AN ABSTRACT OF THE THESIS OF

Jennifer M. Yancey for the degree of Master of Science in Rangeland Ecology and Management presented on May 9, 2008.

Title: Woody Riparian Species Patterns along Northeast Oregon Mountainous Streams and the Relationship to Riparian Capability

Abstract approved:

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Woody riparian vegetation is an essential component of riparian ecosystems, responsible in part for the maintenance of functional ecological processes. The plant community composition and distribution provide an indication of the underlying mosaic of environmental attributes and processes. Restoration and management of riparian communities have been hindered by the lack of measurable criteria for the assessment of a riparian systems modified by human imposed infrastructures. The woody vegetation community offered a quantifiable indicator of the underlying mosaic of environmental, physical, and hydrological attributes, while allowing the investigation of the concept of riparian potential versus riparian capability. The examination of riparian condition was measured through the determination of species-environmental relationships along three mountainous channels in northeast Oregon. The physical and environmental attributes of channel morphology, hydrology, understory community composition, surface particle characteristics, and microclimate variables were quantified and analyzed in relation to the woody vegetation composition and distribution across the three separate streams and within flood-frequency elevation zones. The second component of the study evaluated and described methods for quantifying the concept of riparian capability, based on the measured species-environmental relationships and channel morphology. The evaluation of condition was measured against the reference baseline of Rosgen hierarchical classification and regional hydraulic geometry curves.

Multivariate analyses indicated that vegetation transects grouped by stream and vegetation belt transects weakly grouped by flood zone, based on the species composition quantified within the vegetation transects and flood zones. Secondly, channel geometry, canopy cover, air temperature, channel particle size, understory composition attributes, and flood zone distance were found to be overall gradients, which described the variation in species composition across the three streams in northeast Oregon. Direct individual species-environmental relationship conclusions were weak due to the close clustering of species and multiple physical and environmental gradients.

Riparian condition at the Grande Ronde River and North Fork Catherine Creek was determined to be functioning at riparian capability. Channel geometry measurements at the two stream reaches aligned with Rosgen stream type criteria and regional hydrologic curves, while species composition represented characteristics of potential natural communities. Meadow Creek was concluded to have departed from the highest attainable condition, thus riparian condition was less than capability.

The results suggested that woody riparian vegetation response was a function the physical sttributes: channel morphological widths, bankfull, floodprone, 25-year flood width, valley width, channel sinuosity, and channel slope. Environmental attributes, floodplain canopy cover, air temperature, and understory composition, were further factors that influenced the woody riparian vegetation community variation. The results also suggested species richness and diversity were associated with specific physical and environmental attributes. Finally, the results provided the determination of riparian capability along montane streams in northeast Oregon and criteria acceptable for the determination of riparian capability. These criteria included the physical channel measurements assessed against Rosgen hierarchiecal classification and regional channel geometry curves; and woody vegetation presence and distribution assessed against potential natural community plant associations. Further research should be done across a variety of riparian systems to determine both indicator species and reference values for the physical and environmental attributes that could be utilized for the assessment of riparian capability.

Key Terms: riparian capability, channel morphology, montane stream channels, Nonmetric Multidimensional Scaling, *Salix spp., Alnus spp.*

Woody Riparian Species Patterns along Northeast Oregon Mountainous Streams and the Relationship to Riparian Capability

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Jennifer M. Yancey, Author

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CONTRIBUTION OF AUTHORS

Dr. Tamzen Stringham aided in interpretation and discussion of the data and edited all chapters. Gregg Riegel assisted in experimental design and methods and aided in discussion of the data.

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INTRODUCTION

CONTEXT OF RESEARCH

In the West, and around the world, many riparian ecosystems have been functionally modified by human imposed disturbances such as infrastructure, mining, channelization, and water removal. These constraints affect the morphological characteristics of the channel causing changes in stream hydrological processes and riparian function. When constraints are imposed on a system, an additional level of complexity is added to the current understanding of riparian function. This complexity can be assessed through quantifiable attributes that can provide an indication of the impact of constraints on the ecological processes of the channel.

The foundational characteristics that define riverine riparian systems are the dimension, pattern, and profile of the stream, which are a function of the base – landform (Rosgen 1996). Channel hydrology and riparian vegetation patterns are additional attributes influenced by the landform and by other environmental characteristics, i.e. climate, water table, soil type and structure, sediment loads, aspect, elevation, existing plant communities, and disturbance regimes (Barrington et al 2001, Rosgen 1996, Lytjen 1999, Brunsfeld and Johnson 1985). Flow patterns, both yearly and over multiple years, affect the dimension, pattern, and profile of the channel and the distribution and composition of vegetation communities. These ecological characteristics make up a functioning healthy riparian system, where the system is able to dissipate stream energy, filter and capture nutrients and sediment, continue ground-water recharge, stabilize streambanks, provide habitat for wildlife, and support biodiversity (Prichard et al. 1998). When these characteristics are altered through disturbances such as hardened infrastructure, channelization, water withdrawal, vegetation removal etc., the dynamic processes of the riparian system are influenced and often permanently changed potentially leading to changes in the vegetation community and the pattern, dimension and profile of the channel.

Maintaining or restoring the processes of a riparian system requires an understanding of the current and desired riparian condition. A riparian site of optimal condition is defined as a site that is able to maintain the dimension, profile, and pattern of the channel over time, without significant aggradation or degradation of the channel bed (Rosgen 1996). Rosgen (1996) used the term "potential" to describe the "best channel condition based on quantifiable morphological characteristics" (pp 6.3). These quantifiable characteristics are the dimensionless ratios measured during the inventory of the channel's dimension, pattern, and profile (Rosgen 1996). Barrington et al. (2001) uses the term "site capability" to define the highest attainable site condition, given introduced constraints. Thus, riparian potential defines an unaltered system that is in balance with the landform, sediment load, and stream flow, and supports a fully developed riparian plant community; while riparian capability defines a system in balance with its environment and supporting a fully developed plant community given introduced constraints.

Vegetation is an essential component of riparian ecosystems and is responsible, in part, for the maintenance and resilience of the channel dimension, pattern, and profile. Riparian species composition and distribution is correlated to a wide variety of ecological properties: hydrology, soil, geomorphology, and biota that continually change throughout the year (Bendix 1994 and Harris 1987). Diversity within riparian ecosystems creates a mosaic of species-environmental relationships that are maintained through the dynamic processes of the riparian system.

To understand, maintain, and/or restore riparian areas to a desired condition, i.e. potential or capability, it is imperative to investigate and measure the stream's physical characteristics (dimension, pattern, and profile) and the associated riparian plant community. Through measurement of numerous physical and biotic attributes, species-environmental relationships can be elucidated. The relationships between environmental attributes, geomorphic variables, and riparian plant community characteristics can be used to determine a suite of critical environmental and hydrologic characteristics associated with vegetation species along streams. Additionally, understanding the relationship of discharge events to channel form and vegetation distribution provides insight into the determination of potential or capability. Knowing key species environmental relationships along streams at potential brings clarity to the diversity and environmental mosaics found within riparian ecosystems and allows scientists and managers to predict ecosystem response to introduced constraints.

LITERATURE REVIEW

OVERVIEW

Multiple studies have investigated channel hydrology and the relationship to dimension, pattern, and profile while other studies have investigated the relationship between environmental attributes and riparian plant communities. However, few studies have attempted to understand the complex relationship between the environment, the channel, and the associated plant community. In order to improve our understanding and management of these complex ecosystems it is necessary to investigate the system as a whole. Prior research has laid an excellent foundation for designing the next level of inquiry at the ecosystem level.

ENVIRONMENTAL ATTRIBUTES

Climate, defined by precipitation amount and timing along with air temperature, is an important environmental variable that influences riparian plant species distribution. Clearly, climate affects the length of the growing season, moisture regimes, and temperature gradients within different plant communities (Patten 1998, Mitsch and Gosselink 1993). This is especially true for montane riparian plant communities, which often are very diverse due to a mosaic of climatic conditions occurring throughout a mountain range, i.e. cold air drainages, precipitation patterns, and temperature extremes (Patten 1998, Kovalchik and Clausnitzer 2004, Brunsfeld and Johnson 1985).

In east-central Idaho, Brunsfeld and Johnson (1985) observed that cold air drainages complicated *Salix spp.* (willow species) temperature related distribution patterns because cold air drainages exhibit different temperatures than surrounding riparian landscapes. Kovalchik and Clausnitzer (2004) further noted that in eastern Washington, the annual range in precipitation of 10 to 25 inches affected the distribution of willows. In addition, they also described the distribution pattern of other facultative wetland shrubs with associated environmental characteristics. *Alnus viridis* spp. *sinuata* (Sitka alder) distribution patterns were restricted to areas of higher elevation with shorter growing seasons and heavy precipitation, whereas *A. incana* spp. *tenuifolia* (thinleaf alder) communities were restricted to lower elevations with longer growing seasons (Kovalchik and Clausnitzer 2004). *Cornus stolonifera* (red osier dogwood) was distributed throughout eastern Washington in valleys of lower elevations with longer growing seasons (Kovalchik and Clausnitzer 2004).

Macrosite and microsite light intensity additionally is related to the establishment and distribution of woody riparian species. Sacchi and Price (1992) determined that shading significantly reduced seedling growth and survival among *S. lasiolepis* communities. In field experiments seedlings establishment was reduced in shaded plots and in greenhouse experiments shading reduced the seedling growth through decreased allocation of resources to the roots (Sacchi and Price 1992). Walker and Chapin (1986) found that light intensity was associated with the growth of willow, popular, and alder. In their study of primary succession on the Tanana River floodplain in the interior of Alaska, they found that a 30% reduction of light intensity by alder was associated with a 3-10 fold reduction in photosynthetic rate of seedlings. They concluded that shading was not itself the primary variable associated with the reduction of seedling growth, but part of a suite of abiotic and biotic variables (Walker and Chapin 1986).

Soil moisture and soil texture differences within riparian zones have been found to affect willow segregation patterns and survivability (McBride and Strahan 1984, Brunsfled and Johnson 1985). Brunsfeld and Johnson (1985) determined that willow community dominance shifts occurred in relation to the soil characteristics of soil aeration, moisture content, and temperature. Kovalchik and Clausnitzer (2004) observed this relationship within riparian communities dominated by willow, alder, and red osier dogwood. They observed that willow communities were abundant on mineral or organic soils deposited on fluvial areas, whereas alder communities were closely associated with mineral soils only, and red osier dogwood communities were associated with loam soils of active fluvial surfaces. They also observed that certain species have specific associations with different components of the soils; for example, *Salix candida* and *S. maccalliana*, were associated with calcareous soils, while thinleaf alder was restricted to organic soil when associated with skunk cabbage (*Lysichiton americanus)* and sedges (*Carex scopulorum)* (Kovalchik and Clausnitzer 2004).

In a study in British Columbia, Teversham and Slaymaker (1976) found that *S. lasiandra* was associated with medium fine sediment areas with relatively good drainage, while other *Salix* species (*S. mackenziena, S. sitchensis)* associated with sandy and coarse sediment areas. However, *S. mackenziena, S. sitchensis* were overtaken by other trees along forest reaches and were lost from the system. Finally, McBride and Strahan (1984) determined from a study of seedling survival and establishment that the germination of willows seeds of *S. exigua* and *S. laevigata* Bebb. were most successful on sandy areas of gravel bars due to the longer period of moisture availability compared to the gravel bars.

Elevation also has been found to affect woody riparian plant distribution. Webb and Brotherson (1988) in southwest Utah found elevation gradients along three tributaries of the Virgin River to be associated with woody riparian species distribution. *S. exigua* and *S. gooddingii* were located at lower elevations (780-1430 m); *S. laevigata* (780-1560 m) and *S. lasiolepis* (1250-1340 m) dominated mid-elevations; and *S. bebbiana* (2000-2090 m)*, S. lutea* (1900-2000 m), and red osier dogwood (1350-2090 m) dominated higher elevations. A similar study done in northeast Oregon by Lytjen (1999) found that willow and other woody riparian species were distributed along a longitudinal gradient, where *S. boothii, S. bebbiana, S. exigua* and *S. melanopis* dominated reaches with elevations between 1000 m to 1050 m and *S. sitchensis* and *S. scouleriana* dominated mid-elevations reaches from 1050 m to 1760 m. Kovalchik and Clausnitzer (2004) found that Sitka alder and thinleaf alder preferred elevations between 790 m and1402 m depending on the climate and plant associations. Lytjen (1999) also found that *Alnus* species were distributed along elevation gradients; thinleaf alder dominated areas with elevations between 988 m to 1670 m and Sitka alder dominated areas with elevations between 1150 m to 1800 m. In addition, Lytjen (1999) found red osier dogwood to be present at elevations ranging between 988 m to 1524 m.

Bendix (1994) studied the relationship between vegetation patterns and elevation, stream power, stream width, and fire, to determine if any of these parameters were associated with vegetation distribution. It was determined through ordination analysis and classification techniques that four vegetation groups clustered along the ordination axes; axis one elevation and stream power; axis two fire, valley width, and stream power (Bendix 1994). The author concluded that elevation was the determinant characteristic responsible for describing species-environment interactions at the landscape scale while the remaining environmental variables became significant only within elevation ranges. Therefore, the influence of elevation must be determined and factored out in order to understand the role of site-specific characteristics.

Valley morphology is a primary attribute used in stream classification (Rosgen 1996). Crowe and Clausnitzer (1997), described shrub communities of northeast Oregon in relation to elevation, valley width, valley gradient, sideslopes, and Rosgen's stream type. For example, *Salix lucida* communities were found on the Grande Ronde River within valleys with average gradients of 1% and widths equal to or greater than 200 m whereas, *S. communtata* and *S. eastwoodiea* communities were located in valleys with average gradients of 5% and widths equal to or greater than 95 m (Crowe and Clausnitzer 1997). It was further determined by Kovalchik and Clausnitzer (2004) in eastern Washington that willow abundance increased as valley gradient declined and valley width increased. Alder species were also distributed in relation to valley geomorphology with *Alnus incana* spp *tenuifolia* located in low gradient valleys wider than 99 feet, and *A. viridis* spp. *sinuata* in moderately narrow valleys with steep gradients.

Climate, elevation, soil, and landscape form are environmental variables that relate to the pattern and distribution of woody riparian species. However, there is limited research addressing the importance of these species-environmental associations to the riparian function of mountain streams.

GEOMORPHIC SURFACES AND STREAM ENERGY

Stream energy continuously changes from the headwaters to the mouth and from the streambed to the stream walls. Furthermore, stream energy shapes patterns of erosion, sedimentation, and vegetation distribution (Morisawa 1968). Stream energy distribution and force shape landforms thereby influencing woody species distribution within fluvial riparian areas. Lytjen (1999) attributed the lateral gradient of woody riparian species to the streamflow's influence on the morphology of the riparian area and vegetation communities. *Salix* spp. were found to be associated with fluvial surfaces with a 1 to 3 year flood return interval. These surfaces typically were located below the lower limits of perennial herbaceous vegetation. However, *Alnus* spp. were found only on surfaces flooded annually (Lytjen 1999).

In a similar study, Hupp and Osterkamp (1985) defined four fluvial landforms based on water surface elevation: deposition bars, channel shelf, floodplain, and terrace. The authors tested the hypothesis that hydrogeomorphic processes operating on landforms were of primary importance to riparian vegetation distribution. They determined that of 60 woody riparian species present in the bottomlands, 22 species were significantly related to fluvial landforms with *Alnus serrulata* and *Salix nigra* dominating deposition bars and channel shelves (Hupp and Ostrekamp 1985). Furthermore, Bendix (1999) addressed vegetation distribution patterns in relation to unit stream power and water table depth. From the study of woody riparian species in California, he found a strong relationship between stream power gradients and woody riparian plant distribution with *A. rhombifolia* located in high power locations and *Salix spp.* located in intermediate stream power locations.

STREAMFLOW INUNDATION

Riparian species composition, establishment, and survival have also been linked to the timing of stream flows, volume of flow, and inundation periods (Patten 1998, McBride and Strahan 1984, Ohmann et al. 1990). Ohmann et al. (1990) studied the response of *Salix spp.* and *A. rugosa* (Du Roi) Spreng. seedlings to periodic inundation periods. They determined that willow productivity was adapted to flooding while vigor was maintained through inundation periods of up to 60 days (Ohmann et al. 1990). The authors further determined that *A. rugosa* was sensitive to flooding inundation periods in excess of 30 days (Ohmann et al. 1990). Furthermore, Kovalchik and Clausnitzer (2004) found *Cornus stolonifera,* to be a component of montane riparian areas characterized by moist soil conditions, periodic overbank flows, and well-drained and aerated soils. Teversham and Slaymaker (1976) studied vegetation composition along a floodplain of a river in southern British Columbia, where they observed species groupings to determine indicator plants for predicting flood frequency. The authors found species distribution correlated with floodplain elevation and surface sediments with *Salix* species and *Alnus rubra* correlated to riparian areas with sand or fine sediment on the surface and a flood frequency between 30 and 84 days per year (Teversham and Slaymaker 1976).

STREAMFLOW TIMING

The life history of woody riparian species, such as *Salix* and *Alnus* are adapted to and influenced by the fluctuation in stream flow patterns (Karrenberger et al. 2002). Rood et al. (2003) found that recruitment and persistence of woody riparian species was significantly associated with instream flow patterns and hydrographs. They observed that seed dispersal typically occurred after peak flows, followed by a receding soil moisture rate of about 0.5 cm a day, which they concluded allowed for the successful establishment and root growth of woody riparian species (Rood et al.. 2003). In addition, McBride and Strahan (1984) studied the survival and establishment patterns of woody riparian species on gravel bars. They concluded that *Salix laevigata* and *S. exigua* dispersal and germination occurred in late May and early June. During these months, sandy portions of gravel bars were exposed and moist, leading to successful germination and seedling survival. They also observed *Alnus rhombifolia* and *Salix spp.* sapling cohorts greater than 2 years of age survived and increased in density regardless of high flow disturbance events (McBride and Strahan 1984).

In addition, Harris (1987) observed vegetation distribution zones in active floodplains of California, where plant community zones of survival were related to different levels of flood disturbances. He observed 17 trees, 15 shrubs, and 53 herbaceous species and recorded their cover and occurrence on geomorphic surfaces, which received different levels of flood disturbance. *Salix exigua* and *Populus fremontii* dominated sites with frequent and high-energy disturbances at flood elevations between 1-4 m above the stream channel bottom and a distance of 10-25 m from the stream on gravel/sandy soil surfaces. He noted that the annual flood frequency elevation was about 2.7-3.0 m above the stream channel bottom, which may have encouraged vegetative reproduction of *S. exigua* within high energy level zones, through broken stems and roots. Furthermore, *S. exigua* also dominated sites characterized by low energy disturbances within a cohort of other dominant tree species, *Junglans hindsii, Quercus lobata, Vitis californica, and Artemisia douglasiana* (Harris 1987). The diversity of *S. exigua* communities may be a function of its rhizomatous growth form and ability to sprout from broken stems (Karrenburg et al. 2002).

A study done in Arizona by Lite et al. (2005) concluded that woody species distribution was related to water availability, flow permanence, and floodplain width. They observed longitudinal and lateral gradients of floodplain tree and shrub species (*Populus fremontii, Salix gooddingii, Tamarix ramosissima, Baccharis salicifolia, Hymenoclea monogyra,* and *Ericameria nauseousa)* to determine if the richness of the species varied along these gradients. Along longitudinal gradients, the richness of woody riparian species increased with increasing stream flow permanence, floodplain width, and decreasing elevation above the channel. Increased species richness on the lateral gradient was associated with decreased depth to water table and decreased elevation above the channel along with increased inundation frequency and canopy cover (Lite et al. 2005).

Physiological and phenotypic differences among species create a mosaic distribution based upon specific tolerance levels to declining water availability (William and Matthews 1990). Williams and Matthews (1990) compared *Salix* *laevigata* and *S. lasiolepis* survival to declining water tables depths. They observed that *S. laevigata* was more tolerant of increasing depth to the water table than *S. lasiolepis*, which they attributed to physiological traits of increased stomatal conductance and increased rates of photosynthesis and evapotranspiration exhibited by *S. laevigata* (Williams and Matthews 1990). Additionally, Amlin and Rood (2002) compared *Salix* spp. and *Populus* spp. seedling response to declining water table depths. They concluded that *Salix* spp. exhibited a more vulnerable response to abrupt water table declines. *Salix* spp. exhibited lower rates of root elongation than *Populus* spp. explaining the lower survival of *Salix spp.* with abrupt water table declines (Amlin and Rood 2002).

Stream flow quantity, timing, and floodplain accessibility are variables that relate to the pattern and distribution of woody riparian species. However, in high elevation channels ice floe occurrence has also been found to affect riparian plant community composition and distribution (Smith and Pearce 2000 and McBride and Strahan 1984).

ICE FLOES

Ice floes have been found to influence ecosystem structure by limiting woody riparian plant species establishment. Along two streams in northern Sweden, Nilsson et al. (1989) observed that total species richness was correlated to substrate heterogeneity, which was related to the degree of ice scour. The authors concluded that ice action created spatial heterogeneity in vegetation patterns directly through physical disturbance to the vegetation and indirectly through disturbance to channel morphology (Nilsson et al. 1989). McBride and Strahan (1984) studied survival and establishment of woody riparian species on point bars where they observed that ice scouring was an important factor positively correlated to seedling mortality. Additionally, Smith and Pearce (2000) determined that ice floes played a critical role in the survival and distribution of cottonwood and Russian-olive saplings and trees along braided channels in cold climates. The authors determined that greater than 94% of the saplings and trees sampled, at four out of the five sample sites, were damaged with ice scars. They concluded that ice damage caused scarring, breakage, and toppling may limit the development of riparian woodlands. Smith and Pierce (2000) concluded that ice floes inflicted greater damage on braided channel systems than meandering channels; however, ice floes have been shown to impact river morphology and plant community composition and distribution regardless of channel type.

CAPABILITY

Private land managers and land management agencies often use the Proper Functioning Condition (PFC) assessment tool to qualitatively assess riparian condition. The PFC assessment is based on three primary categories: stream channel hydrology, riparian soils, and the riparian plant community (Prichard et al. 1993 and Prichard et al. 1998). Riparian function is assessed against the assumed highest attainable stream condition known as potential or capability (Prichard et al. 1993 and Prichard et al. 1998). Prichard et al. (1998) defines potential as the "highest ecological status a riparian-wetland area can attain given no political, social, or economical constraints" (pp. 7). Capability is defined as a status less than potential due to the impact of humans. An initial step of the assessment starts with the development of the reference condition by looking at attributes and conditions along reference reaches. Through current and historic photography, research, and documentation of characteristics such as species present, soils, habitat needs, relict conditions, watershed condition, and limiting factors the reference condition is developed.

Barrington et al. (2001) presented the definitions of potential and capability in context of classifying riparian systems for management. His definition consolidates the understanding of potential and capability by stating that capability is the highest attainable ecological condition given infrastructure constraints. However, the authors failed to provide a tool or quantitative assessment method for defining the reference baseline for riparian capability.

Rosgen (1996) advocated the use of a hierarchical classification system to provide a quantifiable assessment of stream condition based on stream stability, potential, and function. In the hierarchical assessment, channel morphological measurements help to determine departure from a reference baseline of geomorphic characteristics. Rosgen's (1996) reference baseline is derived from measurement of the dimension, pattern, and profile of reference channel reaches. Rosgen (1996) defines potential as the "best channel condition based on quantifiable morphological characteristics" (pp 6.3), therefore, a channel that exhibits characteristics outside the reference baseline is defined as being in an altered condition. His system provides a strong framework, based on physical attributes, for assessing functionally of streams, yet does not provide additional quantitative criteria needed to assess functioning processes that are altered and/or damaged due to infrastructure constraints. Additionally, his system is weak in relating riparian vegetation to stream channel morphology and function, especially for montane woody riparian ecosystems.

Species-environmental relationships in the context of confined rivers was explored by Dufour et al. (2007) who studied the effect of channel confinement on woody riparian species in southeast France. Overall, they found that channel geometry, channel gradient, sedimentation, and vegetative communities were affected by river embankments. Pioneer vegetation units within the embanked reach occurred at higher elevations along the active channel compared to the unconstrained reach, partially due to the disconnect between the channel and floodplain. The containment of channel flow within the channel caused flow related disturbances to occur at higher bank elevations explaining the differences in vegetation locations. Additionally, there was greater pioneer vegetation heterogeneity in units located along the unconstrained reach, which was associated with island development in the unconstrained braided channel (Dufour et al. 2007). This study explains the changes in the spatial pattern of pioneer vegetative communities following introduction of dike infrastructure, however the author's did not address the response of perennial vegetation to the change in channel form. Additionally, the study was along a major river that had been modified by humans for at least the last 300 years.

Research has developed environmental-hydrology-species relationships across a broad range of ecosystems. However, knowledge of the functional status of the riparian areas of the researched streams were rarely mentioned or only summarized based on the plant community as late seral, mid seral, early seral done by Crowe and Clausnitzer (1997). In addition, riparian potential versus riparian capability has not been explored in the context of species-environmental relationships. Further complicating this issue is the lack of measurable criteria for defining riparian capability.

RESEARCH OBJECTIVES AND GOALS

Goals

Investigate the concept of potential versus capability within mountainous channels in northeast Oregon through quantification of species-environmental relationships and measured hydrologic characteristics. Determine methods for quantifying the concept of capability and determining departure from potential.

Objectives

1) Quantitatively describe woody riparian species distribution relative to channel morphology, understory vegetation composition, surface particle characteristics, and microclimate variables over three separate streams.
2) Quantitatively describe woody riparian species distribution and height characteristics relative to channel morphology, understory vegetation composition, surface particle characteristics, and microclimate variables based on defined hydrological flood frequency elevations.
3) Describe stream morphology, flood frequency elevations, and condition based on Rosgen classification, regional curves of channel measurements, and measured morphology and hydrologic characteristics.
4) Describe criteria for quantifying riparian capability based on measured channel morphology attributes and determined species-environmental relationships.

METHODS AND MATERIALS

RESEARCH AREA

Grande Ronde River, North Fork Catherine Creek, and Meadow Creek are located in northeast Oregon near La Grande, Oregon. All three streams are part of the Grande Ronde River system, which flows northeast into the Snake River near the Washington-Oregon border. Two of the three channels are located within the Upper Grande Ronde River Drainage encompassing both the Upper Grande Ronde River Watershed (HUC#5 1706010401) and the Meadow Creek Watershed (HUC#5 1706010402). The third research stream reach is part of the Upper Catherine Creek Watershed (HUC#5 1706010405) a third order tributary of the Grande Ronde River, located south of Grande Ronde Valley.

Physical Environment

The Upper Grande Ronde River drainage is part of the Blue Mountain sub-province of the Columbia River Plateau physiographic province and is characterized with various bedrock types. The prominent rock type is Columbia River Basalt, while portions of the Catherine Creek drainage possess granodiorite, marine sedimentary, and volcanic rock types. The soils of the system are predominantly volcanic ash and residual bedrock derived soils. The elevations within the Upper Grande Ronde River drainage range from approximately 1030 meters to 2200 meters. Elevations within the Catherine Creek drainage range from 700 meters to 2300 meters.

The Oregon Climate Service has three weather stations located near the research areas; La Grande, Ukiah and at the Union Experimental Station (Table 3.1). Mean precipitation records were available from 1971-2000. The annual average precipitation for the La Grande station was 44.4 cm, for the Ukiah station 42.04 cm, and for the Union station, near the mouth of Catherine Creek 36.6 cm. Drainage specific rainfall precipitation data were obtained from the United States Forest Service (USFS), La Grande Ranger District watershed rain gauges located adjacent to the watersheds of interest (Table 3.2; Wallowa-Whitman National Forest 2006).

Table 3.1: Summary of weather stations		
Weather Station	Lat/Long	Elevation
LaGrande	45°19’N/118 ° 04’W	839.7 m
Ukiah	45°08’N/118 ° 56’W	1036.3 m
Union	45°12’N/117 ° 53’W	842.8 m

Table 3.2: Rainfall precipitation for research subwatersheds	
Subwatershed	Rainfall June 2006-August 2007
Grande Ronde River- Tanner Gulch	50.6 cm
Middle Meadow Creek	6.6cm (summer only data)
South Fork Catherine Creek	61.6 cm

Snowmelt hydrographs, with late spring and fall rain events, characterize the nature of stream flow within the Upper Grande Ronde river system. Peak flows occur in March and April with baseflow occurring in August. During the winter, most of the large streams in the system have the potential to develop ice, which can lead to large ice flow events.

Study Sites

Three stream reaches of the Grande Ronde River system (Table 3.3) were selected based on the following selection criteria; presence of woody species, proximity to stream gauging station, accessibility, and importance for management. All three stream reaches were located within the Wallowa-Whitman National Forest.

Table 3.3- Summary of drainage area for research streams. Bolded abbreviations for statistical analysis	
Stream	Drainage Area (mi2)
Grande Ronde River (**GRR**)	39.7
Meadow Creek (**MDW**)	48.6
NF Catherine Creek (**NFC**)	33.9

The Upper Grande Ronde River (GRR) stream reach was located near the headwaters of the Grande Ronde River in the Elkhorn Mountains (reach elevation 1370 m). Located approximately 30 km southwest of La Grande is the Starkey

Experimental Forest where the Upper Meadow Creek (MDW) stream reach was located (reach elevation 1260 m). The third research stream reach was located southeast of La Grande, Oregon, along North Fork Catherine Creek (NFC), which originates on the western slopes of the Wallowa Mountains (reach elevation 1130 m).

Historically, the Upper Grande Ronde River system has been subjected to numerous human induced activities, which have altered the riparian systems. All three study reaches have a history of human disturbance including logging, splash dams, railroads, mining, livestock grazing, vegetation removal, and road construction. Specifically, North Fork Catherine Creek is confined by Forest Service Road 7785 and diked to prevent flooding; Upper Grande Ronde River is bordered on the right bank by historical roads and campsites and Meadow Creek has numerous morphological constraints created by previous human influence (i.e. logging and splash dams). North Fork Catherine Creek and Meadow Creek are contained within active livestock allotments. Additionally, all three research streams provide wildlife habitat for a variety of species, specifically deer, elk, and beaver.

In the late 1800's, homesteaders and exploration surveys described the Upper Grande Ronde River system, near the city of La Grande, as being abundantly lined with willows and cottonwoods (Beckham 1994, Duncan 1998). Crowe and Clausnitzer (1997) list *Populus balsamerifera* and *Salix lucida* associations as dominant within the Blue Mountains Ecoregion, especially along Rosgen "C" type channels. Crowe and Clausnitzer (1997) further document Rosgen "B" channels in the Blue Mountain Ecoregion, as having associations of *Salix*, *Alnus,* and *Cornus* species as the dominate shrub species. *Ribes* spp., *Populus* spp, and *Acer glaberatum* were also present, along with coniferous species of *Abies, Pseudotusga, Pinus, Larix,* and *Picea.*

Stream Gauges

The USFS in cooperation with the Oregon Water Resources Department, the Grande Ronde Model Watershed, Union County, and the Bonneville Power Administration established five stream flow gauging stations in 1992 along five tributaries of the Grande Ronde River: North Fork Catherine Creek, Five Points Creek, Grande Ronde River at Woodley, Upper Meadow Creek (in Starkey Experimental Forest), and Lower Meadow Creek. Data from the North Fork Catherine Creek Gauge (#13319900), Grande Ronde River at Woodley Gauge (#13317850), and the Upper Meadow Creek Gauge (#13318060) were utilized within this study. The gauge stations were located within the study reach at Meadow Creek and North Fork Catherine Creek and 2 km upstream of the Grande Ronde study reach.

Discharge data from 1993-2006 water years was used for flood frequency calculations for each stream reach. The gauge stations provided a continuous record of surface water elevation, known as stage, from which continuous measurements of discharge were calculated. The stage and discharge data were obtained from the Oregon Water Resource Department, the agency responsible for management of the stream gauge data. The Oregon Water Resource Department stated that ice floes affected the stage-discharge relationship, thus periods of ice were estimated from previous discharge records, weather data, observations, and nearby basin discharge records before the publication of the stream discharge data. A United States Geological Survey (USGS) permanent gauge station was used for this specific study for verification of flow data on Catherine Creek, near the town of Union, which is approximately 25 miles downstream of the North Fork Catherine study reach.

EXPERIMENTAL DESIGN

Each stream reach (Meadow Creek, Upper Grande Ronde, and North Fork Catherine Creek) used in the study was determined visually based on woody species present, proximity to a gauging station, Rosgen classification, and infrastructure constraints. In order to determine if a relationship existed between species and one or more of the measured physical or environmental attributes of the stream reaches multivariate statistics were utilized. Nonmetric Multidimensional Scaling (NMS), Multi-Response Premutation Procedure (MRPP), and Indicator Species Analysis (ISA) were used to evaluate the species-environmental relationships. MRPP and ISA were used to evaluate group differences based on species composition, while NMS was used to determine environmental gradients and their relationship to species composition. The multivariate analysis included three matrices. The environmental matrix consisted of the environmental attributes temperature and light intensity and the physical attributes of channel morphology, flow regime, and particle composition. Also included in the environmental matrix were the measurements of understory vegetation composition and overstory canopy cover. The community matrices consisted of the woody riparian measurements of density and height. The matrices were analyzed at two different levels of hierarchical structure; the transect level and the flood-zone level. The transect measurements and flood zone delineation are discussed in the following sections.

Field Sampling Methods

Data collection was completed over two consecutive summers from June 2006 to September 2007. In 2006, data collection included plot setup, channel morphologic measurements, hydrologic calculations, and environmental stream characteristics while vegetation measurements were taken in summer 2007.

Seventeen channel cross section transects (referred to as physical transects) were located 50 meters apart, starting at a random distance from the beginning of the stream reach. Each transect was established perpendicular to stream flow and stretched the length of the floodprone width. The physical transects were used to measure channel morphology. Seventeen transects were used to meet the recommended number of sample units for multivariate analysis (McCune, personal communication January 2007). At Meadow Creek and Grande Ronde River, the study reach was bisected by constructed and natural wood jams. The debris jams created a different hydrologic regime, thus presenting a non-representative region of the stream reach; therefore, this portion of the stream reach was eliminated from the sampling area prior to transect placement.

The physical transects were divided into left and right bank units resulting in 34 sample units per channel. This was done to reduce the variation caused by differences in fluvial surfaces. Left and right bank were determined facing downstream. Each of the 34 physical sample units was paired with the vegetation transects for the purpose of species analysis at the transect level. Vegetation transects stretched the length of greenline to floodprone on left and right bank. Measurements of understory composition, surface particle composition, and overstory canopy cover were taken along each of the vegetation transects. Woody riparian species density, height, and ice scarring were sampled in vegetation belt transects. Belt transects stretched from greenline to floodprone placed over the vegetation and physical transects. When the belt width consisted of different fluvial surfaces, the belt was placed over the dominant fluvial surface.

Each of the vegetation and belt transects was subdivided into three flood zones for species analysis at the flood-zone level resulting in 102 sample units per channel. The zones were determined from flood discharge calculations. The designated flood zones were greenline to bankfull, bankfull to 25-year flood elevation, and 25-year flood elevation to floodprone. The first flood zone, greenline to bankfull, ran from the first perennial line of vegetation to the channel forming flow, which has a flood return interval of every 1.5 to 2 years (Rosgen 1996). The second flood zone represented the fluvial surface influenced by high frequency flood events ranging from bankfull to the 25-year flood elevation, which represents the flood event assumed to be the size of flood that a proper functioning riparian ecosystem can withstand without unraveling (Pritchard et al. 1998). The final zone, 25-year flood elevation to floodprone, represented the farthest horizontal fluvial area of the active streamflow influence on the current day landscape. Figure 3.1 displays the difference between the physical, vegetation, and belt transects.

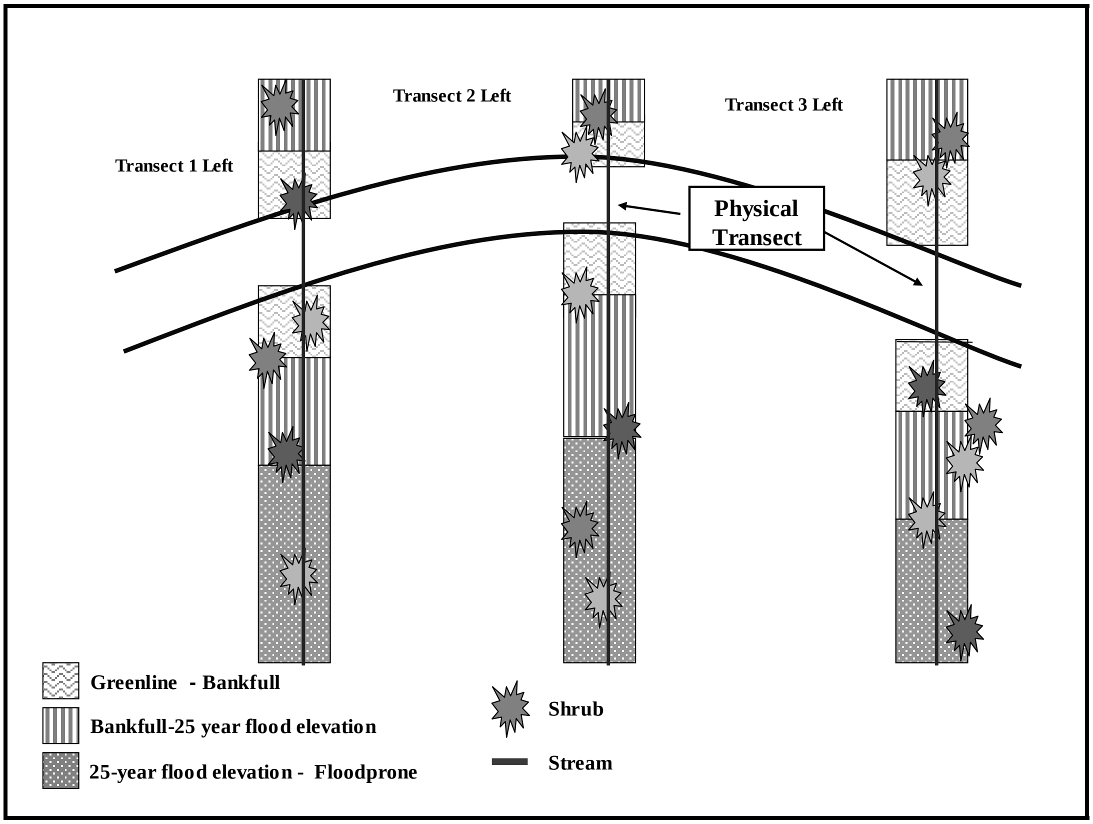


Figure 3.1: Model of field sampling with three transects. Physical transects are depicted as lines stretching the floodprone width. Vegetation transects are the lines, only the width of greenline to floodprone width on each bank. Belt transects (shaded boxes) stretched from greenline-floodprone width on each bank. The divided vegetation transects and belt transects represent the flood zones.

Rosgen Hierarchical Classification

Rosgen hierarchical classification method was used for measurements of channel morphology. Rosgen's (1996) classification system is based on a hierarchical assessment of stream dimension, pattern, and profile. The morphological attributes measured were used to describe the physical environment of each stream reach and provided a quantitative mechanism for assessing the three stream reaches against regional stream reference data for the purpose of determining departure from potential.

A Rosgen Level I stream type determination was completed in the office by measuring valley slope from topograghic maps and channel sinuosity from aerial photos. A Rosgen Level II assessment was conducted at each stream reach to verify the Level I determination of stream type and included the morphological characteristics listed in Table 3.4. All channel transects located within straight reaches were surveyed and utilized in the determination of channel type.

Table 3.4: Channel Morphology Measurements
Bankfull width
Channel particle composition
Channel slope/ Bankfull slope
Entrenchment
Floodprone width
Sinuosity
Stream section (riffle/pool)
Valley width
W:D (width to depth) ratio

The three streams were assigned a Rosgen stream type (A1-A6…G1-G6) based on the measured morphological attributes of the physical transects.

Channel Physical Attributes

Longitudinal profiles, stream sinuosity, channel cross-sections, and channel materials were measured following the protocols described by Harrelson et al. (1994) and Rosgen (1996). Flood elevations were determine from stream discharge data, using Log Pearson Type III probability to calculate flood frequency. The channel physical attributes used to determine environmental gradients and relationship based on the species composition are listed in Table 3.5.

Table 3.5: Channel Physical Attributes
Valley width
Bankfull width
Floodprone width
25-year flood elevation width
Entrenchment
W:D (width to depth) ratio
Channel bottom slope
Sinuosity
Stream section (riffle/pool and straight/corner)
Channel material composition (D50)

Longitudinal Profile

Longitudinal profiles were measured to determine reach length, bankfull elevation, channel bottom elevation of important features (pools and riffles), average bankfull slope and channel slope. The longitudinal profile length was determined to be a minimum of 20 times the channel width at bankfull (Rosgen 1996) or long enough to contain 85 percent of the cross section transects sampled. Bankfull height was determined from hydrologic data and channel form indicators. Table 3.6 lists the physical attributes that were obtained from the longitudinal profile.

Table 3.6: Longitudinal Profile Attributes
Average bankfull slope
Channel bottom profile
Channel slope
Riffle/pool ratio
Stream length

Stream Pattern

In order to determine if species distribution was related to measurements of channel sinuosity and valley width, stream pattern measurements were collected using a Trimble Pathfinder Pro© Global Positioning System (GPS) unit with sub-meter resolution and ArcGIS™ measuring tools. Points were taken at each physical transect, at meander bends within the stream reach, and at the beginning and end of the research stream reach. Length and width measurements were determined through ArcGIS™ software using the GPS points and aerial photos. Sinuosity was calculated by dividing the stream length within two-meander cycles by the valley length. In addition to the pattern measurements, deposition features were visually determined at each reach using Rosgen's (1996) categories for deposition patterns and mid-channel bars. This assessment was used for the description of stream condition and departure for the reference baseline.

Channel Cross Sections

Channel cross section surveys were completed at each physical transect, from floodprone of left bank (looking downstream) and extending to floodprone on right bank using laser and pole methods. Descriptive points such as elevation change, bankfull, floodplain, wetted edge, and flood return interval elevations were indicated. Table 3.7 provides the physical attributes obtained from the cross-section surveys and Figure 3.2 depicts a visual example of cross-sectional data. In addition, cross sectional areas at bankfull, floodprone, and flood elevations along were determined using WnXSPro software (Hardy et al.2005).

Table 3.7: Cross Section Attributes
Bankfull depth
Bankfull lateral distance
Bankfull width
Cross sectional area
Entrenchment ratio
Flood elevations (5, 10, 25, 50 years)
Floodprone area/width
Mean depth
W:D (width to depth) ratio

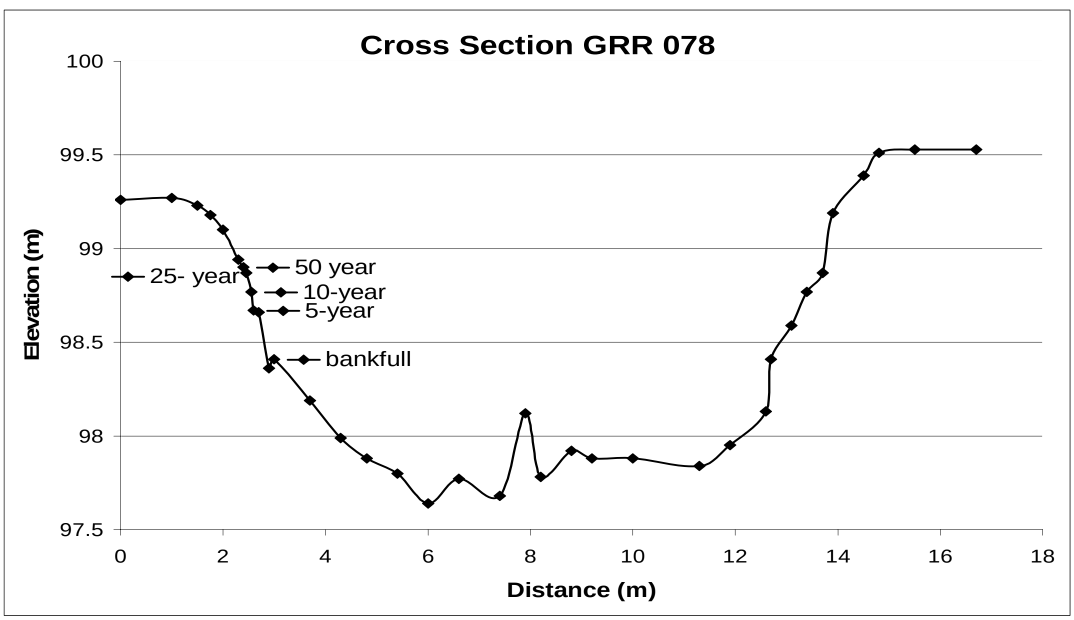


Figure 3.2: Diagram of transect cross section, flood elevation breaks labeled on left bank. Elevations are marked on right bank (looking downstream).

Flow Frequency Analysis

For all research sites, stream discharge data (1993-2006) from the three gauge stations were used for flood frequency calculations. The flood frequency values for bankfull flow and for 5, 10, 25, and 50-year events were calculated to define a range of flood events. Flood frequency discharges were calculated using Log-Pearson Type III calculations in Mircosoft Excel (Interagency Advisory Committee 1982) with a tutorial developed by OSU Civil, Construction, and Environmental Engineering Department (Klingeman 2002).

Stream discharge data were available for water years 1993-2006, which were used for flood return frequency calculations. Though the flood return intervals of 25-years and 50-years cannot accurately be displayed in thirteen years of data, the data were utilized to calculate the flood event's discharge. The calculated discharge values for the 25-year and 50-year flood events were used to provide current and measured values of discharge. These discharge values were determined following the flood frequency methods and were crosschecked with drainage area calculations. Fifty- year discharge values varied greatly from the flood frequency calculation and drainage area calculation; therefore, 25-year flood discharge was the greatest flood discharge used for species and physical analysis.

North Fork Catherine Creek Gauge was replaced several times from 1993-2000 due to ice damage, which skewed several years of data. Therefore, the gauge station on Catherine Creek near Union, Oregon was used to determine the flood return discharges for North Fork Catherine Creek. Flood return discharges were first calculated with data from the gauge station near Union. The flood return event at the gauge station near Union was assumed to correspond with the stream discharge events at North Fork Catherine Creek. Thus, the date of the discharge at the gauge station near Union was used to determine the date and discharge of the flood event at North Fork Catherine Creek.

For all research streams, bankfull and flood return elevations were cross-checked with physical evidence along the stream (Harrelson et al. 1994) and drainage area calculations based on the Eastern Oregon formula supplied by USGS (Cooper 2005). The flood return discharge calculations based on drainage area were high compared to the gauge station discharge values. However, the gauge discharge values were within the range of 95% variability of the drainage area calculations; therefore, gauge discharge values were used.

Bankfull elevation was used for determination of species-environmental relationships and for stream classification. Bankfull height was determined based on flood frequency calculations using the discharge of 1.5 and 2 year flood events. Additionally, the hydrograph of water years 1993-2006 were used to determine the bankflow event at 1.5-2 year events. This information was crosschecked in the field based on bankfull indicators used by Harrelson et al. (1994). The bankfull elevation used in each cross section and longitudinal survey was the elevation determined by the preponderance of evidence from the calculations, hydrographs, and the channel indicator observations.

Flood event elevations were determined from the calculated flood event discharges and the cross sectional area measurements related to each flood event discharge utilizing WinXSPro software (Hardy et al. 2005). The stage height associated with each flood event was projected onto the channel cross-section for determination of flood-zone elevations and widths (Figure 3.3). The flood event elevations and widths were first calculated at each gauge station and then extrapolated to each surveyed transect, based on the assumption that flood discharge would be the same along the study reach. This technique was repeated for each flood event discharge at each cross section along a stream, assuming there were no significant streamflow inputs or outputs.

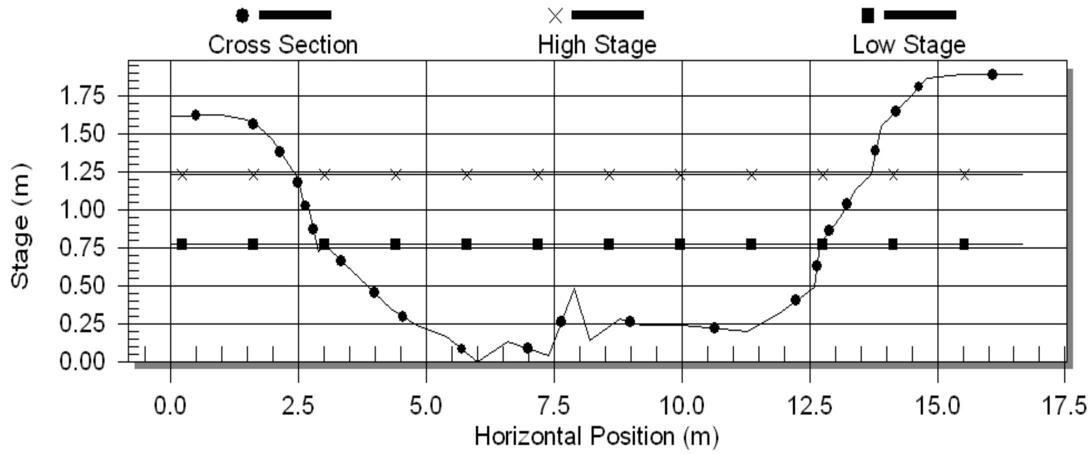


Figure 3.3: WinXSPro output of cross section GRR 078, "x" line represents the stage of 25-year flood elevation, ■ line represent bankfull elevation, ● line is the surveyed cross section.

Particle Distribution

Stream and fluvial surface particle distribution was measured using two separate techniques. For the first method, stream channel particles were measured using a gravelometer particle sieve from bankfull to bankfull along the physical transects, following the Wolman Pebble techniques (Wolman 1954 and Harrelson et al. 1994). Ten transects were randomly selected from the 17 physical transects based on the percentage of transects bisecting riffles and pools (Rosgen 1996). A gravelometer particle sieve was utilized to measure particle size from bankfull to bankfull for a 100 measurements of particle size. The 100 particles were randomly sampled using a heal-toe, zig-zig sampling method (Harrelson et al. 1994).

The pebble composition of the stream channel particles was summarized into four size classes: D35, D50, D84, D95 (Table 3.8). Percent composition of bedrock and fines (less than 6 mm) were also determined from pebble surveys. The four size classes represent the percentage (35, 50, 84, and 95) of the sampled population equal to or finer than the particle diameter (Rosgen 1996). The median particle size (D50) represents the dominant particle size; this value was used for data analysis. The D50 particle diameter class was further classified as a particle type of sand, gravel, cobble, or boulder, for four defined groups in statistical analysis. Grande Ronde River and

Meadow Creek stream reaches were broadly classified as very coarse gravel (45-60 mm), while North Fork Catherine Creek was classified as small cobble (64-90 mm) based on particle size classes presented by Harrelson et al. (1994).

Table 3.8: Channel Material Particle Size

Stream	Fine<6mm	D35	D50	D84	D95	% Bedrock
GRR	17.30%	21.93 mm	43.61 mm	202.29 mm	433.77 mm	0.27%
MDW	14.28%	28.49 mm	45.71 mm	522.45 mm	830.79 mm	1.70%
NFC	3.87%	60.18 mm	87.72 mm	229.99 mm	387.81 mm	0.09%

In the second method, fluvial surface particles were measured from greenline-floodprone along the vegetation transects, utilizing line-point intercept sampling adapted from Elzinga et al. (1998) and Coles-Ritchie (2006). Points were measured every 0.2 m unless there were six consecutive mineral soil (MS) readings, then increments were increased to 0.4 meters. If the MS was 50% or more of the data per flood zone interval, the soil was textured, to provide a description of the soil type within the flood-zone community. Soil texture followed the protocol of National Soil Survey Center (Schoeneberger et al. 2002). Surface particles were summarized as percent cover of boulder, gravel, cobble, sand, or mineral soil (Harrelson et al.1994). Soil texture data were used as a site descriptive value and was not used in species-environmental relationships.

Stream Environmental Attributes

At each stream reach, air temperature and light intensity was measured using Onset© Temperature and Light Intensity Pendant HOBO© loggers. Three loggers at each stream were randomly placed, along the study reach, in an open area near a shrub thicket. Hourly minimum, maximum, and average temperature (degree Celsuis) was recorded from June 2006 through September 2007. Light intensity (lums/ft^2) readings were recorded every 30 minutes over the same time span. Data were downloaded every 75 days to maintain equipment condition and data accuracy.

Data from the nine dataloggers was averaged to produce a minimum, maximum, and average air temperature for each research stream. Mean minimum monthly temperatures were calculated from June 2006 to September of 2007. The data were then summarized by calculating the number of days where the daily minimum temperature average over the stream was below freezing. The number of days below freezing during the period of dormancy was used for species analysis. Dormancy was determined to be September 1st to May 1st. The dormancy ran from the month of recorded continuous freezing (September) to the month recorded continuous days above freezing (May). September showed a sharp increase in days below freezing and the majority of May was above freezing (Appendix A). The loggers recorded temperatures as low as -5°C thus temperatures below this level were not accurately represented. Periods of temperatures colder than - 5°C were used for the calculation of days below freezing and mean monthly temperature. However, the mean monthly temperature during period of freezing may be skewed, representing a higher mean monthly temperature.

Light intensity data were summarized by calculating the average number of hours per day of positive light intensity (Appendix B). Monthly average hours per day of light were calculated for each research stream. The monthly sums of hours per day of light intensity were calculated. The month sum for September and May were used for species analysis, which corresponded to the period of dormancy.

Vegetation Composition

Reconnaissance of the potential study reaches began in the spring of 2006. Samples of pistillate and staminate aments and vegetative features were collected from spring of 2006 through summer of 2007 for species identification using Intermountain Flora Volume Two Part B: Subclass Dilleniidae (Holmgren et al. 2005). Individual plants were flagged and numbered for vegetative sampling in the summer of 2007. Willow species identification was difficult due to species hybridization and a lack of key identification features on a number of plants; therefore, the species were named based on the preponderance of evidence. Appendix C contains a list of species present at the three research streams. *Ribes* spp. and *Rubus* spp. were identified to the genus level, whereas other plants were identified to species or subspecies level.

Vegetative community composition was measured during June 2007 to August 2007, while overstory canopy cover was measured over a two-week period in August 2007. Plant community composition was assessed using plant population measuring techniques of the Bureau of Land Management (Elzinga et al. 1998 and Herrick et al. 2005), riparian vegetation measurements adapted from United States Forest Service-PIBO (Coles-Ritchie 2006), and overstory canopy cover techniques of Kelley and Krueger (2005).

Understory composition and cover

Understory composition was measured using line-point intercept techniques along the 102 vegetation transects. Vegetation basal cover and foliar cover were gathered following methods adapted from Elzinga et al. 1998. The tape stretched from greenline to floodprone. A point measured every 0.2m beginning at greenline. At each point a pin was dropped, the first hit was foliar cover and the last hit was basal cover. Foliar cover was recorded as either absent or by the life form categories of grass, sedge/rush, forb, or shrub. Data were summarized by category and divided by the total hits of all categories for each flood zone and vegetation transect. Basal cover was recorded in the following categories: bareground, rock, moss, litter, wood, grass, sedge/rush, or forb. Data were summarized by category and divided by the total hits of all categories for each flood zone and vegetation transect. Percent cover was rounded to three significant figures. Each category of foliar cover and basal cover were assigned to a cover classes for species analysis in each flood zone and vegetation transect. Table 3.9 displays the class delineations adapted form Daubenmire cover classes (Daubenmire 1959).

Table 3.9- Cover Classes

Class	**Cover**
0	Absent
1	1-5%
2	5-25%
3	25-50%
4	50-75%
5	75-95%
6	95%>

Overstory Cover

Overstory cover was measured with a spherical convex densitometer Model A during a two-week period in August 2007 following the protocols established by Kelley and Krueger (2005). Densitometer readings were taken at bankfull and fifteen meters horizontal from greenline on the 34 vegetation transect per stream. Fifteen-meter canopy cover readings were taken to provide an estimate of canopy cover within the floodprone area. At each location, bankfull or fifteen-meters, four densitometer readings were taken facing north, south, east, and west. The four readings were averaged providing one value of canopy cover for each location, for a total of 34 bankfull and 34 fifteen -meters reading per stream. The average canopy cover, at bankfull and fifteen-meters, was calculated from the 34-densitometer readings per stream.

Density

Woody riparian species density was measured within the 34 belt transects, per channel. Belt width at each stream was determined by randomly choosing six corresponding belt transects of the 34 transects and testing belt widths of 3, 4 and 6 meters. Data from the six belt transects were summarized and the appropriate belt width for sampling was determined by the asymptotic limit of species per unit area. Table 3.10 displays the belt widths used at each stream.

Table 3.10: Belt widths used for density counts

Stream	Belt Width (m)
GRR	6
MDW	4
NFC	3

Individual plants rooted within the belt transect were recorded by species with the exception of the clonal species *S. exigua* and *S. melanopis* where individual stems were recorded. It was characteristic of many of the species to form clumps, so an individual plant was counted based on the distance of separation between the plant bases. Plant base separations greater than 10 cm (approximant width of observer's hand) were considered a separate individual.

Species density was counted within one meter increments along the belt transect starting at greenline. Species counts were divided by the area for density calculations. Species density was calculated for each flood zone to test flood zone differences. Density was also calculated for each belt transect to test transect and stream differences. Density classes were established for the purpose of statistical analysis (Table 3.11).

Table 3.11- Shrub Density Classes

Class	Density
0	Absent
1	0.0-0.1
2	0.1-0.5
3	0.5-1
4	1-5
5	5-10
6	10+

Species Height Distribution

Species height was measured within the belt transects at one meter increments. The height classes for each species were recorded based on the height class categories adapted from Coles-Ritchie (2006; Table 3.12). Height class delineation was based on the range of height of each species within the one-meter increments of the belt.

Table 3.12- Species Height Classes

Class	Height (m)
1	0-0.5
2	0.5-1
3	1-2
4	2-4
5	4-8
6	> 8

Height classes were summarized per flood zone based on the density of each species height class. The formula used for height class calculations was:

$$\frac{H_1 * D_1 + H_2 * D_2 + H_3 * D_3 + \ldots}{S}$$

H=height class, D= density of species of a specific height class, S= sum of species in flood zone

Ice Scarring

Shrubs located within the belt transects were visually inspected for ice scars and presence or absence data were recorded. Scaring from ice floes was typically found on the streamside of the shrub and parallel to the ground. Presence or absence of ice scars were summarized by flood zone.

Assessment of Capability and Potential

For this project, capability was defined as the highest riparian condition where the effective floodplain was constrained by an infrastructure. A stream at potential was defined as the highest riparian condition of a stream void of human imposed constraints, which was able to access the floodplain and within its hydrological feature—floodprone. The riparian condition was assessed utilizing the channel morphology measurements of the three research streams. The determination of riparian condition was evaluated visually and quantitatively against Rosgen (1996) morphological classifications and regional morphology curves. Rosgen criteria for channel morphology and the regional measurements of morphology were the measurements of riparian potential.

The first assessment was the observation of human imposed constraints on each of the channels. Infrastructures, both present and historical, were evaluated by documenting type, location to the channel, current condition of infrastructure. If an infrastructure was present and constraining functioning processes of the stream, the stream was considered for capability. If the stream was void of constraints, then it was considered for potential.

The second assessment was the initial observations of channel sinuosity, valley confinement, valley bottom width, and channel width, using Rosgen (1996) Level I criteria. If the channel type did not agree with the valley type, the stream was considered to have departed from potential. Following Level I assessment, riparian condition was quantitatively assessed against the reference range presented by Rosgen (1996). Measurements of sinuosity, slope, width:depth ratio, entrenchment, and channel material composition for the stream surveys were assessed against Rosgen's criteria for channel types (Appendix E). If a value was outside of the range of natural variability for each morphological measurement, the stream had departed from potential. If these features were constrained by infrastructure, capability was considered. Additionally condition attributes were noted, such as mid channel bars and channel processes.

The final assessment was the use of regional channel morphological curves. A criterion for channel morphology potential has not been documented for streams in northeast Oregon. Thus, the measurements of the Upper Salmon River area in Idaho (Emmett 1975) were used for the assessment of riparian condition. Emmett (1975) presented regional curves and equations of bankfull area as a function of bankfull discharge and as a function of drainage area. The three-research stream measured physical attributes at the gauge station were mathematically evaluated against regional curves produced by the hydrologic evaluation of Emmett (1975). The gauge physical attributes were used to correspond with the regional curves, which were calculated at gauge stations. The measured values of bankfull at the gauge stations were entered into each regional equation. The measured values were then assessed against the calculated value of bankfull width, depth, and area. If the researched channel measurements were outside of the range of variability set by Emmett (1975) on the curve, the channel was again considered to depart from potential and prospectively at capability.

The riparian condition was further assessed based on the expression of the woody riparian plant community's response to the riparian functioning processes. The associated plant community, measured in the belt transects, was evaluated against the potential natural communities of the Wallowa-Whitman National Forest (Crowe and Clausnitzer 1997). These plant associations, described by Crowe and Clausnitzer (1997), represented plant associations of streams unconstrained or at potential for given stream types and geomorphic characteristics. The current plant associations were assumed to reflect the plant response to the constraint. These current plant associations, along channels constrained by infrastructure were assessed against potential natural plant associations for the measured stream type. A channel determined to be at capability, based on the channel measurements, was assumed to have the functioning processes to support a plant association for channels at potential, thus validating the determination of capability.

DATA ANALYSIS

Data Selection

The primary objectives of this study were to quantitatively describe the woody riparian vegetation structure, and its relationships to environmental gradients, at two hierarchical analysis levels. This was done utilizing multivariate analyses of the community data matrices, performed in PC-ORD 5 (McCune and Mefford 2005). Species-environment relationships were tested using plant community data consisting of woody riparian species density and species height delineations. The species structure was correlated to the environmental data. Thirty-one physical and environmental attributes consisting of quantitative measurements and categorical variables were correlated to the plant community structure. Several attributes differed between the flood zone level analysis and the transect level of analysis to concentrate on the site-specific measurements at the flood zone and vegetation transects. Joint plots in multivariate techniques were used to display the correlation between the environmental data and species community gradients. Table 3.13 on the following page describes the environmental variables used.

Table 3.13: Physical and environmental attributes used in the environmental matrix for ordination to plant community data

Attribute	Description	Attribute	Description	Attribute	Description
Valley Width	Width of valley	*Gravel*	Percent surface particle cover that was gravel	*Forb cover*	Forb foliar cover
Bankfull Width	Width at bankfull elevation	*Cobble*	Percent surface particle cover that was cobble	*Shrub Cover*	Shrub foliar cover
Floodprone Width	Width at floodprone elevation	*Mineral Soil*	Percent surface particle cover that was mineral soil	*Overstory Canopy Cover*	Overstory canopy cover measured within the floodplain
25-year width	Width at 25-year flood elevation	*Sand*	Percent surface particle cover that was mineral soil	*Distance from Greenline*	Distance of flood zone from greenline for flood zone analysis only
Entrenchment	Channel entrenchment ratio (only used in transect analysis)	*Bareground*	Bareground basal cover	*Stream*	Categorical variable to distinguish each stream
Width:depth ratio	Width to depth ratio at bankfull height (only used in transect analysis)	*Litter*	Litter basal cover	*Bank*	Categorical variable to distinguish left and right bank
Channel bottom (stream) slope	Slope of the channel bottom	*Foliage*	Foliage basal cover (grass, forb, and sedge/rush)	*Riffle/Pool*	Riffle or Pool categorical variable (only in transect analysis)
Channel Material	Channel material composition	*Wood*	Wood basal cover	*Straight/Corner*	Straight or Corner categorical variable (only in transect analysis)
Sinuosity	Channel sinuosity	*Rock*	Rock basal cover	*Flood zone (6)*	Flood zone categories, six classes, greenline to bankfull, bankfull-25, and 25-floodprone, on each bank
Winter hours	Average hours of light intensity during dormancy	*Moss*	Moss basal cover (only in flood zone analysis)	*Flood Zone (3)*	Flood zone categories, three classes; greenline-bankfull, bankfull-25, 25-floodprone
Freeze Days	Number of days below freezing during dormancy	*Grass foliar cover*	Grass foliar cover	*Zones*	Flood zone categories, three zones per channel, each channel is independent
Boulder	Percent surface particle cover that was boulder	*Sedge/Rush foliar cover*	Sedge/Rush foliar cover		

Data Matrices

Raw data matrices consisted of five different matrices for analysis at two different levels of hierarchical structure with two separate measurements of species attributes. Flood zone matrices are displayed in Appendix E. Transect level analysis, where sample units were vegetation transect, consisted of a community matrix (94 sample units x 22 species) and an environment matrix (94 sample units x 31 environmental variables). Flood zone level analysis, where sample units were three zones per stream each side of the channel, consisted of a community matrix (18 sample units x 27 species) and an environmental matrix (18 sample units x 31 environmental variables). At the flood zone analysis, an additional community height matrix (18 sample units x 27 species) was used for analysis of species height against flood zone. Table 3.14 is a matrix showing the structure of the project with the rows being plots and columns as woody riparian species or environmental variables.

Table 3.14: Example of data study matrices. A: 5 plots x 7 species, E: 5 plots x 5 environmental variables

A	*Species*				*E*	*Environmental Variables*			
	ABGR	***ACGL***	***ALIN***	***ALSI***		***ValleyWidth***	***Rosgen***	***D50***	***Slope***
Plot01	0	0	0.455	0		112.292	1	43.6	0.027
Plot02	0	0	0.667	0		139.347	2	45.7	0.031
Plot03	0	0	0.29	0		81.275	1	87.7	0.008
Plot04	0	0.417	0.833	0.278		112.292	3	43.6	0.006
Plot05…	0	0.229	0.294	0		81.265	1	45.7	0.026

CODES: ABGR-*Abies grandis,* ACGL-*Acer glabrum,* ALIN-*Alnus incana,* ALSI-*Alnus sinuata*

Data Adjustments

Data transformation or relativizations are common data adjustments used to alleviate attributes units of measurement differences, make ordination distance measurements work better, and emphasize groups of species. Neither of these data adjustments were made on the community or environmental matrix for both the transect and flood zone level of analysis. First, the structure of density classification, compared to raw values, alleviated the need for transformations. Second, relativizations were not used in order to focus on the absolute species abundances. Adjustments were not required for the environmental matrixes in order to focus on the absolute physical and environmental measurements. Cover classifications for basal and foliar cover, further alleviated the need for data transformations or relativizations.

Flood Zone Level of Analysis

In multivariate analysis, comparing average community distances between sample units identifies outliers in species space. One outlier (sample unit-M3L, Appendix D for codes) was found among the flood zone categories where the average distance between points using Sørensen distance was greater than 2.0 standard deviations from the mean (2.47). Woody vegetation richness (5 species) within this flood zone was considerably lower than the average flood zone richness of 11 species, in addition, rare species were also present (*Pinus ponderosoa)* leading to the outlier designation. Additionally, sample unit-M1L was identified as an outlier in the attributes of species height with a standard deviation of (2.34) and species richness (3 species). Multivariate analysis tests were run with and without the outliers. All sample units were retained based on the biological importance of the flood zone with low or high abundance of species at the flood zone level.

Transect Level of Analysis

Multivariate statistical analysis Nonmetric Multidimensional Scaling (NMS) requires at least one positive value of species density for all vegetation transects sampled. The environmental-vegetation matrix at the transect level of analysis had several transects with zero species richness. Four vegetative transects (units-MD-3L, MD-4L, MD-15L, and NF-1L) failed to contain a non-zero value, hence they were deleted from the analysis. Additionally, five species occurred in less than 5% of the vegetation transects, which were also deleted from the data matrix in an effort to reduce variation. These species were *Larix occidentalis*, *Salix bebbiana, Salix lucida, Shepherdia canadensis* and *Taxus brevifolia*.

NMS analysis of the vegetation-environmental matrix identified nine additional vegetation transects as outliers with standard deviations ranging from 2.02

to 2.76, using Sørensen distance. The nine transects identified as outliers were analyzed to determine species differences within each outlier. Four outliers were removed from the analysis based on the undesirable species differences. The first vegetation transect was NF-10R, located at the gauging station on North Fork Catherine Creek. Installation and maintenance of the gauging station had lead to vegetation removal, with *Pinus ponderosa* density of 0.02 plants/m^2, separating it from the remaining vegetation transects. Transect MD-2L was removed due to low species density of *Salix eriocephala var. watsonii* (0.06 plants/meter), which was only present on Grande Ronde River and North Fork Catherin Creek. The species may have been misidentified and was found in a vegetation transect on a cutbank with no vegetation. The final two vegetation transects removed from the data matrix were MD-8L and MD-8R, which were located directly upstream of a recent log jam causing active channel re-adjustment during the two years of the data collection. The remaining five outliers (MD-7L, MD-10L, MD-9R, NF-13R, and NF-6R) were retained because of the biological importance of vegetation transects with differing species abundance and presence.

Nonmetric Multidimensional Scaling

Nonmetric Multidimensional Scaling (NMS) is an ordination technique that optimizes the monotonic relationship between the original species distances and ordination distances to minimize stress (Kruskal 1964, Mather 1976). This procedure avoids the assumptions of linearity among community variables, which is desirable in describing plant community relationships found from the dataset (McCune and Grace 2002). NMS ordination was run using Sørensen distance. For both the transect level and flood zone level of analysis, the “slow and thorough” autopilot mode of PC-ORD was utilized in order to identify the final configuration with the lowest stress and highest stability (McCune and Mefford 2006). In autopilot mode, a random starting configuration is chosen for NMS analysis. A maximum of 500 iterations in 250 runs of real data were used to determine ordination. Instability was tested using 250 iterations of the randomized data, where the proportion of randomization with stress less than or equal to the observed stress were evaluated.

Ordinations were rotated to load the environmental variable with the strongest correlation to that axis, onto the axis that explained the greatest variance. This was done to provide the best visualization of the ordination, but did not alter ordination in species space. Winter lum hours explained the greatest amount of variation (r = 0.943) at the flood zone level and the greatest amount of variation (r= 0.671) at the transect level. Ordination scores for each transect/flood zone on each axis were determined from the final configuration of each sample units in species space. The coefficient of determination, the percent of variance exampled by each axis, is the proportion of variance in Sørensen distance from the original matrix that was represented by Euclidean distance in the ordination. The relationships between ordination scores and environmental variables were depicted as joint plots for quantitative variables and overlays for categorical variables. Environmental variables, represented by joint plots, with r^2 values greater than 0.400 (flood zone analysis) and 0.200 (transect analysis) were used to display the strongest variables in relation to species space.

Multi-Response Permutation Procedure

Woody riparian species composition differences were evaluated using Multi-Response Permutation Procedure (MRPP; Mielke 1984) in PC-ORD (McCune and Mefford 2006). MRPP is a non-parametric statistical analysis procedure that is used to determine group differences based on species data matrices. MRPP does not require distributional assumptions, which are often not met with heterogeneous community data. Sørensen distance was used in this analysis to correlate with the distance measure used in ordination methods. Species composition difference between the three streams, six flood zones, and bank location were evaluated to describe stream, flood zone, and bank (right and left) group differences. Flood zone, stream, and bank location differences were assessed using the flood-zone analysis matrices, while stream and bank location, were assessed using transect analysis matrices. The groups were assessed based on average within group distance based on the species matrices. Homogeneity with groups was test with an *A*-statistic, where *A*-statistics near to 1.00 indicated strong cohesive grouping and *A*-statistics far from 1.00 suggested weak groupings.

Nonparametric Permutation-based MANOVA

Woody riparian species composition differences between flood zones were evaluated using Nonparametric Permutation-based MANOVA (PerMANOVA; Anderson 2001) in PC-ORD (McCune and Mefford 2006). PerMANOVA is a nonparametric statistical analysis that is used to analysis variance within multivariate datasets that are nested. In PerMANOVA sums of squares are calculated directly from the distances among data points (Anderson 2001 and McCune and Grace 2002). The method used for testing was a two-way nested design. This procedure was used to analysis the flood zones, greenline-bankfull, bankfull-25 year flood elevation, and 25-year flood elevation-floodprone, differences nested within the three streams. Sørensen distance measure was used in this analysis to correlate with the distance measure used in ordination methods. The flood zone differences were assessed based on the F-value and p-values from the PerMANOVA. The null hypothesis was rejected for p-values greater than 0.05.

Indicator Species Analysis

The Indicator Species Analysis was used to elucidate associations of woody riparian species with geological and hydrologic attributes of three channels in northeast Oregon. Indicator Species Analysis (Dufrene and Legrendre 1997) quantified how well a species is associated to an attribute group. The attribute groups used were streams, flood zones, and bank locations. The indicator species value indicated the species abundance and faithfulness to each group. The statistical significance of the each indicator values was tested with 4999 permutation of the Monte Carlo test. Indicator species of biological importance were species that had indicator scores greater than 60. A value of 100 is a perfect indicator of faithfulness to a specific group (McCune and Grace 2002). The null hypothesis was rejected for p-values greater than 0.05.

RESULTS

DESCRIPTIVE DATA RESULTS

Ice Scarring

Grande Ronde River had the largest percent of ice scarring, followed by Meadow Creek and North Fork Catherine Creek (Table 4.1). The greenline to bankfull flood zone on Meadow Creek and the Grande Ronde River exhibited the highest percent of ice scarring with scarring decreasing in the bankfull to 25-year flood elevation zone. The higher percent of ice scarring within the bankfull-25 flood elevation zone on Grande Ronde River was due to the ice scarring in backflow channels that flowed during flood events greater than bankfull flow events. The backflow channel was relatively new, which was caused by a natural debris log jam upstream of the two vegetation transects with bankflow channels. North Fork Catherine higher percent of ice scarring in the 25-year elevation-floodprone was because of the presence of ice scarring at the distance of one meter from greeline within two vegetation transects. The presence of ice scarring within the 25-year elevation- floodprone may have been due to errors in the determination of this floodprone area, due to the lack of accurate gauge station data over the last 13 years, at North Fork Catherine Creek.

Table 4.1 : Percent of area with ice scarring present on shrubs and trees surveyed (GRR-Grande Ronde River, MDW-Meadow Creek, NFC-North Fork Catherine Creek, GL- Greenline, BF-Bankfull, 25W-25 year flood elevation, FP-Floodprone)

	GRR	MDW	NFC
Total Area Surveyed	1887 m^2	1845.6 m^2	553.23 m^2
Total % Scarring	56.88	39.04	25.3
Total %of scarring within GL-BF	41.14	50.03	36.56
Total %of scarring within BF-	57.74	49.9	21.22
Total %of scarring within 25YW-FP	1.12	0	42.22

Light Intensity

A total of nine light intensity loggers recorded light intensity readings for 470 days every 30 minutes. Two of the three light intensity loggers located on Meadow Creek failed to record for periods during 2007 (MDW #1 failed 5/25/2007 to 8/03/2007, MDW #2 failed 5/25/2007 to 10/17/2007). During this period, calculated values were determined from the third logger. The number of hours of positive light intensity during the period of dormancy (September 1^{st} 2006- May 1^{st}, 2007) was used to calculate the hours of light intensity for an environmental variable in statistical analysis. Table 4.2 displays the monthly hours of daily lums/ft^2 during the period of dormancy.

Table 4.2: Number of hours of positive light intensity from September 1, 2006 to May 1, 2007 (GRR-Grande Ronde River, MDW-Meadow Creek, NFC-North Fork Catherine Creek)

Month	GRR	MDW	NFC
September	395.5	405.0	396.5
October	358.0	366.5	359.0
November	298.0	307.0	300.0
December	287.5	297.5	282.5
January	303.0	309.0	296.5
February	305.0	309.0	307.0
March	387.0	391.0	388.5
April	421.5	426.0	425.0
Total	2755.5	2811.0	2755.0

Air Temperature

A total of nine HOBO© thermistors logged air temperature hourly for 470 days. Daily minimum, maximum, and average temperatures were calculated for the 470 days at each channel. Recorded temperatures were averaged over the stream. One logger on North Fork Catherine Creek and another on Grande Ronde River periodically failed. Data from the remaining two loggers at each stream were averaged to provide temperature data. Minimum temperature values were used to calculate the monthly number of days below freezing, which were used in multivariate statistical analysis (Table 4.3).

Table 4.3: Number of days from September 1, 2006 to May 1, 2007 where the temperature was below freezing (GRR-Grande Ronde River, MDW-Meadow Creek, NFC-North Fork Catherine Creek)

Month	GRR	MDW	NFC
September	14	10	3
October	26	26	20
November	25	26	23
December	30	27	27
January	31	31	31
February	27	26	26
March	29	26	26
April	26	19	16
Total	208	191	172

Woody Riparian Species Presence

The plant associations at each stream was evaluated to support the discussion of riparian capability. Each stream had a different dominant plant species. *Cornus stolonifera* was the dominant species at Grande Ronde River. Subdominant species included *Salix eriocephala var. watsonii, Alnus incana,* and *Salix melanopsis. Alnus incana* was the dominant species at Meadow Creek with subdominant species *Salix melanopsis. Abies grandis* was the dominant species at North Fork Catherine Creek, with subdominant species *Alnus incana, Populus trichocarpa, Cornus stolonifera,* and *Salix sitchensis.* Grande Ronde River had the highest species richness of 26 species, followed by North Fork Catherine Creek (16 species richness) and Meadow Creek (13 richness). Each stream had rare species specific to each channel. Overall most conifers were rare (less than 1%) species, except *Abies grandis* on North Fork Catherine Creek. *Sambucus cerulea, Salix lucida, Salix boothii,* and *Salix bebbiana* were rare species on all three channels. Species names, codes, counts, density at each stream are presented in Table 4.4.

Table 4.4: Density list of 27 species and associated species codes distributed within belt transects. "Count" is the species count for all belt transects, "Density/m^2" the density per square meter surveyed, "Percent Species Density", is the percentage of the total density.

		North Fork Catherine Creek			**Grande Ronde River**			**Meadow Creek**		
Species	Code	Count	Density/ m^2	Percent Species Density	Count	Density/ m^2	Percent Species Density	Count	Density/ m^2	Percent Species Density
Abies grandis	ABGR	159	0.2874	17.36	4	0.0021	0.15	0	0.0000	0.00
Acer glabrum	ACGL	15	0.0271	1.64	20	0.0106	0.75	3	0.0016	0.47
Alnus incana	ALIN	132	0.2386	14.41	364	0.1929	13.63	261	0.1414	40.78
Alnus sinuata	ALSI	4	0.0072	0.44	34	0.0180	1.27	0	0.0000	0.00
Amelanchier alnifolia	AMAL	26	0.0470	2.84	37	0.0196	1.39	5	0.0027	0.78
Cornus stolonifera	COST	122	0.2205	13.32	591	0.3132	22.13	95	0.0515	14.84
Crataegus douglasii	CRDO	0	0.0000	0.00	0	0.0000	0.00	21	0.0114	3.28
Larix occidentalis	LAOC	0	0.0000	0.00	3	0.0016	0.11	0	0.0000	0.00
Lonicera involucrata	LOIN	7	0.0127	0.76	181	0.0959	6.78	0	0.0000	0.00
Pinus contorta	PICO	0	0.0000	0.00	58	0.0307	2.17	0	0.0000	0.00
Picea engelmannii	PIEN	32	0.0578	3.49	183	0.0970	6.85	1	0.0005	0.16
Pinus ponderosa	PIPO	3	0.0054	0.33	4	0.0021	0.15	7	0.0038	1.09
Populus trichocarpa	POTR	130	0.2350	14.19	11	0.0058	0.41	0	0.0000	0.00
Pseudotsuga menziesii	PSME	0	0.0000	0.00	67	0.0355	2.51	2	0.0011	0.31
Ribies spp	Ribes spp	27	0.0488	2.95	157	0.0832	5.88	29	0.0157	4.53
Rubus spp	Rubus spp	32	0.0578	3.49	7	0.0037	0.26	0	0.0000	0.00
Salix bebbiana	SABE	0	0.0000	0.00	2	0.0011	0.07	0	0.0000	0.00
Salix boothii	SABO	6	0.0108	0.66	10	0.0053	0.37	0	0.0000	0.00
Sambucus cerulea	SACE	1	0.0018	0.11	5	0.0026	0.19	1	0.0005	0.16
Salix lucida	SALU	0	0.0000	0.00	1	0.0005	0.04	0	0.0000	0.00
Salix eriocephela var mackenzieana	SAMA	2	0.0036	0.22	59	0.0313	2.21	24	0.0130	3.75
Salix melanopsis	SAME	73	0.1320	7.97	356	0.1887	13.33	190	0.1029	29.69
Salix monticola	SAMO	0	0.0000	0.00	57	0.0302	2.13	0	0.0000	0.00
Salix sitchensis	SASI	104	0.1880	11.35	2	0.0011	0.07	0	0.0000	0.00
Salix eriocephala var watsonii	SAWA	41	0.0741	4.48	446	0.2364	16.70	1	0.0005	0.16
Shepherdia canadensis	SHCO	0	0.0000	0.00	11	0.0058	0.41	0	0.0000	0.00
Taxus brevifolia	TABR	0	0.0000	0.00	1	0.0005	0.04	0	0.0000	0.00

MULTIVARIATE ANALYSES

Overview of Species Community

The species data were combined over the three channels to assess the species-environmental relationships across the three research streams in northeast Oregon. The species community for the study consisted of 27 species that were captured within the belt transects. In addition, two additional species, *Salix exigua var exigua* and *Prunus virginiana* were found along the three streams, yet were not part of the surveyed belt transects. A complete list of the species present on the three channels appears in Appendix C. The average species richness, prior to deleting the outliers (described in chapter 3) was 18.1 species per transect and 7.4 per flood zone. Beta diversity for the transect sampling was 0.49, which is rather homogeneous and 3.65 for flood zone sampling. Table 4.5 (next page) provides each species surveyed name, code, abundance, and frequency determined from the combined species data. The most abundant and frequent species within the study were *Alnus incana, Cornus stolonifera, Salix melanopis,* and *Salix ericocephala var. watsonii.* Species occurring 5% or less of the time (in the vegetation transects) were considered as rare species, which included, *Larix occidentalis*, *Salix bebbiana, Salix lucida, Shepherdia canadensis* and *Taxus brevifolia*.

Table 4.5: Species list of 27 species, species codes, mean density, and frequency (number of sample units in which each species was encountered)

Species	Code	Mean	Freq
Transect sample units			
Abies grandis	ABGR	0.574	26
Acer glabrum	ACGL	0.223	13
Alnus incana	ALIN	1.702	80
Alnus sinuata	ALSI	0.128	11
Amelanchier alnifolia	AMAL	0.426	27
Cornus stolonifera	COST	1.117	49
Crataegus douglasii	CRDO	0.096	8
Lonicera involucrata	LOIN	0.426	26
Pinus contorta	PICO	0.17	13
Picea engelmannii	PIEN	0.585	36
Pinus ponderosa	PIPO	0.106	9
Populus trichocarpa	POTR	0.245	8
Pseudotsuga menziesii	PSME	0.213	17
Ribies spp	Ribes sp	0.489	25
Rubus spp	Rubus sp	0.245	13
Salix boothii	SABO	0.085	7
Sambucus cerulea	SACE	0.064	5
Salix eriocephela var mackenzieana	SAMA	0.266	20
Salix melanopsis	SAME	0.691	28
Salix monticola	SAMO	0.117	8
Salix sitchensis	SASI	0.287	13
Salix eriocephala var watsonii	SAWA	0.553	30
Flood zone sample units			
Abies grandis	ABGR	1.44	9
Acer glabrum	ACGL	0.72	6
Alnus incana	ALIN	3.78	18
Alnus sinuata	ALSI	1.06	8
Amelanchier alnifolia	AMAL	1.61	12
Cornus stolonifera	COST	3.50	15
Crataegus douglasii	CRDO	0.33	3
Larix occidentalis	LAOC	0.11	1
Lonicera involucrata	LOIN	1.28	7
Pinus contorta	PICO	0.83	6
Picea engelmannii	PIEN	2.00	11
Pinus ponderosa	PIPO	0.44	6
Populus trichocarpa	POTR	1.28	6
Pseudotsuga menziesii	PSME	0.94	7
Ribies spp	Ribes sp	2.00	13
Rubus spp	Rubus sp	0.78	7
Salix bebbiana	SABE	0.06	1
Salix boothii	SABO	0.44	5
Sambucus cerulea	SACE	0.39	4
Salix lucida	SALU	0.06	1
Salix eriocephela var mackenzieana	SAMA	1.28	9
Salix melanopsis	SAME	2.61	13
Salix monticola	SAMO	0.94	6
Salix sitchensis	SASI	1.17	7
Salix eriocephala var watsonii	SAWA	2.28	13
Shepherdia canadensis	SHCO	0.39	4
Taxus brevifolia	TABR	0.06	1

Flood Zone Analysis

Plant Community Structure

Nonmetric multidimensional scaling of the flood-zone species density matrix produced a two-dimensional solution for the flood zone level of analysis. The significance of two axes was tested by utilizing a Monte Carlo (250 iterations) test of the probability of a randomized iteration having less or equal stress than the observed final stress. The two-axis solution was found to be stronger than expected by chance (p=0.004). The best solution at the flood zone level of analysis produced a final stress value of 14.105 and a final instability of 0.0000 after 49 iterations. Together the two axes explained 84.6 % of the variance using Sørensen distance measure (Figure 4.1).

The ordination segregated the three individual streams in species space, while the flood zones were less definitively segregated in species space (Figure 4.1). Flood zones with similar species composition were closely grouped, whereas dissimilar flood zones were separated in species space. The strongest community gradients were related to the separation of the three streams followed by the individual flood zones. The first axis accounted for 55% of the variance. *Salix eriocephala var. watsonii* was the species with the strongest association to axis one (r=-0.811; Table 4.6). In addition, the majority of the species were negatively associated (on the left side of the axis) with the first axis. *Crataegus douglasii* and *Pinus ponderosa* showed the only positive relationships with the first axis, while *Picea engelmannii, Cornus stolonifera, Alnus sinuata*, *Populus trichocarpa, Abies grandis, Salix sitchensis, Rubus spp.* and *Lonicera involucrata* were strongly negatively correlated with axis one (Table 4.6 and Figure 4.1).

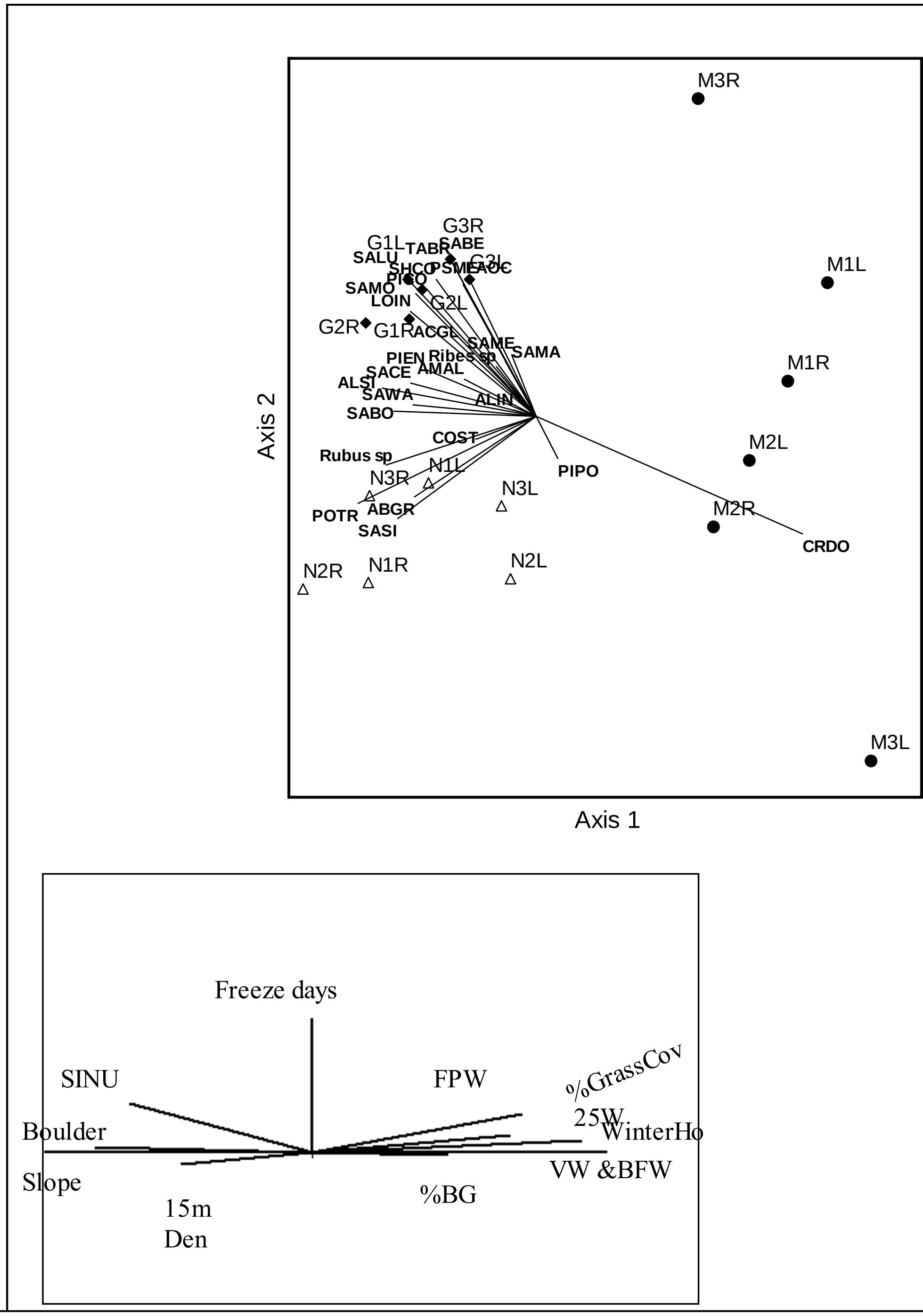


Figure 4.1: Ordination from NMS of flood zones in species space. Flood zones are depicted by diamonds (Grande Ronde River), triangles (North Fork Catherine Creek), and circles (Meadow Creek). Species codes are in Table 4.4. Flood zone codes in Appendix D. Attribute codes are in Table 4.7. Inset lower left corner is the same NMS ordination, with joint plots of physical and environmental variables.

Table 4.6: Significant species and correlation values determined from NMS with flood zone matrices. Listed by strength of correlation, negative correlations present first. (Codes in Table 4.5)

AXIS 1	**Species**	**R-value (density)**	**Species**	**R-value (height)**
	SAWA	-0.811	SAWA	-0.799
	PIEN	-0.723	PIEN	-0.75
	COST	-0.72	COST	-0.744
	ALSI	-0.674	ALSI	-0.671
	POTR	-0.607	LOIN	-0.662
	ABGR	-0.59	ABGR	-0.577
	SASI	-0.566	Rubus spp	-0.564
	Rubus spp	-0.555	SAMO	-0.555
	LOIN	-0.53	SAME	-0.546
	CRDO	0.667	CRDO	0.653
AXIS 2	**Species**	**R-value (density)**	**Species**	**R-value (height)**
	PSME	0.563	SASI	-0.564
	PICO	0.528	SAMA	0.649
	SAMO	0.525	PSME	0.542
			PICO	0.529
			SAMO	0.519
			CRDO	0.517

Physical and environmental attributes were overlaid as joint plots in the ordination of flood zones in species space. Percent bareground cover, boulder cover, and grass foliar cover were associated with axis one. High percent bareground, high grass foliar cover and low boulder cover clustered on the positive end (right side, Figure 4.1) of axis one while high boulder cover, low grass foliar cover and low bareground clustered at the negative end of this environmental attribute gradient (Table 4.7). Meadow Creek flood zones clustered on this cover gradient with high percent bareground, high grass foliar cover, and low percent boulder, while Grande Ronde River and North Fork Catherine Creek flood zones were clustered on the opposing end of the cover gradient (Figure 4.1). The second gradient consisted of light intensity (WinterHr), positively associated (r=0.943) with axis one and floodplain canopy cover was negatively associated (r= -0.632) with this axis (Table 4.7). Both North Fork Catherine Creek and Grande Ronde River flood zones clustered on the negative end of the second gradient, high floodplain canopy cover and low light intensity. Meadow Creek flood zones were associated with high light intensity and low floodplain canopy cover.

The third gradient consisted of the horizontal and longitudinal gradients of the channel geometry and flood elevations. Horizontal distance of flood zones from greenline was positively associated with axis one (Table 4.7), yet flood zone groups failed to cluster along this distance gradient. See Figure 4.1 for this illustration. Sinuosity and slope were negatively correlated, while valley, bankfull, floodprone and 25-year flood elevation width were positively associated with axis one (Table 4.7). Flood zones of Meadow Creek were correlated to zones with low sinuosity and slope, and wide channel geometry and 25-year flood elevation widths (Figure 4.1). Conversely, Grande Ronde River tightly clustered near flood zones with increased sinuosity and slope, and decreased channel geometry and 25-year flood elevation widths. North Fork Catherine Creek flood zones also grouped near Grande Ronde River flood zones, yet were more scattered based on species composition difference between the flood zones (Figure 4.1).

Table 4.7: Significant physical and environmental attributes (name, code, and correlation values) determined from NMS with species density and species height flood zone matrices. Listed by strength of correlation, negative correlations present first.

AXIS 1	Attribute	Code	R-value (density)	R-value (height)
	Channel slope	%STRSL	-0.933	-0.933
	Sinuosity	SINU	-0.744	-0.823
	Boulder cover	Boulder	-0.811	-0.717
	Canopy cover in the floodplain	15mDen	-0.632	-0.651
	WinterHour	WinterHr	0.943	0.921
	Bankfull width	BFW	0.943	0.912
	Valley width	VW	0.937	0.894
	25-year flood width	25W	0.901	0.831
	Floodprone width	FPW	0.795	0.688
	Grass foliar cover	GrassCov	0.773	0.747
	Bareground basal cover	%BG	0.639	0.469
	Horizontal distance to flood zone	Distance	0.605	0.378
AXIS 2	**Attribute**	**Code**	**R-value (density)**	**R-value (height)**
	Number of days below freezing	FreezeDays	0.637	0.688
	Channel material composition	D50	-0.561	-0.665

The second axis accounted for 29.6% of the variance. There were several species that were moderately positively (0.500<r< 0.600) associated with this axis *Salix monticola, Pinus contorta,* and *Psuedotsuga menziesii* (Table 4.6 and Figure 4.1). The environmental variables associated with the second axis were positively correlated number of days below freezing and negatively correlated channel material composition (Table 4.7). The flood zone of each of the streams weakly clustered on the gradient of day below freezing and channel material composition (Figure 4.1). North Fork Catherine Creek and Grande Ronde River flood zones separated on this gradient. Grande Ronde River flood zones correlated with greater number of days below freezing and smaller channel material, while North Fork Catherine Creek flood zones correlated to fewer freezing days and larger channel material. The flood zones on Meadow Creek separate along axis two, based on the species composition difference correlated to this gradient (Figure 4.1)

Species Height Matrices

Nonmetric multidimensional scaling was also used to determine plant community structure using the flood-zone species-height class matrix. Species height classes were analyzed to determine if streams and flood zones segregated in species space. Results produced a two-dimensional solution for the flood zone level of analysis. The significance of two axes was tested by utilizing a Monte Carlo (250 iterations) test of the probability of a randomized iteration having less or equal stress than the observed final stress. The two-axis solution was found to be stronger than expected by chance (p=0.004). The best solution resulted with a final stress value of 12.927 and final instability of 0.00049 after 500 iterations. Together the two axes explained 86.9 % of the variance using Sørensen distance measure (Figure 4.2).

Similar plant community structure and environmental attribute relationships were determined from the species height-class analysis at the flood zone level. The ordination segregated the three streams in species space, while flood zones were less definitively segregated in species space (Figure 4.2). The first axis accounted for 68.9% of the variance. As with species density data, *Salix eriocephala var. watsonii* was the species with the strongest association to axis one (r=-0.799; Table 4.6). Species correlated with axis two using species height data differed slightly from species determined from species density data (Table 4.6). The strongest associated species with axis one were *Salix eriocephala var. watsonii, Picea engelmannii, Cornus stolonifera, Alnus sinuata*, the same strongly associated species from the species density flood-zone analysis. The species with weaker correlation to axis one, *Salix monticola, Salix melanopsis, Lonicera involucrata, Abies grandis,* and *Rubus spp.* differed in the strength of the association from the species associations determined in the analysis with species density (Table 4.6).

The environmental and physical gradients associated with axis one and axis two using species height data were similar to the gradients determined with the species

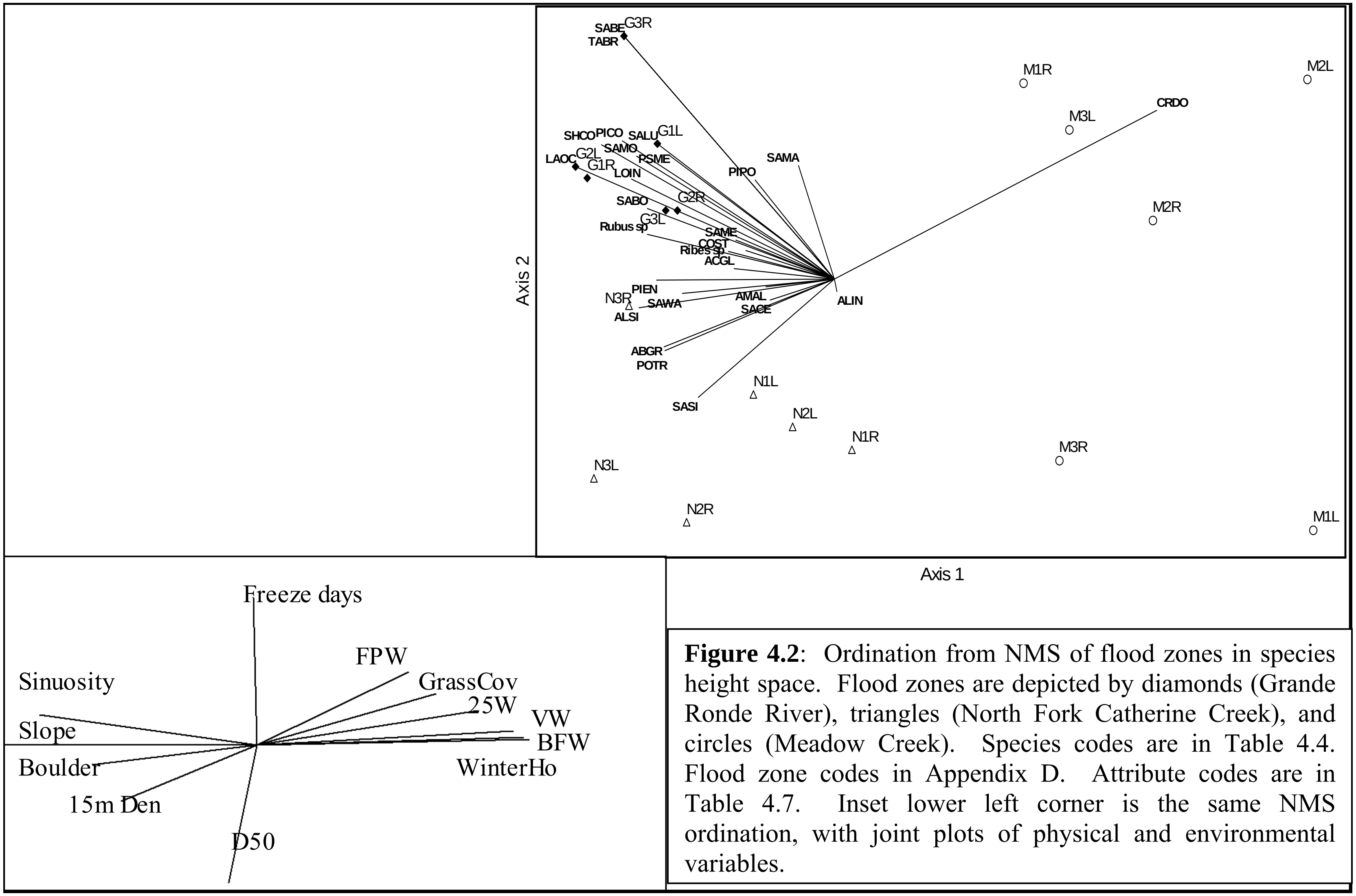


Figure 4.2: Ordination from NMS of flood zones in species height space. Flood zones are depicted by diamonds (Grande Ronde River), triangles (North Fork Catherine Creek), and circles (Meadow Creek). Species codes are in Table 4.4. Flood zone codes in Appendix D. Attribute codes are in Table 4.7. Inset lower left corner is the same NMS ordination, with joint plots of physical and environmental variables.

density data. Percent boulder cover and grass foliar cover were strongly associated with axis one, yet bareground cover had a weaker relationship to species height (Table 4.7). Hours of winter light intensity and floodplain canopy cover were also strongly associated with axis one and species height composition (Table 4.7). The third gradient associated with axis one consisted of the horizontal and longitudinal gradients of the channel geometry and flood elevations. The species height showed weak relationships to the horizontal distance of flood zones from greenline, yet were strongly associated with the channel geometry measurements (Table 4.7). The flood zones clustered along the environmental and physical gradients of axis one similar to the flood zone clustering with species density data (Figure 4.2).

The second axis using the species height matrix accounted for 18.0% of the variance. As with axis one, the species and environmental gradients determined from the species height data were similar to the species density data, which further supported the determined plant community structure relationships. Additional species were found to be associated with axis two, where *Salix sitchensis* was negatively associated with axis two and *Salix eriocephala var. mackenziena, Psuedotsuga menziesii, Pinus contorta, Salix monticola,* and *Crataegus douglasii* were positively associated with axis two (Table 4.6 and Figure 4.2). The environmental variables associated with the second axis were positively correlated number of days below freezing and negatively correlated channel material composition (Table 4.7). As with the species density data, flood zones of each of the streams weakly clustered on the gradient of day below freezing and channel material composition (Figure 4.2), while Grande Ronde River and North Fork Catherine Creek segregated. Meadow Creek flood zones separated in species height space along axis two.

The similarity of the two analyses, species density and species height, was due to species density overshadowing the distinct height classification of each species. Species height classes were determined using species density to calculate the weighted average height for each species. Hence, the results from the two analyses were expected to be similar, yet were used to determine if stream and flood zones separated in species space. The difference between the two analyses indicated the individual species height differences. The results with the species height data were used to further support the relationships and segregations determined with the species density data at the flood-zone level of analysis.

Multi-Response Permutation Procedures Analysis

Results from Multi-Response Permutation Procedures (MRPP) using flood-zone species density and environmental matrices (Appendix E) indicated that there was a significant difference between streams; Grande Ronde River, Meadow Creek and North Fork Catherine Creek ($p<0.0001$). Within group homogeneity was explained as greater than random expectation (chance-corrected within-group agreement is A= 0.4321). Results from MRPP using flood zone species height and environmental matrices additionally indicated significant differences between streams with a chance-corrected within group agreement of A= 0.4807

Results from MRPP using species density and environmental matrices further indicated that there was not a significant difference between flood zones across all three streams ($p=0.4035$). Within group homogeneity was described as very slightly greater than the random expectation (A=0.0056). The inconclusive difference between flood zones may have been the effect of strong difference between the three streams. 2). Nonparametric MANOVA (PerMANOVA) methods were used to test the flood zone differences using a two level nested design of replicates nested within the three flood zones greenline to bankfull, bankfull to 25-year flood elevation, and 25-year flood elevation to floodprone, nested with the three streams. Results indicated that there was no significant difference between the three flood zones (F value= 1.329, $p=0.1980$), but further supported the species difference between streams (F value=6.262, $p=0.0042$). Results from (PerMANOVA) using species height data indicated no significant difference between the flood zones (F value= 0.8257, $p=0.7828$)

Multi-Response Permutation Procedures (MRPP) were used to test right and left bank species composition differences. Results from MRPP indicated inconclusive evidence of right and left bank difference for all streams ($p=0.6568$, A-statistic =

-0.0173). MRPP permutation tests using species height matrix results with no significant difference between bank (A=0.0411, p=0.9575; from MRPP).

Indicator Species Analysis

Indicator Species Analysis further explained important species based on abundance and faithfulness of the species appearing in stream groups. Results indicated several species were prominent indicators for the Grande Ronde River and North Fork Catherine (Table 4.8; indicator score >60%, p<0.05). Distinct species were found to be important indicator species for North Fork Catherine Creek and Grande Ronde River (Table 4.8). Indicator Species Analysis with flood zone and bank location grouping variables indicated no species with indicator values stronger than expected by chance.

Table 4.8: Indicator Species Analysis: Stream grouping- 18 sample units (flood zones)

Species	Group	Observed IV	p*
Abies grandis	NF	84.6	0.0004
Lonicera involucrata	GR	91.3	0.0006
Pinus contorta	GR	100	0.0006
Picea engelmannii	GR	63.9	0.0012
Pseudotsuga menziesii	GR	73.5	0.0034
Salix monticola	GR	100	0.0006
Salix sitchensis	NF	90.5	0.0008

These strong differences between stream systems and slight differences between flood zones by species density and height structure were additionally supported by the segregation of streams in species space with NMS ordination (Figure 4.1 and Figure 4.2). NMS ordination of sample units in species space did not segregate into bank location, which is consistent with permutation tests and indicator species analysis (Figures 4.1 and 4.2).

Transect Analysis

Plant Community Structure

Autopilot mode of NMS recommended three-dimensional solutions for the transect level of analysis, which was chosen by the reduction of stress from the 1-dimensional ordination to the 3-dimensional ordination. The significance of three axes was tested by analyzing the probability of a randomized iteration of ordination having less or equal stress than the observed final stress, using 250 runs of a Monte Carlo test. The three-axis solution was found to be stronger than expected by chance (p=0.004). The best solution at the transect level of analysis resulted with a final stress value of 18.043 and a final instability of 0.00021 after 500 iterations. This high value of stress could partly be attributed to the structure of community data, the overall low density of species and the final instability of the ordination solution. The value of instability after 500 iterations is moderate compared to the desired stable criterion (0.00001, set in the slow and thorough mode) (McCune and Grace 2002). However, the structure of the species density and the convergence of a three-dimensional solution may have influenced the high final stress. Together the three axes explained 76.2 % of the variance using Sørensen distance measure.

Results from NMS ordination indicated that streams segregated in species space (Figures 4.3, 4.4, and 4.5). Vegetation transects with similar species composition were closely grouped, whereas dissimilar transects were separated in species space. In the axis 1 versus axis 2 ordination (Ordination 1, Figure 4.3) and axis 2 versus axis 3 ordination (Ordination 2, figure 4.5), axis 2 represented the greatest amount of variance (32.4% Ordination 1, 30.6% Ordination 2). The majority of the species were negatively associated with axis two, where *Cornus stolonifera* showed the strongest negative relationships with the second axis (r =-0.67, Table 4.9). *Crataegus douglasii, Alnus incana*, and *Salix eriocephela var mackenziena* showed the only positive relationships with axis two (Table 4.9).

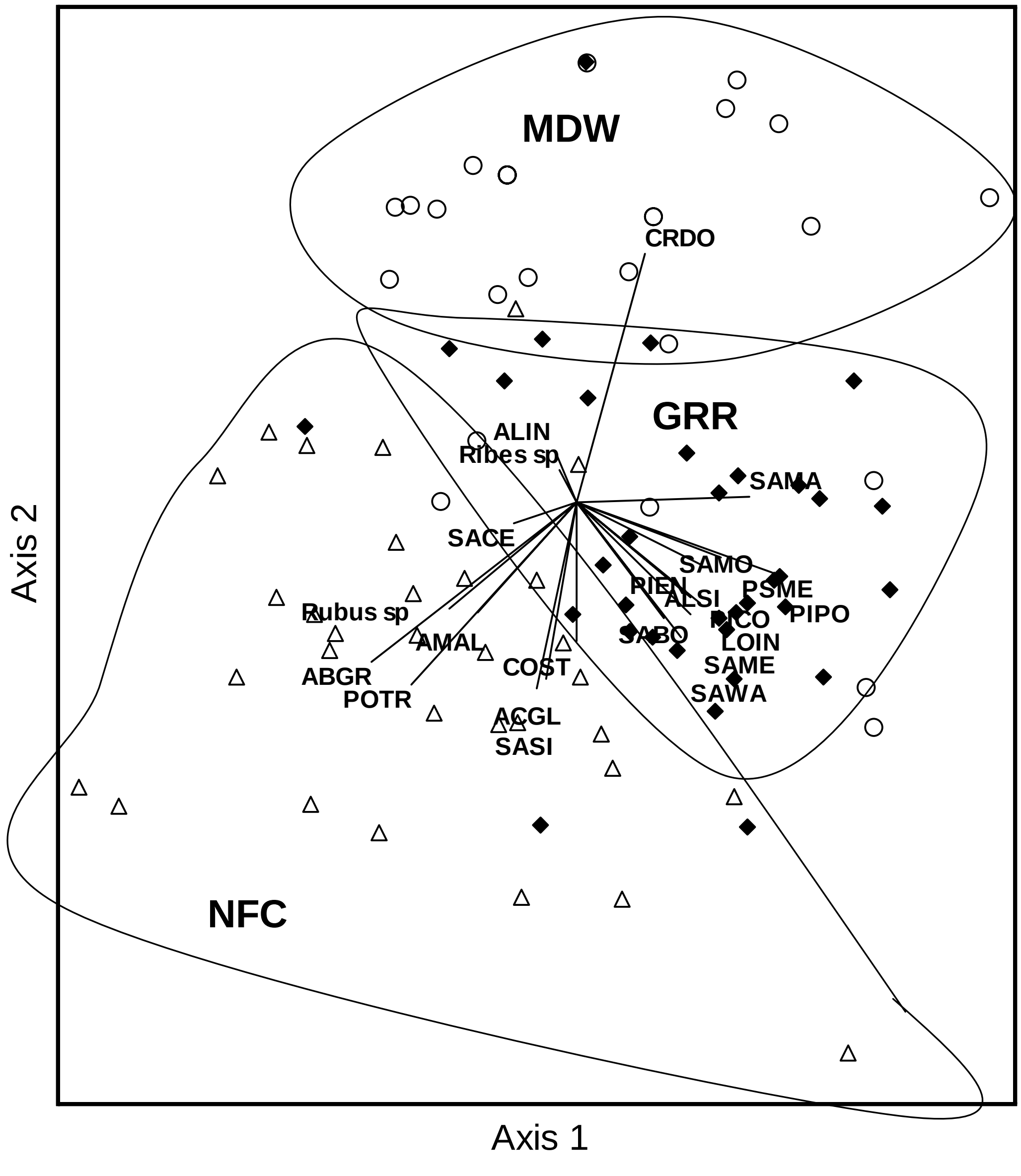


Figure 4.3: Ordination 1 from NMS of vegetation transects in species space. Transects are depicted by diamonds (Grande Ronde River -GRR), triangles (North Fork Catherine Creek-NFC), and circles (Meadow Creek-MDW). Species codes are in Table 4.4. Overlaid circles encompass stream groupings.

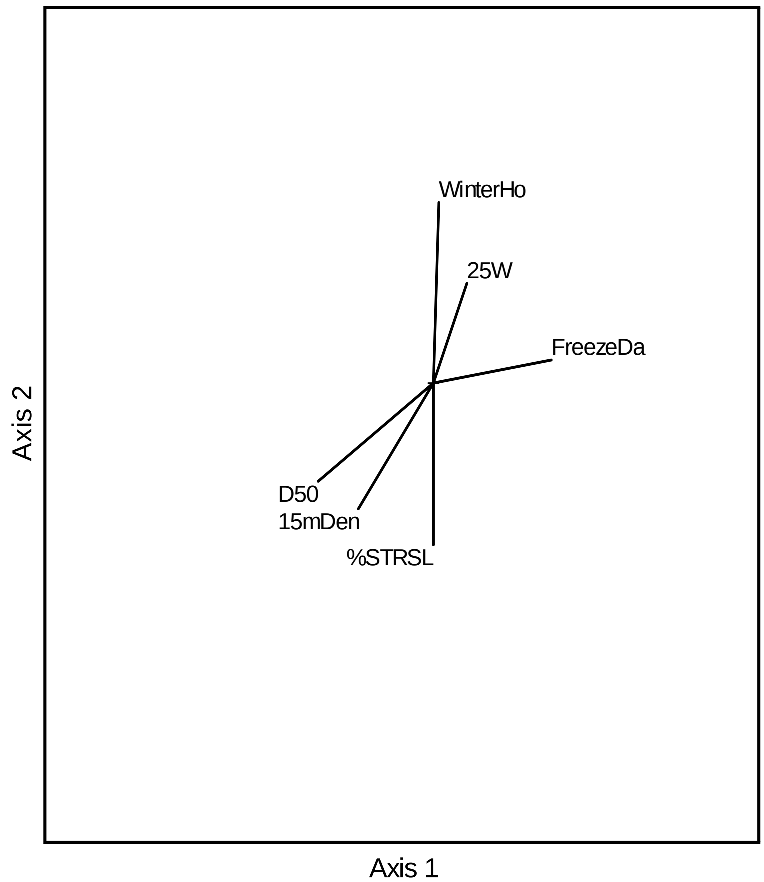
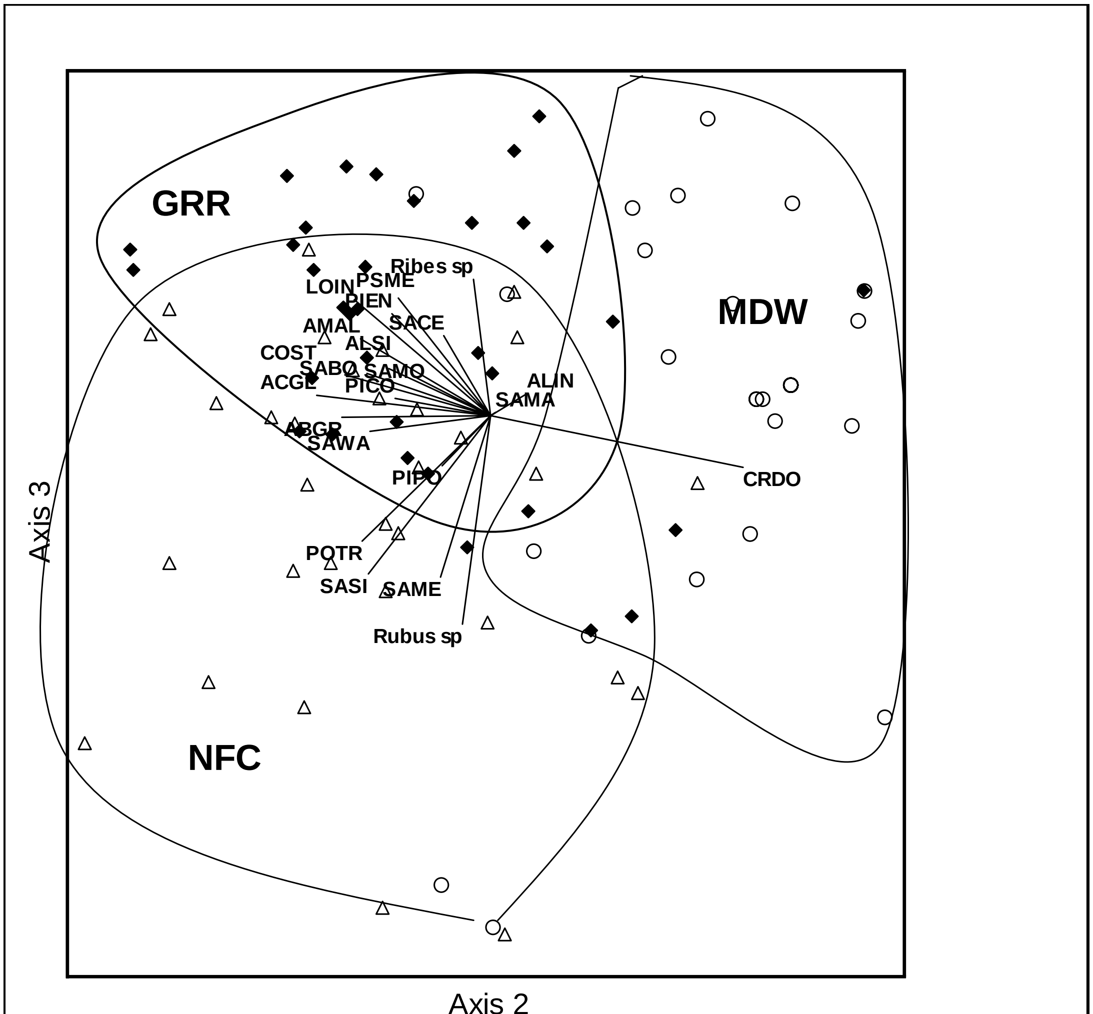


Figure 4.4: Joint plots of physical and environmental attributes corresponding to Ordination 1 of Figure 4.3. Attribute codes are found in Table 4.10.



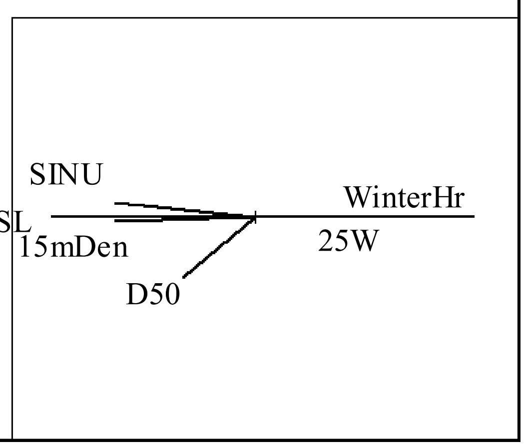


Figure 4.5: Ordination 2 from NMS of vegetation transects in species space. Transects are depicted by diamonds (Grande Ronde River -GRR), triangles (North Fork Catherine Creek-NFC), and circles (Meadow Creek- MDW). Species codes are in Table 4.4 and attribute codes are in Table 4.10. Overlaid circles encompass stream groupings. Inset lower right is the same ordination, with joint plots of physical and environmental variables.

Table 4.9: Significant species and correlation values determined from NMS with transect level matrices. Listed by strength of correlation, negative correlations present first.

AXIS 1	Species	R-value
	Abies grandis	-0.617
	Salix eriocephela var. mackenzieana	0.452
AXIS 2	**Species**	**R-value**
	Cornus stolonifera	-0.67
	Abies grandis	-0.421
	Crataegus douglasii	0.37
	Alnus incana	0.3
AXIS 3	**Species**	**R-value**
	Salix melanopsis	-0.522
	Rubus spp	-0.424
	Salix sitchensis	-0.317
	Ribes spp	0.406
	Picea engelmannii	0.4

Axis 2 was associated with several environmental and physical gradients. Twenty-five year flood elevation width and winter lum hours were positively associated with axis 2 (Table 4.10). Vegetation transects with greater 25-year flood width and hours of winter light intensity were clustered at the positive end of axis two (top in Figure 4.3, and Figure 4.4), whereas transects with narrow 25-year flood elevation width and low hours of winter light intensity clustered near the bottom. Channel slope and floodplain canopy cover were negatively associated with axis two (Table 4.10). Hence, vegetation transects with narrow 25-year width and low hours of winter light intensity were additionally associated with greater channel slope and high canopy cover within the floodplain. The three streams segregated along the environmental and physical gradients of 25-year flood width, hours of winter light intensity, channel slope and floodplain canopy cover. Meadow Creek transects were clustered on the positive end of axis two, followed by Grande Ronde River clustered near the center, and North Fork Catherine Creek clustered at the negative end of axis two (Figures 4.3 and 4.4).

The third axis of the transect ordination represented a smaller portion of variance (27.3% Ordination 2, 29.6% Ordination 3-axis 1 versus axis 3). *Salix melanopsis* showed the strongest negative association with axis three (r = -0.522), while *Picea engelmannii* and *Rubus spp.* showed moderate positive association with this axis (Table 4.9). Axis 3 was weakly associated with the majority of the environmental and physical variables with no variables having greater than r = 0.372 correlation with the axis, after rotation onto axis two (Table 4.10). Streams did not segregate along this axis, transects clustering along axis three were correlated to weakly associations with sinuosity and associations to axis two (Figure 4.5).

Table 4.10: Significant physical and environmental attributes (name, code, and correlation values) determined from NMS with transect level matrices. Listed by strength of correlation, negative correlations present first.

AXIS 1	Attribute	Code	R-value
	Channel material composition	D50	-0.556
	Canopy cover in the floodplain	15mDen	-0.447
	Canopy cover at bankfull	BnfDen	-0.365
	Number of days below freezing	FreezeDa	0.563
	Grass foliar cover	GrassCov	0.33
	25-year flood width	25W	0.3
AXIS 2	**Attribute**	**Code**	**R-value**
	Channel slope	%STRSL	-0.635
	Canopy cover in the floodplain	15mDen	-0.561
	Channel material composition	D50	-0.496
	Sinuosity	SINU	-0.332
	WinterHour	WinterHo	0.671
	25-year flood width	25W	0.497
	Valley width	VW	0.396
	Bankfull width	BFW	0.346
	Grass foliar cover	GrassCov	0.313
AXIS 3	**Attribute**	**Code**	**R-value**
	Sinuosity	SINU	0.4
	Percent wood basal cover	%WOOD	0.365
	Number of days below freezing	FreezeDa	0.344
	Shrub foliar cover	ShrubCov	0.307

Axis 1 represented the smallest portion of variance with 18.3% Ordination 1 and 12.9% Ordination 2. *Abies grandis* was the species with the greatest correlation to axis one (r = -0.617; Table 4.9). The remainder of the species were weakly associated with axis one. Days below freezing expressed a strong positive associated with and opposed associated with channel material composition. Transects with greater number of days below freezing and small channel material size clustered on the right of axis one, while transect with fewer number of days below freezing and larger channel material size clustered on the left of axis one (Figure 4.3). The three streams weakly segregated into along this environmental gradient associated with axis one. North Fork Catherine Creek vegetation transects clustered on the far left of the axis one along the environmental gradient of days below freezing and channel material size. Grande Ronde River and Meadow Creek transects very weakly separated along this environmental gradient associated with axis one.

Multi-Response Permutation Procedures Analysis

Results from Multi-Response Permutation Procedures (MRPP) using transect species density and environmental matrices indicated that there was a significant difference between streams; Grande Ronde River, Meadow Creek and North Fork Catherine Creek ($p<0.0001$). Within group homogeneity was explained as greater than random expectation (chance-corrected within-group agreement is A= 0.2804). Further results from MRPP using species density and environmental matrices at the transect level indicated that there was not a significant difference between right and left bank across the three streams ($p=0.0398$). Within group homogeneity was slightly greater than random expectation (A=0.0142).

Indicator Species Analysis

Indicator Species Analysis further explained important species based on abundance and faithfulness of the species appearing in stream groups. Results indicated several species were prominent indicators for the Grande Ronde River and North Fork Catherine (Table 4.11; indicator score >60%, $p<0.005$). Distinct species were found to be important indicator species for North Fork Catherine Creek and Grande Ronde River (Table 4.11). Indicator Species Analysis with bank location grouping variables indicated no species with indicator values stronger than expected by chance.

Table 4.11: Indicator Species Analysis: Stream grouping-94 sample units (transect)

Species	Group	Observed IV	p*
Abies grandis	NF	68.1	0.0002
Lonicera involucrata	GR	66.8	0.0002
Picea engelmannii	GR	54.4	0.0002

These differences between stream systems are additionally supported by the segregation of streams in species space with NMS ordination (Figure 4.3, Figure 4.5). NMS ordination of sample units in species space did not segregate into bank location, which is consistent with permutation and indicator species analyses.

Riparian Capability Analysis

Rosgen Classification

Rosgen stream classification procedures were completed on each of the three stream reaches contained within the study (Rosgen 1996). Table 4.12 displays the Level I classification completed from aerial photos and topographic maps and the Level II classification completed at each stream reach. The Level II field survey included measurement of the dominant channel material, channel slope, sinuosity, width-depth ration (W:D) and entrenchment ratio. Table 4.13 displays the select attributes from Rosgen's key for classification of natural streams. The complete Rosgen classification table is displayed in Appendix F.

Table 4.12: Rosgen Classification Summary

	GRR	MDW	NFC
Rosgen Level I Class	B	C	B
Entrenchment Ratio	1.9	2.2	2.1
W:D Ratio	27	42	30
Sinuosity	1.3	0.97	1.1
Slope	2.70-3.14%	0.63-0.79%	2.61%
Channel Material	D50- 43.61 mm very coarse gravel	D50- 43.61 mm very coarse gravel	D50- 87.72 mm small cobble
Rosgen Level II Class	B4	Very wide C4	B3

Table 4.13: Key to stream classification (adapted from Rosgen 1996)				
	Entrenchment Ratio	W:D Ratio	Sinuosity	Slope
Rosgen B	*Moderate, 1.4*	*Moderate >12*	*Moderate >1.2*	*2-10%*
Rosgen C	*Slight >2.2*	*Moderate to High >12*	*Moderate to High >1.2*	*0.1-4%*
Rosgen D	NA	*Very High >40*	*Very Low*	*0.1-4%*
Rosgen D_A	NA	*Highly variable*	*Highly variable*	*<0.05%*

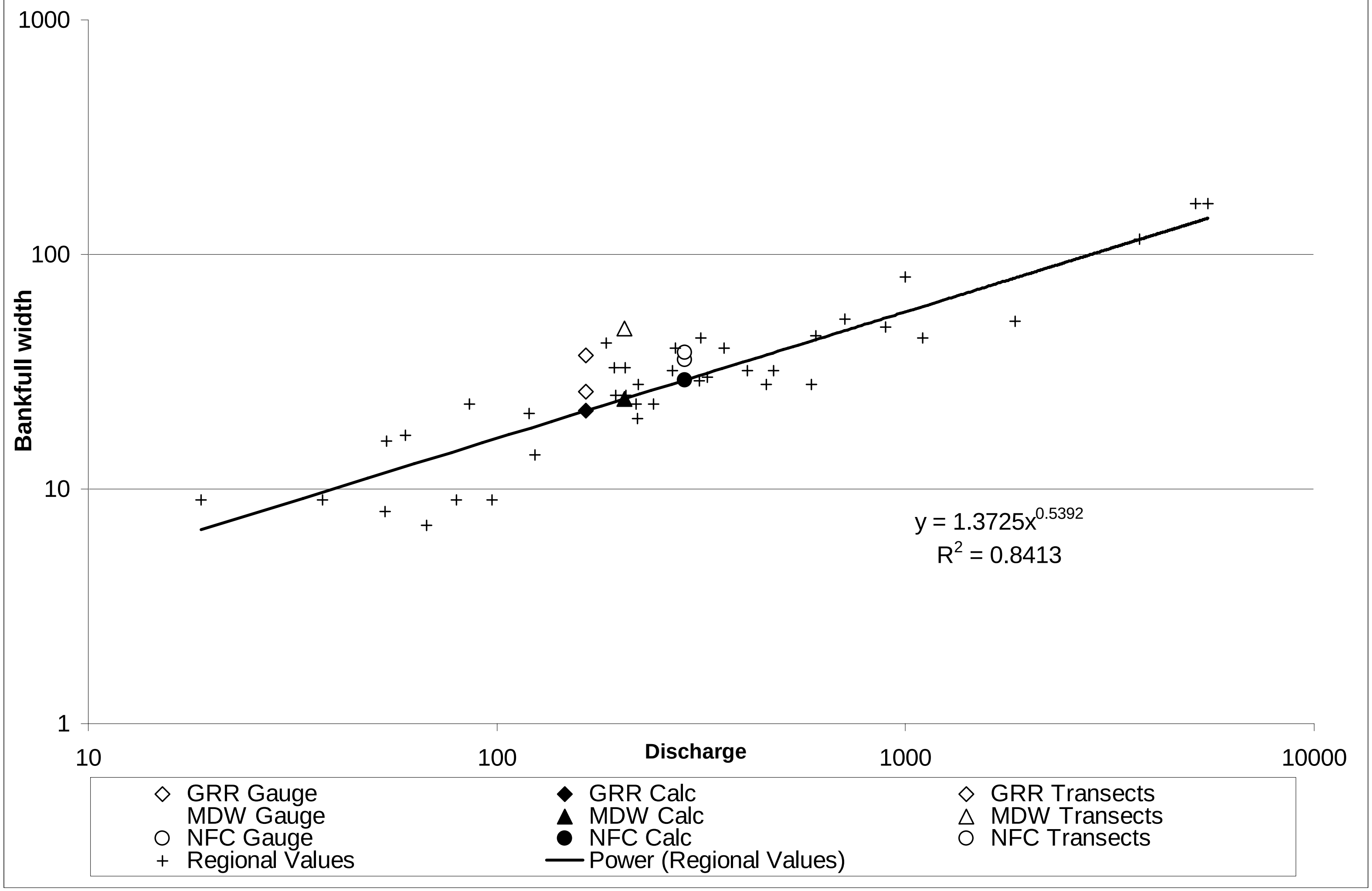
Grande Ronde River channel attributes keyed directly to a B4 channel, which fit within the geomorphic stream type of a B channel. The sinuosity value of 1.2 was likely caused by the old road running along the right bank. Meadow Creek did not key to a classified stream. Meadow Creek classified to a borderline C4 channel based primarily on the entrenchment ratio of 2.2 and sinuosity of 0.97. The entrenchment ratio describes, "the vertical containment of a river channel" (Rosgen 1996), calculated as floodprone width divided by bankfull width. The borderline entrenchment ratio at Meadow Creek suggested that the channel was wide at bankfull for the vertical containment at floodprone. Secondly the width:depth ratio of the channel was similar to the multiple channels classification (Rosgen D and Rosgen D_A) with a very high width to depth ratio and very low sinuosity. The channel was given the class of a very wide C4 channel due to that fact it was a single thread channel and the borderline entrenchment ratio. North Fork Catherine Creek keyed to a B3 channel. The entrenchment ratio and width:depth ratio were both characteristics of a B-type channel. The lower value of sinuosity (1.0) was in the range of variability (+/-0.2 units) and was likely a result of the road running along the right bank (Rosgen 1996).

Regional Curves

Values of bankfull width, bankfull depth, and bankfull area were evaluated as a function of the bankfull discharge. The values were assessed against regional curves calculated from numerous gauged reference reaches located in the Upper Salmon

River Area (Emmett 1975). The values used from this study were the gauge station values, measured at the gauge station to correspond to the regional gauge station references presented by Emmett (1975), and physical transect values, summarized as an average of each measurement from the physical transects. The regional curve equations and measured values as a function of bankfull discharge are presented in Table 4.9, while 4.10 presents the channel geometry values measured at reference reaches (Emmett 1975). The regional reference values, calculated, and actual research values were plotted on a log versus log scale (Figures 4.6, 4.7, and 4.8). The values in Figures 4.6, 4.7, and 4.8 are indicated by shapes corresponding to each stream and calculated or measured value. The calculated values are the regional reference values for the discharge at each stream, the gauge values are the measured variables at each gauge station, and the transect values are the measured variables averaged over the each stream reach. The line associated with the regional reference values is represented by the regional curve equation. These regional curve equations were used to calculate the expected ("calculated", Table 4.14) values for the research streams as a function of the bankfull discharge.

Figure 4.6: Bankfull Surface Width as a Function of Bankfull Discharge



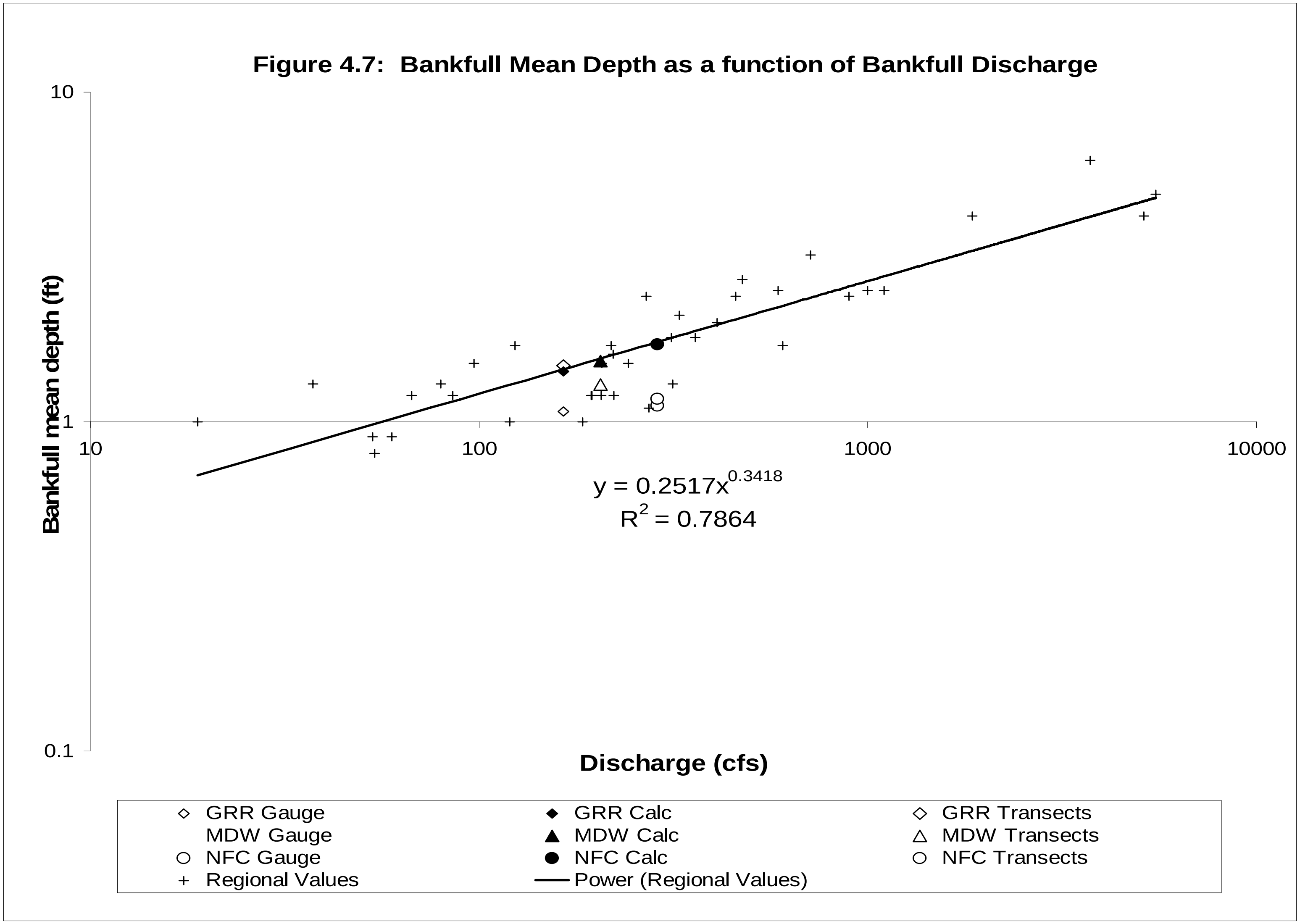


Figure 4.7: Bankfull Mean Depth as a function of Bankfull Discharge

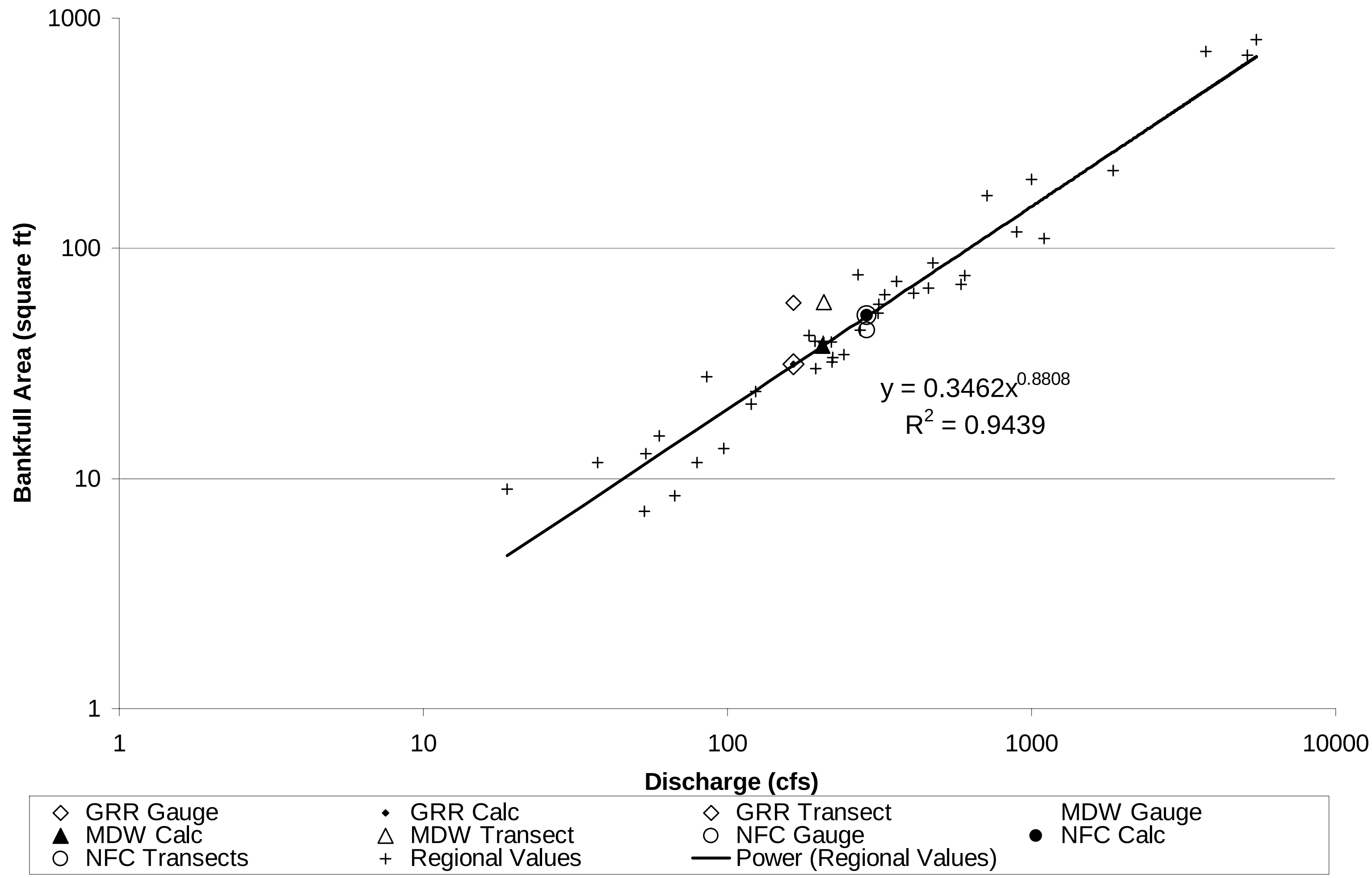


Figure 4.8: Bankfull Area as a Function of Bankfull Discharge

Table 4.14: Hydrologic geometry calculated from Emmett (1975) for research gauge stations and physical transects (17 transect values averaged per stream) Nomenclature: A_b-bankfull Area, D_b-bankfull depth, W_b-bankfull width, Q_b-bankfull discharge, GRR-Grande Ronde River, NFC-North Fork Catherine Creek, MDW-Meadow Creek

Bankfull width as a function of bankfull discharge

Equation: $W_b = 1.37Q_b^{0.54}$ $r=0.917$

Site	Q_b	Calc W_b	Actual W_b
GRR Gauge	165	21.59	25.92
GRR Transects	165	21.59	37.13
MDW Gauge	205	24.27	44.29
MDW Transects	205	24.27	48.23
NFC Gauge	288	29.16	35.60
NFC Transects	288	29.16	38.32

Bankfull depth as a function of bankfull discharge

Equation: $D_b = 0.25Q_b^{0.34}$ $r=0.887$

Site	Q_b	Calc D_b	Actual D_b
GRR Gauge	165	1.42	1.07
GRR Transects	165	1.42	1.48
MDW Gauge	205	1.53	1.28
MDW Transects	205	1.53	1.29
NFC Gauge	288	1.71	1.12
NFC Transects	288	1.71	1.17

Bankfull area as a function of bankfull discharge

Equation: $A_b = 0.35Q_b^{0.88}$ $r=0.972$

Site	Q_b	Calc A_b	Actual A_b
GRR Gauge	165	31.29	31.30
GRR Transects	165	31.29	57.92
MDW Gauge	205	37.88	63.08
MDW Transects	205	37.88	58.48
NFC Gauge	288	51.09	46.00
NFC Transects	288	51.09	44.23

Table 4.15: Summary of bankfull stage, Table 12 from Emmett (1975).

Station No.	Surface Width (ft)	Mean Depth (ft)	Flow Area (ft^2)	Discharge (ft^3/sec)
13-2922.00	40	1.8	72	360
2924.00	33	1.2	39.6	194
2932.00	25	1.2	30	195
2934.00	25	1.5	39	207
2950.00	80	2.5	200	1000
2956.50	32	2.7	86.4	475
2960.00	53	3.2	169.6	712
2965.00	116	6.2	719.2	3740
2970.00	45	1.7	76.5	604
2971.00	28	1.2	33.6	222
2972.50	21	1	21	120
2973.00	9	1.5	13.5	97.2
2973.10	33	1.2	39.6	206
2973.20	16	0.8	12.8	53.8
2973.30	40	1.1	44	273
2973.40	30	2.1	63	328
2973.50	8	0.9	7.2	53.3
2973.60	28	2.4	67.2	457
2973.80	165	4.2	693	5128
2973.84	29	1.8	52.2	313
2973.88	14	1.7	23.8	124
2973.96	23	1.7	39.1	219
2974.00	49	2.4	117.6	894
2974.04	32	2	64	410
2974.18	7	1.2	8.4	67.2
2974.25	44	2.5	110	1100
2974.40	17	0.9	15.3	59.7
2974.45	32	2.4	76.8	269
2974.50	44	1.3	57.2	315
2974.80	42	1	42	185
2974.85	9	1.3	11.7	79.6
2975.00	20	1.6	32	221
2975.30	23	1.5	34.5	242
2976.00	28	2.5	70	588
2976.70	9	1.3	11.7	37.4
2976.80	9	1	9	18.9
2977.00	23	1.2	27.6	85.6
2980.00	52	4.2	218.4	1856
2985.00	165	4.9	808.5	5498

It was determined that Meadow Creek measured channel geometry and gauge station geometry differed greatly from the regional calculated values reference reaches in Upper Salmon River Area. Bankfull width as a function of bankfull discharge was approximately two times the calculated bankfull width from the regional curve equation. In addition, bankfull area was about 20 ft greater than the regional bankfull area. Bankfull depth was slightly less than the regional depth as a function of discharge, which further supported the entrenchment ratio. Rosgen (1996) defined floodprone elevation is measured as two times bankfull depth; hence, a shallow bankfull depth has a lower floodprone elevation and narrower floodprone width. A decreased floodprone width and increased bankfull width would correspond to a channel that has been entrenched. Meadow Creek gauge station and transect values were plotted with the regional curve and appeared on the edge of the scatter of the regional reference values. The bankfull area and width values were a greater distance from the regional curve, compared to Grande Ronde River and North Fork Catherine Creek.

North Fork Catherine Creek measured channel and gauge geometry values differed from the regional curves (Table 4.14). Both bankfull depth and area were less than the regional curves for area and depth. The low bankfull depth value corresponded to the high bankfull width on this channel, which was physically constrained by a road. This difference in bankfull width and depth was potentially a result of the road constraining the effective floodplain, therefore the channel has widened to dissipate stream energy. The measured transect and gauge station values are distributed within the regional reference scatter (Figures 4.6, 4.7, and 4.8). Bankfull depth as a function of discharge had the greatest distance from the regional curve, compared to the other North Fork Catherine Creek values

Grande Ronde River channel geometry values at the gauge station slightly differed from the regional curves for bankfull width and area (Table 4.14). Measured bankfull depth varied greatly at the gauge station. The measured bankfull width and area of the physical transects were approximately 1.8 times greater than the regional values. The discrepancy between the gauge station and the physical transects was potentially due to the location of the gauge station. The gauge stations at Meadow Creek and North Fork Catherine Creek were within the study reach, yet the Grande Ronde River reach was approximately 2 km downstream of the gauge station. Though no major stream inputs were within the 2 km, the discharge was potentially greater at the research stream reach, due to seeps, groundwater input, and runoff. Consequently, the values measured at the stream reach were a greater distance from the regional curve, compared to the gauge station values (Figures 4.6, 4.7, and 4.8).

DISCUSSION

Past research demonstrated the variety of environmental-hydrologic species relationships across a broad range of ecosystems (Hupp and Osterkamp 1985, Bendix 1994, Lytjen 1999, and Teversham and Slaymaker 1976). Additionally, research has demonstrated that riparian community condition can be classified over different ecosystems and diverse types of riparian constraints (Rosgen 1996 and Barrington et al. 2001). This field study has described woody vegetation relationships to physical, environmental, and hydrologic attributes and applied these relationships to validate the riparian condition of three mountainous streams. The overall environmental gradients suggested physical and environmental attributes that influenced species composition and distribution along three streams in northeast Oregon. Direct individual species-environmental relationship conclusions were weak due to the close clustering of species and multiple physical and environmental gradients. The impacts of human-imposed constraints on the physical attributes of these montane riparian ecosystems were expressed in woody vegetation distribution and composition. Therefore, the physical and environmental relationships to species variations that were measured suggested this methodology was appropriate for the determination and validation of riparian capability.

STREAM AND FLOOD ZONES DIFFERENCES

The study focused on determining species distribution in relation to physical and environmental attributes across three mountainous streams and across six flood zones. Multivariate analyses indicated that vegetation transects grouped by stream; while vegetation belt transects weakly grouped by flood zone, based on the species composition quantified within the vegetation transects and flood zones.

Stream differences based on species composition

Through past research, it has been determined that woody riparian species distributions differ based on a plethora of physical, climatic, and hydrologic attributes (Brunsfeld and Johnson 1985, Walker and Chapin 1986, Webb and Brotherson 1988, Bendix 1994, and Harris 1987). It was hypothesized that the three streams would differ based on the species composition as well as physical and environmental attributes. This study determined that the streams were different based on species composition in response to the specific physical and environmental attributes. These determined site and species differences led to the conclusion that physical and environmental attributes of the streams could be used for differentiating stream systems, reiterating Patten's (1998) conclusion of diversity between riparian systems and the mosaic of riparian vegetation communities. Vegetation transect sample units slightly overlapped in the NMS ordination analysis at the transect level. This slight overlap indicated similar species composition within the vegetation transects across the three streams. These three streams of northeast Oregon are three riparian systems within the Wallowa-Whitman National Forest of the Blue Mountain Ecological Province. Thus, these slight overlaps were expected. The range of variability between and within these three channels provided evidence that they were unique one from another, yet they displayed similar species compositions.

The grouping of the three separate streams, in both analyses, ranged from tight grouping among the Grande Ronde River sample units, to scattered grouping among the Meadow Creek sample units. The proximity of sample units signified the close relationship between the sample units' species attributes. The tight grouping of the vegetation transects along the Grande Ronde River indicated that the species composition was very similar between the vegetation transects, while North Fork Catherine Creek and Meadow Creek had a wider range of species composition variability between the vegetation transects. The lack of similarities between vegetation transects within individual streams may have been due to changes in hydrology, energy, or nutrient cycling processes along the channel due to channel confinement. These differences may have led to the diverse species composition within North Fork Catherine Creek and Meadow Creek transects.

Several species were found to be indicator species for each channel determined from Indicator Species Analysis (ISA) and were found to be associated with the ordination of stream sample units. The indicator species associated with North Fork

Catherine Creek were *Abies grandis* and *Salix sitchensis.* Ordination results further displayed these species' strong association to North Fork Catherine Creek flood zones and transects. *Lonicera involucrata, Picea engelmannii, Pinus contorta, Pseudotsuga menziesi,* and *Salix monticola* were the determined five indicator species for Grande Ronde River. In addition, NMS analyses found that all of these species were within close ordination to Grande Ronde River flood zones and transects. No indicator species were determined by ISA for Meadow Creek, due to low species counts of unique species such as *Crataegus douglasii*. However, NMS analyses indicated *Crataegus douglasii* was associated with Meadow Creek. The indicator species were not the dominant species at each stream, but suggested species that were unique to the physical and environmental attributes at each stream reach. The physical and environmental gradients associated with this study's species composition are discussed in later sections.

Flood zone differences based on species composition

Past research on riparian systems and development of classification systems have focused on understanding hydrological variables that are related to riparian species presence and distributional patterns (Bendix 1994, Hupp and Osterkamp 1985, Rosgen 1996, and Harris 1987). Hydrogeomorphic attributes that operate on riparian landforms, such as stream power, water inundation, stream morphology, and particle distribution, have been documented as being related to species distribution with flood zones (Hupp and Osterkamp 1985, Lite et al. 2005, and Bendix 1999). The findings of this study indicated that physical measurements of hydrological patterns were related to species composition, supporting previously researched relationships.

It was hypothesized that the woody riparian species would grow in different locations lateral to the active stream channel in relation to the flood regimes. Yet, NMS ordination showed that similar flood zones did not group together (i.e. MD-3L and MD-3R, Figures 4.1 and 4.3). The weak grouping of similar flood zones was strongly impacted by the differences between the three channels, where streams separated into three different regions of species space. The further analysis of flood zone differences with PerMANOVA indicated that streams were significantly different, while flood zones were not significantly different. This indicated the weak utility for using flood zone classes as a stratification layer for determining species distribution lateral to the active channel.

The lack of flood zone grouping and overlap between groups was potentially related to the effect of dikes and roads on hydrologic processes, such as water inundation and stream power. The confinement of the floodplain may have influenced species composition differently depending on the location and proximity of the constraint to the active stream channel along the stream reach. For example, on North Fork Catherine Creek, the road ran along the right side of the stream, and dikes composed most of the right floodplain. However, the proximity of the dikes changed as the stream and road sinuosity changed. When the dike was close to the stream, channel width was greatly confined, hence stream energy increased, resulting in reduced species presence and changes in species lateral distribution. Similar species composition responses to channel confinement were determined by Dufour et al. (2007). They found that species diversity decreased as a response to channel confinement, and the predominant species shifted towards more drought-tolerant species (Dufour et al. 2007). Further studies with more thorough quantification techniques on channels of contrasting conditions should be done to support this observation.

The weak flood zone separation was likely associated with an environmental or physical variable that was not quantified. Efforts were made to measure and statistically analyze the flood zones within each vegetation transect; however, the lack of species density within many flood zones created a species matrix that was unable to be analyzed with multivariate techniques. Hence, future analysis of woody species flood zone differences should implement a different technique to quantify woody riparian species composition.

It was additionally determined that ice floes may be a potential environmental attribute influencing species composition at each flood zone, specifically species height composition. Ice scarring usually does not kill woody riparian species, yet it influences the growth and composition of the vegetation community (Smith and Pearce 2000, Nilsonn et al. 1989). Ice floes were most prevalent within the greenline-bankfull flood zone, which may have influenced the species composition and height along all three streams. The ice scarring added complexity to the species distribution in the flood zones yet provided further evidence of the response to ice floes on riparian communities.

WOODY VEGETATION DISTRIBUTION RELATIVE TO PHYSICAL AND ENVIRONMENTAL GRADIENTS

The ordinations from multivariate analyses at the vegetation transect and flood zone level revealed several physical and environmental gradients associated with the species composition and the segregation of the three streams. Channel geometry, canopy cover, air temperature, channel particle size, flood zone distance, and understory community attributes were found to be overall gradients, which described the variation in species composition across the three streams in northeast Oregon.

Channel Geometry Gradients

The channel dimension and profile measurements quantitatively captured the longitudinal and lateral gradients of the stream system. Ordinations revealed the strong physical gradient where species composition differed in response to changes in channel dimension, pattern, and profile. The gradients consisted of sinuosity, slope, and measured width at bankfull, 25-year flood elevation, floodprone, and valley edge. These gradients displayed the trend of channel morphology from narrow, steep, and sinuous channels to wide, low slope, and low sinuosity channels.

Transects and flood zones at narrow, steep, sinuous stream reaches were dominated with a greater diversity of species including: *Cornus stolonifera, S. eriocephela var. watsonii, Alnus sitka, Picea engelmanii, Salix sitchensis, Abies grandis, and Populus trichocarpa*. Wide, low slope and low sinuosity channels were associated with *Crataegus douglasii,* a riparian shrub associated with disturbed riparian ecosystems (Crowe and Clausnitzer 1997). Similar patterns in woody vegetation cover were also found to be related to the channel width (Aguiar and

Ferreira 2005). The species relationship to channel morphology supported previous research that has shown woody species composition relationship to channel geometry differences (Dufour et al. 2007) and to lateral and longitudinal channel measurements (Lytjen 1999). Additionally, it supported research that showed hydrologic processes, indicated by channel geometry measurements, influence species composition, and diversity (Harris 1987, Bendix 1994, van Coller et al. 2000, and Dufour et al. 2007).

These species-environmental relationships suggested that species composition was related to narrow channels with high slope and high sinuosity, while disturbance-related species were related to wide channels with low slope and sinuosity. However, this does not yield causality of one to the other, but merely represents the gradient of species and environmental relationships. The species composition relationship to changes in channel dimension, pattern, and profile suggested that these species composition patterns could be used in conjunction with a stream classification system based on channel measurements. Further research should be done to determine the utility of the species relationships to the assessment of stream type.

This study found that there was a strong association of species distribution to 25 –year flood elevation width. Prichard et al. (1998) described the assessment of riparian condition based on high frequency floods (25-30 year flood) as the measurement of the maximum flood disturbance a riparian ecosystem can repair from before unraveling. The determined association of species to the 25-year flood width gradient indicated the potential utilization of this width as a quantitative measurement for the indication of woody vegetation plant communities. Thus, the 25-year flood width could be used as an indication of riparian community condition and resistance to change, where widening or confinement of the 25-year flood width may alter the effective woody vegetation community. This measurement should be further studied to determine its use as an indication of potential damage to the functional processes of a riparian ecosystem.

The channel geometry gradients further manifested the channel morphology differences of the three channels. Both Grande Ronde River and North Fork Catherine Creek species compositions were similar and associated with narrow, steep, and sinuous channels, while Meadow Creek species composition were associated with a wide, low slope and low sinuosity channel. Channel type determinations were based on the channel geometry measurements of each stream. This study found that these measurements of channel dimension, pattern, and profile were strongly related to the species composition at the three stream reaches. Crowe and Clausnitzer (1997) used the Rosgen channel classification system as a descriptor of each plant association. Additionally, Rosgen (1996) used basic vegetation categories to assess condition of classified stream channels. This present study demonstrated that species strongly associate with the channel morphology measurements of each stream type, thus suggesting the further application of species composition to the classification of channel type and assessment of riparian condition.

Canopy Cover Gradient

The second determined gradient was the environmental attribute floodplain canopy cover and hours of light intensity during dormancy. This gradient was expected, where intense canopy cover blocked light from entering the shrub canopy and understory communities, thereby lowering light intensity. It was determined that riparian zone canopy cover and light intensity during periods of breaking and entering dormancy were related to the species composition. The ordinations indicated that more species were related to the lower levels of light intensity and higher values of canopy cover. Channels with high floodplain canopy cover and low hours of light intensity during dormancy (September to May) were dominated with *Cornus stolonifera, S. eriocephela var. watsonii, Alnus sitka, Picea engelmanii, Abies grandis, Salix sitchensis,* and *Populus trichocarpa.* Grande Ronde River and North Fork Catherine Creek units clustered with these species. Meadow Creek, which had low canopy cover and numerous hours of light intensity during dormancy, was associated with *Crataegus douglasii.*

Past research has determined that seedling establishment and growth were reduced by shading (Sacchi and Price 1992), and reduction of light intensity was associated with decreased alder photosynthetic rates (Walker and Chapin 1986). The discrepancy between past research and high species richness associated with high floodplain canopy cover was concluded to be a result of other physical characteristics of each of the channels and the species physiological characteristics. *Cornus stolonifera, Alnus sitka, Picea engelmanii, S. eriocephela var. watsonii , Abies grandis,* and *Salix sitchensis* are often riparian species associated with overstory canopy cover created by conifers *Picea engelmanii* and *Abies grandis* (Crowe and Clausnitzer 1997). Additionally, these species are often associated with mountainous, high-elevation ecosystems (Kovalchik and Clausnitzer 2004, Brunsfeld and Johnson 1985). Thus, this suggested that the measure of light intensity during dormancy was a secondary factor of woody riparian species composition within northeast Oregon.

The lack of species on Meadow Creek did not support the past research of growth reduction by shading (Sacchi and Price 1992), yet other hydrologic and physical characteristics influenced the lack of species. Meadow Creek has yearly ice floes, which break and damage young seedlings (Smith and Pearce 2000). Further, McBride and Strahan (1984) determined that species establishment and growth was related to the timing and the specific surface particle composition of the gravel bars created by the hydrologic patterns. It was concluded that water inundation timing of the widened Meadow Creek channel potentially no longer created viable surfaces for seedling establishment of *Salix spp.* and *Alnus spp.* Additionally, the floodplain plant community was dominated by grass (percent grass cover associated with Meadow Creek subunits, Chapter 4), which potentially competed with young saplings for resources.

Temperature and Channel Material Composition Gradient

The ordination revealed a gradient composed of the abiotic attribute of channel material composition (D50) and the number of days of freezing. Dominant species were shown to be associated with lower values for the average channel material composition and higher number of days below freezing. Specific species relationships to the gradients differed between the ordination analyses of flood zones and transects. *Salix monticola, Psuedotsuga menziesii, Pinus contorta* and *Salix eriocephela var* *mackenzieana* were the determined dominant species across the three ordination analyses. These species were those strongly associated with Grande Ronde River sample units, which grouped in a positive correlation with the number of days below freezing.

This gradient indicated that temperature was an environmental attribute that was related to the response of species distribution between three separate streams within northeast Oregon. This supported the broad species distribution observed by Brunsfield and Johnson (1985) and Kovalchik and Clausnitzer (2004). Kovalchik and Clausnitzer (2004) determined that the broad distribution of woody riparian species was related to the changes in precipitation as a function of elevation, and the length of the growing season as a function of temperature. The species dominant along the gradients; *Salix monticola, Psuedotsuga menziesii, Pinus contorta* and *Salix eriocephela var mackenzieana,* were associated with the Grande Ronde River, which experienced a greater number of days below freezing, indicating a shorter growing season. Thus, the number of days of freezing between the months of September to May suggested that the length of the growing season was associated with the species distribution.

Additionally, channel particle composition was strongly related to the stream discharge, energy, and slope characteristics within the water column along the stream (Rosgen 1996, Gordon et al. 2004). The pebble composition association was determined to be weak in both ordination analyses, and most species were weakly correlated with the axis. This gradient provided little evidence that the channel particle composition was a primary factor related to the species differences.

Flood Zone Distance Gradient

Ordinations of flood zones in species composition space revealed the hydrologic flood zone distance gradient. This lateral distance gradient was weakly associated with the ordination of the flood zones. The expression of species distribution along this hydrologic gradient was weak compared to the strong species association to the other physical and environmental gradients, such as channel morphology. Its weak correlation to species composition supported past research, which determined that suites of physical and environmental variables often describe variation in woody riparian species. Bendix (1994) determined that valley width, site elevation, and stream power were environmental variables which described variations in woody riparian species composition. Similarly, Lytjen (1999) determined that species distribution was related to both the physical lateral and longitudinal gradients along the channel.

Cornus stolonifera, S. eriocephala var watsonii, Alnus sitka, Picea engelmanii, Lonicera involucrata, and *Populus trichocarpa* were found to be associated with a distance nearer to the active channel. *Cornus stonlonifera, Alnus spp,* and *Populus spp.* have been shown in other research to be associated with intermediate to high stream power, frequent inundation, and moist sediment (Kovalchik and Clausnitzer 2004, Ohmann et al. 1990, and Harris 1987). *Salix spp.* and *Alnus incana* exhibited lower values of correlation to the flood zone distance gradient (Figure 4.1, Table 4.6, and Table 4.7). This differed from the species associations with active flood zones determined in other studies on seedling growth and species presence (Hupp and Osterkamp 1985, Kovalchik and Clausnitzer 2004, and Ohmann et al. 1990). Therefore, it was concluded that the lateral distance from the active channel is a secondary factor that influences the species expression on North Fork Catherine Creek, Meadow Creek, and the Grande Ronde River.

Understory Community Gradient

Flood zones with high bareground cover, grass cover, and low boulder composition were found to be associated with species representative of Meadow Creek. While high boulder composition, low bareground cover, and grass cover were associated with species representative of North Fork Catherine Creek and the Grande Ronde River (Figure 4.1 and Figure 4.2). This species-environmental relationship was determined to be the understory community gradient. Flood zones with higher boulder cover, low bareground cover, and grass cover were associated with species *Cornus stolonifera, S. eriocephala var watsonii, Alnus sitka, Picea engelmanii, Lonicera* *involucrata,* and *Populus trichocarpa*. These species were the same species found to be strongly associated with the physical and environmental attributes of North Fork Catherine Creek and the Grande Ronde River. Similarly, *Crataegus douglasii* was associated with Meadow Creek, a meadow riparian system with low boulder composition and high grass cover.

Boulder composition, and both grass and bareground covers were attributes of the understory and ground cover communities. These attributes characterized the ground cover and understory communities which were determined to be a factor influencing species composition within the flood zones. Similar species patterns were determined by Hupp and Osterkamp (1985) who concluded that woody riparian species distribution primarily was related to the geomorphic surface characteristics of different flood zones. This present study also supported Aquiar and Ferreira (2005) who found that hard substrate, such as boulder, was a environmental variable influencing the woody vegetation composition.

The described species-environmental relationships and gradients of the flood zones offered valuable utility for measuring understory attributes (grass cover and surface particle cover). These could be used to indicate species presence and potential stream energy impacts either for restoration purposes or for determination of change in a particular riparian community following a constraint introduction. However, the ordination based on species composition in flood zones was strongly influenced by species differences between the three streams; hence, the significance of the gradient to differentiate flood zones should be further examined independent of stream differences.

Species Association to Gradients

Ordination results showed that species cluster along the physical and environmental gradients. *Crataegus douglasii* was the only species that clustered separate from the other measured species, and was associated with the physical and environmental variables at Meadow Creek. Conclusions of species groups associated along the gradients were determined; however, other individual species distributions along the physical and environmental gradients were unable to be determined due to the dense clustering of species. Species richness and diversity were associated with narrow, sinuous, moderate sloping channels, with greater floodplain canopy cover and fewer hours of light intensity during dormancy. This higher value of species richness was associated with vegetation transects of the Grande Ronde River and North Fork Catherine Creek sample units (Figures 4.1, 4.2, 4.3, and 4.5). This suggested that the two streams were capable of supporting a diversity of species given the current stream conditions and physical and environmental attributes. Diversity within the riparian ecosystem is created by the dynamic processes of the riparian system and is responsible for the maintenance and resilience of the channel dimension, pattern, and profile. Channels defined at the highest attainable condition, based on the channel geometry, support a diverse riparian plant community; an indication of a functioning healthy riparian system. Therefore, the diversity measured on Grande Ronde River and North Fork Catherine Creek offered further validation for the determination of the channel condition at capability or potential.

RIPARIAN CONDITION: POTENTIAL OR CAPABILITY

All three channels within this study had human-induced constraints on the ecosystem; therefore, ecological potential was derived from river channel morphology measurements of Emmett (1975) and Rosgen (1996). This field study utilized measurements of channel morphology, bankfull width, bankfull depth, channel entrenchment, channel slope, channel sinuosity, and streambed particle composition, to assess the condition of each stream reach. It was determined that the stream reaches were at different levels of riparian condition, where present and past human-induced constraints had influenced the effective channel morphology by constraining the potential floodprone and bankfull width.

Grande Ronde River

The Grande Ronde River stream reach did not have current active roads, dikes, or other constraints. However, past roads and mining had created large boulder deposits within the floodplain. Therefore, riparian condition was considered for designation as riparian capability. The Grande Ronde River valley type was determined as a narrow, moderately sloping valley fitting the valley type II description associated with B-stream types (Rosgen 1996). Channel measurements of the stream reach keyed out to a B4 Rosgen channel, which indicated that the channel geometry was in agreement with the valley type. The low value of sinuosity within the B-stream type range was probably a result of the past road construction, which had straightened the potential channel sinuosity. This lower value of sinuosity was concluded to be the highest attainable sinuosity for the channel due to the past influence of roads and mining. Hence, channel physical attributes were within the reference stream condition baseline established by Rosgen (1996), and the stream reach was further considered for riparian capability.

Channel morphology measurements were determined to be within the highest attainable physical condition, based on the regional curve for bankfull area versus bankfull discharge. The gauge station values and the physical transect values differed from one another. These differences in scatter around the regional curve was determined to be the result of bankfull discharge, which potentially differed from the bankfull discharge at the gauge station 2 km upstream. This study assumed that bankfull discharge was similar, yet it may have been greater at the stream reach due to runoff or a stream flow input. The Grande Ronde River values distribution away from the regional curve (Figures 4.6 and 4.7) indicated that the channel condition was less than potential but at the highest attainable physical condition due to channel confinement. The observed physical mining and past road developments had confined stream flow, where the effective floodplain had been narrowed. This channel narrowing may have led to a change in channel geometry away from potential, affirming the consideration of riparian capability for the condition at the Grande Ronde River.

The vegetation species composition and distribution offered further validation for the final determination that the Grande Ronde River was functioning at riparian capability. The dominant plant association present on the streambanks of the vegetation transects was the Mountain Alder- Red-osier Dogwood /Mesic Forb plant association (*Alnus incana-Cornus stolonifera/*Mesic forb; Table 5.1).

TABLE 5.1: Vegetation Composition for Grande Ronde River

GRR Vegetation Composition on Streambanks	
Tall shrubs	*Alnus incana* *Cornus stolonifera* *Salix melanopsis* *Salix eriocephala var. watsonii* *Ribies spp.* *Lonicera involucrata*
Mid-Montane Community Association	Mountain Alder-Red-osier Dogwood/Mesic Forb

Crowe and Clausnitzer (1997) defined this plant association as a potential natural vegetation type that is generally present on streams within narrow, V-shaped valleys associated with B2, B3, and B4 streams in northeast Oregon. Additionally, they determined the mean valley width associated with this plant association to be 63 m (Crowe and Clausnitzer 1997). This present study determined the average valley width of the Grande Ronde River to be 61 m. This plant association demonstrated that the ecosystem was at a stable condition where ecosystem processes were functioning to support this potential natural community.

The observed vegetation response to ice floes and past constraints additionally indicated that the ecosystem was fully functioning at the highest attainable condition. Ice floes maintain channels widened from previously imposed channel manipulations such as mining or splash dams (Smith and Pearce 2000 and Smith 1980). Though the Grande Ronde River developed ice and had the highest percentage of ice scarring of the three channels, the woody vegetation community was quite diverse and was observed throughout the flood zones; indicating that ice floes were not controlling the functioning process of this ecosystem.

Additionally, vegetation surveys showed that a wide variety of bank stabilizing woody riparian species, *Alnus spp.* and *Salix spp.*, were distributed both longitudinally and laterally along the stream channel. The species also varied in age, where both young saplings and older, well-developed trees were established within floodprone width. This indicated resilience of the system to respond to stream energy and resistance to remain the same during past flood and high stream energy disturbances. The diverse and rich species composition related to the appropriate valley morphology measurements led to the conclusion that the Grande Ronde River stream reach was at riparian capability.

Meadow Creek

The Meadow Creek stream reach was constrained by road development and experienced splash dams from 1890-1906, resulting in channel widening. The channel morphology was additionally altered through annual ice floes, which led to continuation of a widened channel. From the cross section surveys, the channel showed signs of floodplain confinement due to the road, such as back flow channels to create sinuosity and abandoned sinuous channels. This confinement of the channel narrowed the focus of determining riparian condition to considering riparian capability.

Meadow Creek was within a moderately wide, less than 4% slope, U-shaped valley described as a valley type V (Rosgen 1996). These valley types are often associated with C, D, or G stream types. The channel morphology measurements showed that the channel was not a Rosgen-C channel, due to the calculated entrenchment ratio and measured bankfull width (Tables 4.12 and 4.13). The entrenchment ratio of Meadow Creek was characteristic of a widened stream channel within a constrained floodplain, while bankfull width was very wide for a single thread stream channel. The low entrenchment value and high width:depth ratio for this single-thread channel was in agreement with the valley type. However, the departure from the reference baseline (Rosgen classification) suggested that Meadow Creek was not at capability, but at a condition departed from capability. Research has defined a functioning healthy riparian system as a system able to dissipate the stream energy, filter and capture nutrients and sediment, continue ground-water recharge, stabilize streambanks, provide habitat for wildlife, and support biodiversity (Prichard et al. 1998). However, Meadow Creek's widened channel potentially prevented and restrained floodplain recharge and the dissipation of stream energy, because the flood discharges remained within the channel, thereby weakening the connection with the floodplain. Thus, both the impact of splash dams, which had originally widened the channel, and the confinement of the valley bottom by roads narrowed the floodprone width and suggested damaged hydrologic and energy cycle processes.

Furthermore, the channel's physical measurements failed to fit the reference morphology of the regional curves (Figures 4.6, 4.7, and 4.8). Table 4.14 and Figure 4.6 show that the bankfull width at the gauge station and physical transects were greatly distributed from the regional curve. The plot of the actual measured values of bankfull width and area at the gauge station and transects were on the border of the regional reference point scatter. The failure to fit within the scatter of the regional reference values provided further support for the determination that Meadow Creek was below the highest physical condition.

The historic human manipulation of the channel through construction of splash dams for log transport, widened the channel, thus dispersing flood discharges across the altered channel width and depth. A system can potentially repair from the disturbance of channel widening if sediment is captured and vegetation is able to establish (Rosgen 1996). However, when ice develops yearly and breaks in ice floes, the channel repair cycle is setback, thus perpetuating the disturbance cycle of maintaining a wide channel. Smith (1980) stated that the geomorphic effects of ice floes include bank scouring, channel widening, sinuosity reduction at meander bends, and overbank deposition and scour. These processes lead to the development of a characteristic channel geometry described as wide, enlarged, non-sinuous channel where bankfull area was found to be up to three times greater than rivers without ice floes (Smith 1980). Meadow Creek was determined to have the enlarged channel geometry shaped by historic splash dams and maintained with ice floes.

Nilsonn et al. (1989) determined that ice scouring created spatial vegetation patterns based on the physical disturbance of the vegetation. In this present study, it was determined that ice floes were present along Meadow Creek, based on the ice scarring present from greenline to 25-year flood elevation. Meadow Creek was expected to have a high percent of ice floe damage due to the width and depth, but instead it had less ice scarring, by percentage, than the Grande Ronde River. This may have been related to Meadow Creek's low density of vegetation within the greenline-bankfull and bankfull-25-year flood elevation zones, where ice scarring was not present because vegetation was scarce along the channel. It was concluded that Meadow Creek's wide and entrenched channel geometry has continued because ice floes continue to hinder the establishment of sediment-capturing vegetation and bank-stabilizing woody species. In addition, it was observed with the species collection that the dominant species, *Alnus incana,* was distributed within the bankfull to 25-year flood elevation flood zone at a relatively uniform height. This led to the conclusion that woody riparian species had a low range of age distribution within the active floodplain, which suggested hindered resilience of the system to respond to stream energy and resistance to remain the same. Therefore, Meadow Creek was at a functioning state unable to support necessary vegetation; it was concluded that the ecosystem had departed from the highest attainable condition of capability.

The vegetation along Meadow Creek further indicated a riparian system that was not functioning at the highest attainable condition. The dominant species, *Alnus incana* and *Salix melanopsis,* indicated the disturbance induced seral plant association Mountain Alder/Kentucky bluegrass (*Alnus incana/Poa pratensis)* rather than the potential natural community Mountain Alder-currant/mesic forb (*Alnus incana-Ribes* spp/ mesic forb) described by Crowe and Clausnitzer (1997). Second, ordination results determined that *Crataegus douglasii* was the only species strongly associated with Meadow Creek vegetation transects (Figures 4.1, 4.2, 4.3, and 4.5). *Crataegus douglasii* has been found to be related to disturbance induced seral stages of potential natural shrub and forest communities (Crowe and Clausnitzer 1997). Therefore, the species composition at Meadow Creek indicated an ecosystem where functioning processes have been damaged or are unbalanced with the landscape.

The woody vegetation may have been hindered by the grazing of cattle, elk, and deer. Since grazing pressure on the channel was not a factor measured in the study, relationships between the grazing pressure and woody vegetation structure density were not evaluated in terms of riparian condition. Grazing may have influenced riparian plant community composition; however, data from this study along with historical record of logging strongly suggest that the physical processes of annual ice floe is controlling Meadow Creek channel dimension, pattern, and profile.

North Fork Catherine Creek

The research stream reach of North Fork Catherine Creek was constrained by a road and rock dikes that prevented flooding onto the roadway. The road had confined the channel within a narrower valley, thereby altering the effective floodplain and leading to straightened channel sinuosity and steepened channel slope. Therefore, this channel was assessed using the potential criteria to determine if it was at riparian capability. North Fork Catherine Creek was in a valley type II, defined as a steep to moderate side slope gradients with valley gradients less than 4% (Rosgen 1996). Valley type II is often associated with B-stream types.

The channel morphology measurements were determined to be within the range of variability of the reference baseline established by Rosgen (1996). The channel morphology attributes keyed out to a B3 Rosgen channel, with a low value of channel sinuosity (see discussion in Chapter 4 on range of variability). The classification of North Fork Catherine Creek indicated that the channel type delineation agreed with the valley type. Thus, this channel was considered for the determination of riparian capability.

Bankfull measurements at the physical transects and gauge station on North Fork Catherine Creek aligned with the regional curve for bankfull area versus bankfull discharge (Figures 4.6, 4.7, and 4.8). This indicated a channel condition at a physical condition similar to streams at potential. Similar to the Grande Ronde River, the scatter displayed in bankfull width and bankfull depth from the regional curve was less than the reference potential, an indication of a physically altered channel. The bankfull measurements of width and depth were within the scatter of the regional reference streams, thereby suggesting that North Fork Catherine Creek was at the highest physical condition given the channel confinement by the road.

It was observed during the physical and vegetation surveys that several mid-channel bars and backflow channels were present. Their presence was an indication of either current or past channel adjustments, such as changes in flow regime, floods, or vegetation removal, or channel morphology changes (Rosgen 1996). Thus, the presence of the mid-channel bars was an indication of depositional physical channel changes. Woody vegetation composition was established on the mid-channel bars, with a diversity of age classes, which suggested that system processes were repairing, or had repaired, to allow for new establishment of vegetation on the depositional mid-channel bars. The species richness of woody vegetation present throughout all flood zones and upon the man-made rock dikes offered further evidence of a riparian system that was able to support desired woody riparian vegetation. Additionally, the presence of young saplings along the bankfull-25-year flood elevation indicated the increased bank stability and improvement of riparian hydrology processes.

The vegetation species composition and distribution offered further validation for the riparian condition of North Fork Catherine Creek. The dominant plant association present on the streambanks of the vegetation transects was the complex of Black Cottonwood/Mountain Alder- Red-osier Dogwood plant association *(Populus trichocarpa/Alnus incana-Cornus stolonifera*; Table 5.2) where the subdominant overstory community was grand fir instead of black cottonwood.

TABLE 5.2: Vegetation Composition for North Fork Catherine Creek	
NFC Vegetation Assocaitions	
Overstory	*Abies grandis*
Subdominant Overstory	*Populus trichocarpa* *Picea engelmannii*
Tall shrubs	*Alnus incana* *Cornus stolonifera* *Salix sitchensis*
Mid-Montane Community	Black Cottonwood/Mountain Alder-Red-osier Dogwood plant association with grand fir dominant overstory species

The cottonwood plant association is often associated with B3, B4, C3, and C5 channels with an average valley width of 107 m in northeast Oregon (Crowe and Clausnitzer 1997). North Fork Catherine Creek was determined to be a B3 channel, with a confined average valley width of 57 m. The overstory subdominance of grand fir was determined to be a response to the valley width confinement where the establishment of *Populus spp.,* a flow dependent species (Lite et al. 2005 and Harris 1987) was hindered. In this study, it was concluded that the plant association with the overstory grand fir component was the plant association responding to the highest attainable physical attributes. Further studies should test the potential factor influencing this species dominance. The determined channel and valley morphology measurements and responding vegetation attributes of richness and diversity led to the conclusion that the North Fork Catherine Creek stream reach was at riparian capability.

RIPARIAN CAPABILITY CRITERIA

The final objective of the project was to describe criteria that could be applied to the determination of riparian condition, i.e. potential or capability. Barrington et al. (2001) proposed a definition of capability for management application, yet failed to offer measurement criteria for determining capability. Rosgen (1996) formulated a system used to assess river condition with quantitative measurement criteria, which was used in this study for the determination of riparian capability. However, his system offered weak reference to species composition responding to the stream condition. This field study determined that the utilized measurements of riparian potential, regional curves, and Rosgen stream type classifications were acceptable methods for assessment of the physical condition of each stream reach. In addition, species composition and association to the physical and environmental attributes were determined to offer further criteria for determination of riparian capability.

The physical and environmental gradients determined from this study were the factors that explained that variance in species composition along two streams at riparian capability and one stream below capability. The species composition association to bankfull, 25-year flood elevation, and floodprone widths supported the use of channel measurements for the determination of species composition on streams that have been physically assessed for riparian capability. The additional measurement of 25-year flood elevation suggested additional criteria that could be included in the determination of riparian capability, specifically in relation to vegetation condition. However, further research should be done to determine its effectiveness and to establish acceptable measurements across montane riparian systems throughout the United States.

The other gradients associated with species distribution across the three streams and their flood zones provided further criteria that could be used to assess riparian vegetation communities present along streams at riparian capability. Gradients such as canopy cover, light intensity, dormancy air temperature, channel substrate, and understory vegetation attributes could be used in a detailed assessment of the vegetation component of riparian condition. The application of each gradient to the assessment of riparian capability should be further studied to determine the range of acceptable measurements across montane riparian systems throughout the United States.

Overall, the physical and environmental attributes determined to influence species composition on these streams can be used for riparian management efforts. First, the study demonstrated potential results quantifying woody riparian vegetation in the context of physical and environmental attributes. Second, the determined species-environmental relationships offered potential factors that could be assessed prior to woody riparian restoration effects or management. Finally, this field study provided the quantitative analysis of riparian capability along montane streams in northeast Oregon and an acceptable method for the determination of riparian capability.

CONCLUSIONS

Significance of Research

Past research has provided a wealth of information about the environmental variables that influence the distribution of woody riparian species. However, there is little information relating both the environmental and hydrologic variables to species distribution and structure. Additionally, little effort has been given to understanding the relationships between channels assessed as being at potential versus channels assessed as functioning at capability. Hence, the project strove to fill the gap in the understanding of woody riparian ecosystems and to provide a current application to montane riparian ecosystems in northeast Oregon.

The aim of the research was to expand the information, first by evaluating physical and environmental variables related to woody riparian distribution within three streams and their hydrologic flood elevations. Second, the aim was to provide morphologic/environmental factors and relationships that could be quantified and monitored to assess woody riparian vegetation. Finally, the objective was to assess the riparian condition (i.e. potential or capability) of three montane channels confined by an introduced constraint. Through this research, the hope was to expand the research base for managers and agencies, which would enable better riparian management and lead to a better understanding and classification of riparian systems' current and attainable condition.

Research Limitations

Though the intent of this research was to fill the gap of knowledge of montane riparian systems, it is important to mention its extent and limitations in order to insure the appropriate application of the observed ecological relationships. The determined key environmental variables and species relationships hold true for the three stream reaches within the Wallowa-Whitman National Forest. Relationships of riparian characteristics to the definition of capability additionally only apply to the three stream reaches, each under the current infrastructure constraints. Potentially, the relationships and measurable variables can be applied to related streams with similar morphologic classification and a similar extent of the constraint upon the landform and hydrology. It is advised that comparisons between similar riparian systems and the researched streams, as well as causal relationships for the species distribution patterns, should be used with caution.

Additionally, the measured species-environmental relationships were found to be a function of both the current and historical attributes of the three separate watersheds. Though efforts were made to gather extensive flow and environmental data, there was a limit of only thirteen years of applicable flow data and two growing seasons of climatic data. Therefore, the hydrologic zones and climatic conditions were limited to current hydrologic impacts and did not include historic hydrologic and climatic patterns that established the majority of the woody riparian vegetation.

Overview of Key Woody Vegetation Relationships and Capability

Physical, environmental, and hydrologic attributes were measured to determine their relationship to woody riparian species composition along streams of varying conditions. Overall, key environmental gradients related to species composition and distribution were determined through the study. These gradients were the physical characteristics of the channel, environmental attributes of canopy cover in the riparian zone; weaker gradients were days below freezing during dormancy, channel and surface particle composition, and flood zone distance. Each of these key physical and environmental attributes of the three streams were related to ordination of vegetation transects based on species composition differences within the vegetation transects. These attributes initially demonstrated utility for the assessment of woody riparian composition and distribution. Additionally, the attributes provided a suite of quantifiable factors, which could be added to the woody vegetation assessment prior to restoration or as part of an assessment of channel condition at a stream with human-imposed constraints.

As with Rosgen's criteria for assessing river systems at potential, channel width and channel material composition were determined to be criteria related to the species composition of these three streams determined to be at or near capability. The physical and environmental gradients offered evidence that channel and flood zone widening brought about by infrastructure constraints or other channel adjustments resulted in different woody riparian communities. The grouping of each stream, based on the species composition, showed that the strong physical variables of bankfull width, floodprone width, valley width, and the 25-year flood elevation width were measurable attributes, which could be used to indicate riparian vegetation composition and distribution or to assess riparian condition. Further research should be done across a variety of riparian systems to determine the reference values of the channel morphology and 25-year flood widths that would be the indication of a channel functioning at riparian capability.

In addition to the physical attributes of the ecosystem, it was determined that environmental attributes of canopy cover, temperature, particle composition, and understory vegetation were additional factors related to the stream differences, and potentially an indication of the range of woody vegetation community characteristics of channels at riparian capability. However, the reference baseline values of these attributes could not be determined from this study and should be further analyzed for effective use in assessment of riparian capability.

Ordination results showed that understory community attributes of boulder, grass, and bareground cover were related to the species composition of the flood zones; while distance from greenline of the flood zone boundary was weakly associated to the species composition variation. These understory community attributes supported the analysis of shrub understory composition, which could be applied to the assessment and maintenance of woody species communities. Species composition differences between the defined flood zones—greenline to bankfull, bankfull to 25-year flood elevation, and 25-year flood elevation to floodprone—were not found to be significant. This indicated the weak utility for the application and measurement of flood zone physical and environmental attributes.

This field study described the riparian condition of each channel based on measured morphology and hydrologic characteristics assessed against Rosgen's stream condition assessment and regional curves of channel measurements. It was concluded that the Grande Ronde River and North Fork Catherine Creek were at the highest attainable condition given valley and floodplain confinement by roads. Meadow Creek was found to be below riparian capability, where roads and splash dams had altered the channel morphology and hydrologic patterns, and where ice floes hindered the vegetation establishment and channel repair mechanisms. The species composition differences between the three channels supported the conclusion of riparian condition. In addition, the physical and environmental gradients were found to be criteria that could be used for the assessment of riparian capability.

LITERATURE CITED

Aguiar, F.C. and M.T. Ferreira. 2005. Human-disturbed landscapes: effects on composition and integrity of riparian woody vegetation in the Tagus River basin, Portugal. Environmental Conservation. 32(1):30-41.

Amlin, N.M., S.B. Rood. June 2002. Comparative tolerances of riparian willows and cottonwoods to water table decline. Wetlands 22 (2) 338-346.

Anderson, M.J. 2001. A new method for non-parametric multivariate analysis of variance. Austral Ecology 26:32-46.

Barrington, M., D. Wolf, and K. Diebel. 2001. Analyzing Riparian Site Capability and Management Options. Journal of American Water Resources Association 37(6):1665-1678.

Beckham, S.D. 1994. Grande Ronde River, Oregon: River widths, vegetative environment and conditions shaping it conditions, Elgin to Headwaters. Eastside Management Project.

Bendix, J. 1994. Among-site variation in riparian vegetation of the southern California Transverse Ranges. American Midland Naturalist, 132(1):136-151.

Bendix, J. 1999. Stream power influence on southern California riparian vegetation. Journal of Vegetation Science 10: 243-252.

Brunsfield, S.J., F.D. Johnson. 1985. Field Guide to the Willows of east-central Idaho. University of Idaho. Forest, Wildlife, and Range Experimental Station. Bulletin NO. 39. 82 pp.

Coles-Ritchie M. 2006. Effectiveness monitoring for streams and riparian areas within the Upper Columbia River Basin: Sampling protocol, Vegetation parameters. Logan, Utah: U.S.D.A. Forest Service, PIBO Effectiveness Monitoring Program. 31pp.

Cooper, R.M. 2005. Estimation of peak discharges for rural, unregulated streams in eastern Oregon: U.S. Geological Survey Scientific Investigations Report 06-001. 152pp.

Crowe, E.A., R.R. Clausnitzer. 1997. Mid-Montane wetland plant associations of the Malheur, Umatilla and Wallowa-Whitman National Forests. USDA Forest Service, Wallowa-Whitman National Forest Tech. Paper R6-NR-ECOL-TP-22-97. 306pp.

Daubenmire, R. 1959. A canopy–coverage method of vegetation analysis. Northwest Sci., 33:43-64.

Dufour, S., N. Barsoum, E. Muller and H. Piegay. 2007. Effects of channel confinement of pioneer woody vegetation structure, composition and diversity along the River Drome (SE France). Earth Surface Processses and Landforms. 32:1244-1256.

Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 76:345-366.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby. 1998. Measuring and Monitoring Plant Populations. BLM tech. Reference. BLM/RS/ST-98/005+1730. Denver CO: U.S. Department of the Interior, Bureau of Land Management, Nat. Applied Resource Sciences Center. 492p.

Emmett, W.W. 1975. The channels and waters of the Upper Salmon River area, Idaho. US Department of the Interior, Geological Survey. Professional Paper 870-A: Denver, CO. 113p.

Gordon, N.D., T.A. McMahon, B.L. Finlayson, C.J. Gippel, and R.J. Nathan. 2004. Stream Hydrology: an introduction for ecologists. Second edition. JohnWiley and Sons Inc. New Jersey. 422p.

Hardy, T., P. Panja, and D. Mathias. 2005 WinXSPRO, A Channel Cross Section Analyzer, User's Manual, Version 3.0. Gen. Tech. Rep. RMRS-GTR-147. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 94 p.

Harrelson, C.C., C.L. Rawlins, J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station. 61p.

Harris, R.R. 1987. Occurrence of vegetation on geomorphic surfaces in the active floodplain of a California alluvial stream. American Midland Naturalist. 118(2): 393-405.

Herrick, J.E., J.W. VanZee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2005. Monitoring Manuel for Grassland, Shurbland, and Savanna Ecosystems: Volume II: Design, supplementary methods and interpretation. USDA-ARS Jornada Experimental Range. 199 p.

Holmgren, N.H., P.K. Holgrem, and A. Cronquist. 2005. Intermountain Flora, Volume 28: Subclass Dilleniidae. New York Botanical Garden Press, New York. 488p.

Hupp, C.R., W.R. Osterkamp. 1985. Bottomland vegetation distribution along Passage Creek, Virginia in relation to fluvial landforms. Ecology. 66(3):670-681.

Interagency Advisory Committee on Water Data. 1982. Guidelines for determining flood flow frequency: Bulletin 17B of the Hydrology Sub- committee. Office of Water Data Coordination U.S. Geological Survey. Reston, Virginia. 28 p.

Karrenberg, S., P.J. Edwards, J. Kollmann. 2002. The life history of Saliacaceae living in the active zone of floodplains. Freshwater Biology. 47:733-748.

Kelley, C.E, and W.C. Krueger. 2005. Canopy cover and shade determination in riparian zones. Journal of American Water Resources Association 41(1): 37-46.

Klingeman, P. 2002. Analysis Technique Flood Ananlysis Tutorial with Daily Data. Stream Flow Evaluation for Watershed Restoration Planning and Design. Oregon State University. Year observed 2006. http://water.oregonstate.edu/streamflow.

Kovalchik, B.L. and R.R. Clausnitzer. 2004. Classification and Management of Aquatic, Riparian, and Wetland Sites on the National Forests of Eastern Washington: Series Description. USDA-Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-593. 141-160.

Kruskal, J.B. 1964. Nonmetric multidimensional scaling: a numerical method. Psychometrika 29: 115-129.

Lite, S.J., K.J. Bagstad, J.C. Stromberg. 2005. Riparian plant species richness along lateral and longitudinal gradients of water stress and flood distrurbance, San Pedro River, Arizona, USA. Journal of Arid Environments 63: 785-813

Lytjen, D.J. 1999. Ecology of Woody Riparian Vegetation in Tributaries of the Upper Grande Ronde River Basin, Oregon. Master Thesis OSU library. 76p.

Mather, P.M. 1976. Computational methods of multivariate analysis in physical geography. J. Wiley and Sond, London. 532 p.

McBride, J.R., Strahan, J. 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream. American Midland Naturalist. 112 (2): 235-245.

McCune, B. Personal Communication. January 2007.

McCune, B. and J.B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Glendeden Beach, Oregon. 300p.

McCune, B. and M. J. Mefford. 1999. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.05 MjM Software, Gleneden Beach, Oregon, U.S.A

Miekle, P.W., Jr. 1984. Meterological applications of permutation techniques based on distance functions, p. 813-830. In P.R. Krishaniah and P.K. Sen, eds., Handbook of Statistics, Vol. 4. Elsevier Science Publishers.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold: New York, 642 p.

Morisawa, Marie. 1968. Streams: their dynamics and morphology. McGraw-Hill Book Company: New York, 166 p.

Nilsson, C., G. Grelsson, M. Johansson, and U. Sperns. 1989. Pattern of plant species richness along riverbanks. Ecology. 70(1):77-84.

Ohmann, L.F., M.D. Knighton, R. McRoberts. 1990. Influence of flooding duration on biomass growth of alder and willow. Res. Paper NC-292. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 5 p.

Patten, D.T. 1998. Riparian ecosystems of semiarid North America: Diversity and human impacts. Wetlands 18(4):498-512.

Prichard, D.E., H. Barrett, J. Cagney, R. Clark, J. Fogg, K. Gilbert, P.L. Hansen, B. Mitchell, and D. Tippy. 1993. Riparian area management: process for assessing proper functioning condition. US Department of the Interior, Bureau of Land Management, Technical Reference 1737-9: Denver, CO. 51p.

Prichard, D.E., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leanard, B. Mitchell, and J. Staats. 1998. Riparian area management: a users guide to assessing proper function condition and the supporting science for lotic areas. US Department of the Interior, Bureau of Land Management, Technical Reference 1737-15: Denver, CO. 126p.

Rood, S.B., J.H. Braatne, F.M.R. Hughes. 2003. Ecophysiology of riparian cottonwoods: stream flow dependency, water relations and restoration. Tree Physiology 23: 1113-1124.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology: Pagosa Springs, CO. 8.43pp

Sacchi, C.F., and P.W. Price. 1992. The relative roles of abiotic and biotic factors in seedling demography of Arroyo willow (*Salix lasiolepis*: Salicaceae). American Journal of Botany. 79(4):395-405.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C., and Broderson, W.D. (editors), 2002. Field book for describing and sampling soils, Version 2.0. National Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Smith, D. G., and C.M. Pearce. 2000. River ice and its role in limiting woodland development on a sandy braid-plain, Milk River, Montana. Wetlands. 20(2):232-250.

Smith, D.G. 1980 River ice processes: threshold and geomorphologic effects in northern and mountain rivers. In: Coates, D.R., J.D. Vitek. eds. 1980. Thresholds in geomorphology. George Allen and Unwin LTD, London.

Stromberg, J.C., D.T. Patten, B.D. Richter. 1991. Flood flows and dynamics of Sonoran riparian forests. Rivers. 2(3):221-235.

Teversham, J.M. and O. Slaymaker. 1976. Vegetation composition in relation to flood frequency in Lillooet River Valley, British Columbia. Catena. 3:191-201.

van Coller, A.L., K.H. Rogers, G.L. Hertiage. 2000. Riparian vegetation-environment relationships: Complimentarity of gradients versus patch hierarchy approaches. Journal of Vegetation Science. 11(3):337-350.

Walker, Lawrence R., and F. Stuart Chapin. 1986. Physiological controls over seedling growth in primary succession on an Alaskan floodplain. Ecology. 67(6):1508-1523.

Wallowa-Whitman National Forest. 2006. La Grande Ranger District monitoring Fish and Water Department.

Webb, G.M., J.D. Brotherson. 1988. Elevational changes in woody vegetation along three streams in Washington County, Utah. Great Basin Naturalist. 48(4):512-529.

Williams, JG; Matthews, G. 1990. Willow ecophysiology: Implication for riparian restoration. Environmental Restoration Science and Strategies for Restoring the Earth. 196-202p.

Winward, A.H. 2000. Monitoring the vegetation resources in riparian areas. Gen. Tech. Report. RMRS-GTR-47. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49p.

Wolman, M.G., 1954. A method of sampling coarse bed material. American Geophysical Union, Transactions. 35:951-956.

APPENDICES

APPENDIX A- TEMPERATURE CHART

Mean Minumum Monthly Temperatures, in degrees Celsius						
	2006			2007		
Month	GRR	MDW	NFC	GRR	MDW	NFC
January	-----	-----	-----	-4.28	-4.31	-4.21
February	-----	-----	-----	-3.08	-2.82	-2.51
March	-----	-----	-----	-2.8	-2.17	-1.65
April	-----	-----	-----	-1.7	-0.97	-0.16
May	-----	-----	-----	-0.08	0.64	1.54
June	-----	-----	-----	3.29	3.8	5.3
July	6.33	7.11	8.72	7.22	7.73	9.42
August	2.97	3.78	5.81	3.35	4.39	6.43
September	1.3	1.84	3.84	0.06	0.51	3.03
October	-2.51	-2.27	-0.7	-----	-----	-----
November	-2.37	-2.22	-1.23	-----	-----	-----
December	-3.81	-3.84	-3.63	-----	-----	-----

APPENDIX B: LIGHT INTENSITY CHART

Sum of Daily lums/ft² by Month						
	2006			2007		
Month	GRR	MDW	NFC	GRR	MDW	NFC
January	-----	-----	-----	303	309	296.5
February	-----	-----	-----	305	309	307
March	-----	-----	-----	387	391	388.5
April	-----	-----	-----	421.5	426	425
May	-----	-----	-----	480	483.5	481.5
June	-----	-----	-----	491.5	492.5	489
July	498.5	501.5	494.5	494.5	497.5	493.5
August	458.5	465.5	458	458.5	467	457.5
September	395.5	405	396.5	394.5	397	396
October	358	366.5	359	-----	-----	-----
November	298	307	300	-----	-----	-----
December	287.5	297.5	282.5	-----	-----	-----

APPENDIX C: SPECIES LIST

Species list nomenclature from Flora of the Pacific Northwest for shrubs and trees, Intermountain Flora for willows

Code	Common Name	Scientific Name
ABGR	grand fr	*Abies grandis* (Dougl.) Forbes
ACGL	Rocky mountain Maple	*Acer glabrum* Torr.
ALIN	Mountain alder	*Alnus incana* (L.) Moench
ALSI	Sitka Alder	*Alnus sinuata* (Regel) Rydb.
AMAL	serviceberry	*Amelanchier alnifolia* Nutt.
CADO	hawthorn	*Crataegus douglasii* Lindl.
COST	red osier dogwood	*Cornus stolonifera* Michx.
LAOC	Western Larch	*Larix occidentalis* Nutt.
LOIN	twinberry	*Lonicera involucrata* (Rich.) Banks
PICO	lodgepole pine	*Pinus contorta* Dougl.
PIEN	engelmann spruce	*Picea engelmannii* Parry
PIPO	ponderosa pine	*Pinus ponderosa* Dougl.
POTR	cottonwood	*Populus trichocarpa* T.&G.
PRVI	chokecherry	*Prunus virginiana* L.
PSME	Douglas fir	*Pseudotsuga menziesii* (Mirbel) Franco.
Ribes	currant	*Ribies spp*
Rubus	raspberry	*Rubus spp*
SABE	bebbs willow	*Salix bebbiana* Sarg.
SABO	booths willow	*Salix boothii* Dorn
SACE	elderberry	*Sambucus cerulea* Raf.
SAEX	coyote willow	*Salix exigua* Nutt.
SALU	Whiplash willow	*Salix lucida* Muhl.
SAMA	mackenzie's willow	*Salix eriocephela* Michx. *Var mackenzieana* (Hook.) Dorn
SAME	Dusky willow	*Salix melanopsis* Nutt.
SAMO	Mountain willow	*Salix monticola* Bebb
SASI	sitka willow	*Salix sitchensis* Sanson ex Bong
SAWA	yellow willow	*Salix eriocephala* Michx. *Var watsonii* (Bebb) Dorn
SHCO	buffaloberry	*Shepherdia canadenis*
TABR	Yew	*Taxus brevifolia*

APPENDIX D: DATA MATRICES NOMENCLATURE

Transect Level of Analysis Nomenclature

GR-1L

Stream- TransectNumber Bank

Streams

GR- Grande Ronde River

MD- Meadow Creek

NF –North Forth Catherine Creek

Transect

Vegetation transect

Bank

L-Left

R-Right

Flood Zone Level of Analysis Nomenclature

G1L

StreamFloodZoneBank

Streams

G- Grande Ronde River

M- Meadow Creek

N –North Forth Catherine Creek

FloodZone

1-Greenline to Bankfull

2-Bankfull to 25-year elevation

3-25-year elevation to floodprone

Bank

L-Left

R-Right

APPENDIX E: FLOOD ZONE DATA MATRICES

Environmental Matrix: Flood Zone Level of Analysis, 18 flood zones, 20 attributes

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	C	Q	Q	Q	Q
	Distance	D50	15mDen	VW	FPW	25W	FreezeDays	WinterHour	%STRSL	SINU	STREAM	Gravel	Cobble	Sand	MS
G1L	2.35	43.61	54.33	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	2	2	2	2
G1R	2.02	43.61	51.55	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	1	1	2	3
G2L	4.06	43.61	54.33	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	1	1	1	3
G2R	3.63	43.61	51.55	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	3	2	3	2
G3L	7.51	43.61	54.33	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	2	2	2	3
G3R	8.70	43.61	51.55	61.93	27.14	15.10	208.00	2755.50	2.92	1.30	1	1	1	2	3
M1L	3.60	45.71	28.71	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	3	2	2	3
M1R	4.40	45.71	44.47	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	2	1	2	3
M2L	6.90	45.71	28.71	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	1	1	1	3
M2R	8.61	45.71	44.47	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	3	2	2	3
M3L	15.61	45.71	28.71	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	1	1	0	3
M3R	11.53	45.71	44.47	88.06	32.84	21.96	191.00	2811.00	0.71	0.97	3	2	1	0	3
N1L	0.50	87.72	85.21	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	3	2	2	2
N1R	0.74	87.72	60.05	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	2	2	2	2
N2L	1.47	87.72	85.21	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	1	1	1	4
N2R	0.97	87.72	60.05	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	3	2	2	2
N3L	4.26	87.72	85.21	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	3	2	2	3
N3R	6.41	87.72	60.05	57.42	20.03	11.89	172.00	2755.00	2.61	1.10	2	2	2	1	3

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	C	C	C	C
	Boulder	GrassCov	ForbCov	ShrubCov	SedgeCov	%FOLIAGE	%BG	%LITTER	%ROCK	%WOOD	%MOSS	ZONE1	ZONE3	R/L Bank	XS Zone
G1L	2	2	2	2	1	0	3	2	3	1	2	1	1	1	1
G1R	2	2	3	2	1	1	2	3	2	2	2	1	1	2	2
G2L	1	2	3	2	1	1	3	3	2	2	2	2	2	1	3
G2R	2	2	2	2	1	2	3	2	3	1	2	2	2	2	4
G3L	1	2	2	2	0	1	3	3	2	2	2	3	3	1	5
G3R	1	2	2	2	1	1	3	3	2	2	2	3	3	2	6
M1L	0	3	2	0	2	2	3	1	3	1	2	4	1	1	1
M1R	0	3	2	2	2	1	3	2	2	2	1	4	1	2	2
M2L	0	3	2	2	1	2	4	3	1	1	1	5	2	1	3
M2R	0	3	2	2	2	2	3	2	3	1	2	5	2	2	4
M3L	0	3	3	2	1	1	4	2	2	2	2	6	3	1	5
M3R	1	3	3	2	0	1	3	2	2	2	2	6	3	2	6
N1L	2	1	2	2	1	1	3	1	3	1	3	7	1	1	1
N1R	2	2	2	3	1	1	2	2	3	1	3	7	1	2	2
N2L	0	1	2	2	0	0	3	3	2	1	2	8	2	1	3
N2R	2	1	3	2	1	1	2	1	4	1	2	8	2	2	4
N3L	2	1	2	2	1	0	3	2	3	0	0	9	3	1	5
N3R	1	2	2	2	0	1	3	3	2	2	2	9	3	2	6

Community Matrix: Flood Zone Level of Analysis, 18 transects, 27 species. Density were converted to density classes.

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
	ABGR	ACGL	ALIN	ALSI	AMAL	COST	CRDO	LAOC	LOIN	PICO	PIEN	PIPO	POTR	PSME
G1L	1	0	4	2	2	5	0	0	4	2	4	0	0	3
G1R	0	2	5	3	2	4	0	0	4	2	3	0	1	0
G2L	2	0	5	3	3	5	0	0	4	3	4	1	0	4
G2R	0	4	5	4	4	5	0	0	4	2	4	2	4	2
G3L	1	0	4	1	2	4	0	2	2	4	4	0	0	4
G3R	0	1	2	0	2	4	0	0	3	2	4	1	0	2
M1L	0	0	4	0	0	0	0	0	0	0	0	0	0	0
M1R	0	0	4	0	0	0	2	0	0	0	1	0	0	0
M2L	0	0	4	0	0	4	2	0	0	0	0	1	0	1
M2R	0	0	4	0	0	4	0	0	0	0	0	0	0	0
M3L	0	0	1	0	1	3	2	0	0	0	0	2	0	0
M3R	0	2	2	0	2	0	0	0	0	0	0	0	0	1
N1L	4	0	4	0	4	4	0	0	0	0	3	0	2	0
N1R	3	0	4	2	0	4	0	0	0	0	0	0	6	0
N2L	3	0	4	0	2	4	0	0	0	0	0	0	0	0
N2R	4	0	4	3	0	5	0	0	0	0	3	0	6	0
N3L	4	2	4	0	3	4	0	0	0	0	3	0	0	0
N3R	4	2	4	1	2	4	0	0	2	0	3	1	4	0

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Ribes spp	Rubus spp	SABE	SABO	SACE	SALU	SAMA	SAME	SAMO	SASI	SAWA	SHCO	TABR	
G1L	5	0	0	2	2	1	3	5	4	0	4	2	0	
G1R	2	1	0	1	0	0	4	5	3	0	6	0	0	
G2L	4	0	0	0	0	0	0	4	3	0	2	2	0	
G2R	2	2	0	0	0	0	4	4	3	2	6	0	0	
G3L	2	1	0	0	0	0	2	2	2	0	1	2	0	
G3R	3	1	1	1	1	0	2	4	2	0	3	1	1	
M1L	0	0	0	0	0	0	0	4	0	0	1	0	0	
M1R	3	0	0	0	0	0	2	3	0	0	0	0	0	
M2L	0	0	0	0	0	0	3	4	0	0	0	0	0	
M2R	2	0	0	0	0	0	2	0	0	0	0	0	0	
M3L	0	0	0	0	0	0	0	0	0	0	0	0	0	
M3R	2	0	0	0	1	0	0	1	0	0	0	0	0	
N1L	4	0	0	0	0	0	0	6	0	4	4	0	0	
N1R	0	0	0	2	0	0	0	4	0	4	3	0	0	
N2L	2	2	0	0	0	0	0	0	0	3	2	0	0	
N2R	0	4	0	0	3	0	0	0	0	3	4	0	0	
N3L	4	0	0	0	0	0	0	0	0	1	2	0	0	
N3R	1	3	0	2	0	0	1	1	0	4	3	0	0	

Community Matrix: Flood Zone Level of Analysis, 18 transects, 27 species. Species height classes

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
	ABGR	ACGL	ALIN	ALSI	AMAL	COST	CRDO	LAOC	LOIN	PICO	PIEN	PIPO	POTR	PSME
G1L	1	0	3	2	1	3	0	0	2	2	2	0	0	3
G1R	4	0	3	2	1	2	0	0	2	4	3	2	0	3
G2L	3	0	2	2	1	3	0	4	2	2	3	0	0	3
G2R	0	1	3	3	2	3	0	0	2	2	4	0	1	0
G3L	0	1	3	2	1	3	0	0	2	1	4	3	2	3
G3R	0	3	3	0	2	3	0	0	2	4	2	2	0	4
M1L	0	0	2	0	0	0	0	0	0	0	0	0	0	0
M1R	0	0	3	0	0	2	2	0	0	0	0	1	0	1
M2L	0	0	3	0	1	0	3	0	0	0	0	2	0	0
M2R	0	0	4	0	0	0	1	0	0	0	0	0	0	0
M3L	0	0	4	0	0	3	2	0	0	0	0	0	0	0
M3R	0	2	4	0	2	0	0	0	0	0	0	0	0	1
N1L	2	0	3	0	3	2	0	0	0	0	4	0	2	0
N1R	1	0	5	0	2	3	0	0	0	0	0	0	0	0
N2L	3	2	4	0	2	2	0	0	0	0	3	0	0	0
N2R	5	0	4	4	0	2	0	0	0	0	0	0	1	0
N3L	2	0	4	3	0	2	0	0	0	0	5	0	2	0
N3R	4	3	3	3	2	2	0	0	2	0	3	4	2	0

	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	Ribes spp	Rubus spp	SABE	SABO	SACE	SALU	SAMA	SAME	SAMO	SASI	SAWA	SHCO	TABR	
G1L	1	0	0	2	2	3	2	2	2	0	2	1	0	
G1R	2	0	0	0	0	0	0	3	2	0	3	2	0	
G2L	2	2	0	0	0	0	2	2	2	0	3	2	0	
G2R	2	2	0	1	0	0	2	2	3	0	1	0	0	
G3L	1	1	0	0	0	0	2	2	3	2	1	0	0	
G3R	2	2	4	4	2	0	3	3	3	0	3	1	2	
M1L	0	0	0	0	0	0	0	1	0	0	1	0	0	
M1R	0	0	0	0	0	0	1	2	0	0	0	0	0	
M2L	0	0	0	0	0	0	0	0	0	0	0	0	0	
M2R	1	0	0	0	0	0	3	1	0	0	0	0	0	
M3L	1	0	0	0	0	0	3	0	0	0	0	0	0	
M3R	1	0	0	0	3	0	0	1	0	0	0	0	0	
N1L	2	0	0	0	0	0	0	2	0	2	1	0	0	
N1R	2	1	0	0	0	0	0	0	0	2	2	0	0	
N2L	1	0	0	0	0	0	0	0	0	2	2	0	0	
N2R	0	0	0	2	0	0	0	2	0	2	2	0	0	
N3L	0	1	0	0	2	0	0	0	0	3	3	0	0	
N3R	1	2	0	2	0	0	2	3	0	3	3	0	0	

APPENDIX F: ROSGEN'S CLASSIFICATION KEY FOR NATURAL RIVERS

Taken from Applied River Morphology (Rosgen 1996) Figure 5-3