution more than the substrate properties (Youngblood *et al.*, 1985). Sjoberb and Danell (1983) found that shoot densities of beaked sedge were high on seasonally flooded soils. They also colonize permanently flooded sites (Manning and Padgett, 1995). Kauffman *et al.* (1985) described sedge soils as fine textured A-horizons above a coarse textured horizon forming a water restrictive horizon. Even though the measured sedge communities occurred on fine textured (loam) soils, as did the measured willow communities, there were more coarse fragments in the gravelly loam willow communities (22%) than in the sedge dominated communities (15%). This similarity in soil characteristics and significant water table depths between willow and sedge communities may explain why sedge communities convert to willow sites when a drop in the water table occurs (Hansen *et al.*, 1988).

Conclusions

Riparian Classifications

This study confirms that many of the broad descriptions of riparian community soils and water tables are valid. For example, Kauffman *et. al.* (1985) found cottonwood soils, along Catherine Creek in northeastern Oregon, to be well-drained loamy soils with sand, gravel and cobbles. Hansen *et al.* (1995) noted black cottonwood recent alluvial bar communities on silt loam soils. Youngblood *et al.* (1985) and Manning and Padgett (1995) found beaked sedge to inhabit sites with high water tables (around 0.2 m). Hansen *et. al.* (1995) and Manning and Padgett (1995) described beaked sedge soils as clay and loamy clay to sandy loam. Geyer's willow stands were found to occupy fine textured soils (Youngblood, 1985; Manning and Padgett, 1995) with water tables at 0.4 m (Hansen *et. al.*, 1995).

This study further indicates that water tables are within 1 m of the soil surface and that soils all contain a mix of fine textures such as loam. Yet, this study indicates that riparian vegetation has a more narrow affinity for specific soil textures, coarse fragment percentages and water table depths than are described in the existing riparian vegetation classifications.

Management Recommendations

Riparian areas and stream ecosystems are very dynamic (Padgett *et al.*, 1989; Svejcar, 1997). Because they are so dynamic multiple steady states (communities) may exist at any given site (Borman and Pyke, 1994). Floods, as well as flood suppression from deposition, droughts, and intrinsic channel changes etc. have caused channel geometry and riparian forest changes (Albertson and Weaver, 1945; Boggs and Weaver, 1992; Schumm and Lichty, 1963; Friedman *et al.* 1996, 1997). Nevertheless, this study points out that riparian communities are also controlled by abiotic factors (Dyksterhuis, 1949; Daubenmire, 1970) such as soil texture, coarse fragment percentages and depth to water table.

Due to the dynamics of riparian areas, managers should consider in their inventory of riparian areas water table depth, soil texture and coarse fragment percentages to aid them in determining a plant community that most closely meets their management goals (Smith, 1987). This approach to managing riparian areas allows managers to work within the bounds of riparian communities controlled by multiple steady states and state-and-transition models of succession in which multiple states may exist at any given site (Borman and Pyke, 1994). Further studies may explore favorable soil aeration, capillary fringe, disturbance and duration of riparian community types to further clarify the spatial and temporal distribution of riparian community types.

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APPENDICES

APPENDIX A

Black Cottonwood Recent Alluvial Bar Percent Cover

Populus tricocharpa (black cottonwood) recent alluvial bar			
	% Canopy Cover		
Species	**Average**	**Range**	**Constancy**
Tree			
Populus tricocharpa (black cottonwood)	29.56	9.8 - 54.65	100
Shrub			
Cornus stolonifera (redosier dogwood)	0.18	0 - 1.05	16.67
Prunus virginiana (chokecherry)	0.03	0 - 0.15	16.67
Rosa woodsii (woods rose)	0.22	0 - 1.15	33.33
Salix exigua (sandbar willow)	1.85	0 - 8.65	50
Graminoids			
Agropyron caninum var *unilaterale* (slender wheatgrass)	0.03	0 - 0.15	16.67
Agropyron repens (quack grass)	0.18	0 - 0.3	33.33
Agropyron riparian (streambank wheatgrass)	0.07	0 - 0.15	33.33
Agrostis stolonifera (bent redtop)	2.21	0 - 6.5	83.33
Agrypyron trachycaulum (slender wheatgrass)	0.23	0 - 1	50
Bromus inermus (smooth brome)	3.32	0 - 9.8	66.67
Bromus marginatus (mountain brome)	0.05	0 - 0.15	33.33
Broumus tectorum (cheatgrass)	0.03	0 - 1.25	16.67
Carex nebrascensis (Nebraska sedge)	0.98	0 - 5.9	16.67
Dactylus glomeratus (orchard grass)	0.03	0 - 0.15	16.67
Phalaris arundinacea (reed canarygrass)	0.21	0 - 1.25	16.67
Phleum alpinum (alpine timothy)	0.09	0 - 0.4	33.33
Phleum pratense (common timothy)	0.05	0 - 0.15	33.33
Poa compressa (Canada bluegrass)	2.67	0 - 11.25	66.67
Poa pratensis (Kentucky bluegrass)	2.76	0.5 - 7.65	100
Forbs			
Aquillea milifolium (western yarrow)	0.07	0 - 0.25	33.33
Artemisia ludoviciana (prairie sage)	0.19	0 - 1.15	16.67
Bellis spp. (daisy)	0.12	0 - 0.55	33.33
Berteroa incana (berteroa)	0.07	0 - 0.4	16.67
Centaurea maculatum (spotted knapweed)	0.93	0 - 4.5	50
Cirsium canadensis (Canada thistle)	0.08	0 - 0.3	33.33
Grindelia holllii (Hollil's grindelia)	0.04	0 - 0.25	16.67
Melilotus alba (white sweet-clover)	0.15	0 - 0.9	16.67
Melilotus officionale (yellow sweet-clover)	0.37	0 - 1.9	33.33
Senicio spp. (groundsel)	1.36	0 - 8.15	16.67
Symphoricarpos albus (common snowberry)	3.97	0 - 16.9	33.33
Taraxacum officionale (dandelion)	0.09	0 - 0.3	33.33
Townsendia montana (daisy)	0.22	0 - 1.15	33.33
Trifolium sp. (clover)	2.55	0 - 7.5	83.33
Unknown forb spp.	1.88	0.65 - 2.7	100
Vicia americana (american vetch)	0.03	0 - 0.15	16.67
Ferns and Allies			
Equisitum arvense (common horsetail)	0.24	0 - 0.75	66.67

Populus tricocharpa (black cottonwood) recent alluvial bar			
	% Canopy Cover		
Species	Average	Range	Constancy
Litter, Rock, and Bare ground			
Bare ground	11.31	0.75 - 19.05	100
Litter	54.26	21.1 - 67.4	100
Rock	5.45	0.15 - 25.65	100

APPENDIX B

Geyer's Willow Dominated Percent Cover

Salix geyeriana (Geyer's willow) community type			
	% Canopy Cover		
Species	**Average**	**Range**	**Constancy**
Tree			
Abies grandis (grand fir)	0.03	0 - 0.15	16.67
Picea pungens (blue spruce)	0.32	0 - 1.9	16.67
Shrub			
Ribes sp. (currant)	2.71	0 - 7	50
Ribes lacustre (prickley currant)	0.03	0 - 0.15	16.67
Rosa woodsii (woods rose)	0.37	0 - 1.5	66.67
Salix geyeriana (Geyer's willow)	34.88	16.05 - 52.9	100
Salix lasiandra (pacific willow)	3.59	0 - 21.55	16.67
Salix lutea (yellow willow)	2	0 - 12	16.67
Salix planifolia (planeleaf willow)	1.5	0 - 9	16.67
Graminoids			
Agropyron trachychaulum (slender wheatgrass)	0.07	0 - 0.4	16.67
Agrostis stolonifera (bent redtop)	1.53	0 - 3.75	33.33
Bromus marginatus (mountain brome)	0.28	0 - 1.65	16.67
Bromus tectorum (cheatgrass)	0.04	0 - 0.25	16.67
Carex lasiocarpa (slender sedge)	0.42	0 - 2.5	16.67
Carex praegracilis (clustered field sedge)	0.03	0 - 0.15	16.67
Carex rostrata (beaked sedge)	12	0 - 44.9	83.33
Carex sp. (sedge)	0.19	0 - 1.15	16.67
Iris spp. (Iris)	0.13	0 - 0.75	16.67
Juncus balticus (baltic rush)	2.55	0 - 15.15	33.33
Phleum alpinum (alpine timothy)	0.13	0 - 0.75	16.67
Phleum pratense (common timothy)	3.8	0 - 15.55	33.33
Poa compressa (Canada bluegrass)	0.63	0 - 3.8	16.67
Poa pratensis (Kentucky bluegrass)	2.08	0 - 7.75	66.67
Scirpus microcarpus (small fruit bullrush)	0.04	0 - 0.25	16.67

Salix geyeriana (Geyer's willow) community type			
	% Canopy Cover		
Species	**Average**	**Range**	**Constancy**
Forbs			
Aquillea milifolium (western yarrow)	0.83	0 - 5	16.67
Aster campestris (western meadow aster)	0.32	0 - 1.9	16.67
Aster integrifolius (aster)	0.82	0 - 2.75	33.33
Aster spp. (aster)	0.71	0 - 2.55	33.33
Brassica spp. (mustard)	0.49	0 - 2.8	33.33
Cirseum canadensis (Canada thistle)	1.49	0 - 4.55	66.67
Epilobium watsonii (Watson's willow-herb)	0.17	0 - 1	16.67
Erigeron peregrinus (wandering daisy)	0.38	0 - 2.25	16.67
Fragaria virginiana (Virginia strawberry)	3.68	0 - 20.15	33.33
Geranium richardsonii (white geranium)	2.18	0 - 5.65	50
Geranium viscosissimum (sticky geranium)	1.23	0 - 7.4	16.67
Juncus spp. (rush)	0.08	0 - 0.5	16.67
Ledum glandulosum (trapper's tea)	0.03	0 - 0.15	16.67
Mentha arvense (field mint)	0.72	0 - 2.65	33.33
Mertensia spp. (bluebells)	0.21	0 - 1.25	16.67
Polygonum spp. (smartweed)	0.38	0 - 2.25	16.67
Ranunculus acriformis (sharp buttercup)	0.53	0 - 3.15	16.67
Ribes areum (golden currant)	2.76	0 - 11.3	33.33
Ribes irriguum (Ida gooseberry)	0.05	0 - 0.15	33.33
Rumex spp. (dock)	0.83	0 - 5	16.67
Crepis sp. (hawksbeard)	0.18	0 - 1.05	16.67
Senicio spp. (groundsel)	0.13	0 - 0.75	16.67
Smilacina racemosa (false solomon's seal)	0.3	0 - 1.15	33.33
Solidago mollis (goldenrod)	4.24	0 - 15.55	33.33
Spiranthes romanzoffiana (hooded ladies-tresses)	0.32	0 - 1.9	16.67
Taraxacum officionale (dandelion)	0.48	0 - 2.9	16.67
Thalictrum (meadow rue)	0.44	0 - 2.65	16.67
Trifolium spp. (clover)	0.08	0 - 0.5	16.67
Unknown forb spp.	5.51	1.36 - 15.53	100
Urtica dioica (stinging neddle)	0.03	0 - 0.15	16.67
Viola aduna (early blue violet)	0.13	0 - 0.75	16.67
Viola nuttallii var *bakeri* (baker violet)	0.07	0 - 0.4	16.67
Viola spp. (violet)	0.21	0 - 1.25	16.67
Ferns and Allies			
Equisetum arvense (common horsetail)	0.94	0 - 4.35	66.67
Litter, Rock, and Bare ground			
Bare ground	0.64	0 - 2.4	66.67
Litter	32.32	16.65 - 48.4	100
Water	2.23	0 - 13.4	16.67

APPENDIX C

Beaked Sedge Dominated Percent Cover

Carex rostrata (beaked sedge) habitat type			
Carex rostrata (beaked sedge) phase	% Canopy Cover		
Species	**Average**	**Range**	**Constancy**
Shrub			
Ribes cereum (wax currant)	0.16	0 - 0.75	33.33
Salix exigua (sandbar willow)	0.28	0 - 1.3	33.33
Graminoids			
Agrostis stolonifera (bent red top)	1.39	0 - 5.05	50
Bromus marginatus (mountain brome)	0.025	0 - 0.15	16.66
Carex hooderii (Hood's sedge)	0.09	0 - 0.55	16.66
Carex nebrascensis (Nebraska sedge)	0.025	0 - 0.15	16.66
Carex rostrata (beaked sedge)	44.04	36.5 - 59.25	100
Juncus patens (spreading rush)	0.09	0 - 0.55	16.66
Juncus sp. (rush)	0.21	0 - 1.25	16.66
Phleum alpinum (alpine timothy)	0.15	0 - 0.9	16.66
Phleum pratense (common timothy)	0.58	0 - 3.5	16.66
Poa compressa (Canada bluegrass)	0.025	0 - 0.15	16.66
Poa pratensis (Kentucky bluegrass)	1.47	0 - 4.4	33.33
Scirpus microcarpus (small fruit bulrush)	0.04	0 - 0.25	16.66
Typha latifolia (cattail)	0.04	0 - 0.25	16.66
Forbs			
Achilea milifolium (western yarrow)	0.09	0 - 0.3	33.33
Arenaria sp. (Sandwort)	0.025	0 - 0.15	16.66
Brassica sp. (mustard)	0.15	0 - 0.75	33.33
Cerbra	0.025	0 - 0.15	16.66
Cirsium canadensis (Canada thistle)	2.38	0 - 4.65	83.33
Epilobium sp. (willow-herb)	1.95	0 - 11.55	33.33
Fragaria vesca (woods strawberry)	0.075	0 - 0.9	16.66
Geranium richardsonii (wild white geranium)	0.9	0 - 4.4	50
Luscarella sp.	0.025	0 - 0.15	16.66
Mentha arvense (mint)	3.6	0.3 - 11.8	83.33
Mimulus sp. (monkey flower)	0.96	0 - 5.75	16.66
Ranunculus sp. (buttercup)	0.025	0 - 0.15	16.66
Smilacina racemosa (false solomon's-seal)	0.025	0 - 0.15	16.66
Taraxacum officionale (dandelion)	0.48	0 - 2.75	33.33
Thlapsi arvense (Penny Cress)	0.13	0 - 0.75	16.66
Trifolium sp. (clover)	2.32	0 - 13.9	16.66
Unkown forb	1.2	0.25 - 1.88	100
Viola sp. (violet)	0.125	0 - 0.75	16.66
Ferns and Allies			
Equisitum arvense (common horsetail)	0.33	0 - 2	16.66
Litter, Rock, and Bare ground			
Bare ground	0.89	0 - 2.4	66.66
Litter	35.86	13.25 - 56.4	100
Water	1	0 - 6	16.66