AN ABSTRACT OF THE THESIS OF

Louanne R. Zweygardt for the degree of Master of Science in Rangeland Resources presented on May 30, 1995.

Title: Application of Stream Classification and Historical Land Uses for Managed Riparian Systems of Eastern Oregon.

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Twelve stream segments in the Silvies River drainage system were classified in the fall of 1993 and again in 1994, using a morphological classification of natural rivers (Rosgen 1994). Bankfull flow of stream channels is the key feature of this system. Measurement of bankfull is used in the calculation of entrenchment ratio and width/depth ratio. Analysis of the differences of the averages between years in bankfull measurements showed that despite being consistently repeated at the same locations along the channel, the measurements were found to be different ($p = 0.000163$ for entrenchment ratios and $p = 0.0208$ for width/depth ratios). Bankfull was found to be a non-repeatable field measure, therefore, a poor benchmark for a classification scheme.

Historical information collected for the study area indicated a history of domestic livestock use that dates back as far as the mid-nineteenth century. Although grazed by livestock for several years, settlement of the Bear and Silvies Valleys occurred mostly around the turn of the twentieth century after the stockgrower's homestead acts were passed. Ownership today is dominated by large (relative to the homestead days) ranches.

APPLICATION OF STREAM CLASSIFICATION AND HISTORICAL LAND USES FOR MANAGED RIPARIAN SYSTEMS OF EASTERN OREGON

by

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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.

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Louanne R. Zweygardt, Author

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INTRODUCTION

Riparian areas are becoming an increasingly debated topic in both the scientific community and for the general public as well. The importance of these relatively small but unique areas has been well documented (Kauffman and Krueger 1984, Roath and Krueger 1983, Elmore and Beschta 1987). Numerous symposia have been conducted and a great deal of study has been done to try to increase our understanding of the nature and processes involved in maintaining these highly resilient ecosystems. The portion of the riparian zone responsible for its creation and maintenance is the stream channel itself. Streams come in many different shapes and sizes, therefore, in order to have some way to compare the results of one study to other streams, some type of classification needs to be done to determine the similarity of the systems involved (Rosgen 1985).

Several classification systems have been developed to accomplish this, some very general and some very intricate and specific. The usefulness of a classification scheme depends on its ability to relate to a number of different stream types and to be "user friendly". David L. Rosgen has devoted a large portion of his career to the development of a classification scheme for natural rivers. As Mr. Rosgen's knowledge of river systems has increased his classification system has evolved and changed. In particular, his definition of entrenchment, a critical component in his classification scheme has changed. This along with other significant changes has produced a discontinuity in the classification of streams through time using his system. His versions from 1989 to 1991 are currently used by many of the Forest Service districts (Swanson 1994). This project attempted to implement the most recent form of the morphological classification of natural rivers (Rosgen 1994).

SARE Project

In 1992 a grant was awarded to the Departments of Agriculture and Resource Economics, Fisheries and Wildlife and Rangeland Resources by Sustainable Agriculture in Research and Education (SARE). The project was to examine alternative grazing systems on riparian areas of semi-arid Eastern Oregon. This thesis deals specifically with the history of the study area and the riparian pastures involved in the study, and the classification of the streams that run through them.

Research Questions

1) Is there historical evidence that after a century of livestock grazing and vegetation management (manipulations) geomorphology has changed or been affected?

2) Is bankfull a repeatable field measurement?

3) Are water table levels related to the creek entrenchment ratios and width/depth ratios of the morphological classification of natural rivers (Rosgen 1994) classification system?

Objectives

1) To collect pertinent historical data available on the research area. Included was information on post-settlement grazing, vegetation manipulation as well as other disturbances on the site.

2) To determine if a relationship exists between history and current geomorphology.

3) To classify the streams in the experimental area in terms of the morphological classification of natural rivers (Rosgen 1994).

4) To determine if bankfull can be repeatably identified in the field.

5) To determine if a relationship exists between water table levels, creek entrenchment ratios, and width/depth ratios.

6) To determine if a relationship exists between vegetation structure (primarily woody riparian corridor vegetation) and stream geomorphology as it is manifested in terms of entrenchment ratios, width/depth ratios and water table levels.

Conceptual Framework

Vegetation is a very efficient stabilizer of stream banks as it serves to dissipate the kinetic energy of the running water as well as hold the soils together with extensive root systems. Removal of the vegetation and changing the composition (from woody to annuals) can have a significant affect on the ability of the banks to withstand erosive forces. There are a number of factors that can bring about these vegetative changes. Once the bank stability is decreased, erosion may occur in the form of bank sloughing and the sediment will be carried downstream in a laterally unstable stream. This change in bank form will increase the width/depth ratio of the stream which will lower the water table. Some woody species are dependant on ground water during the dry season, so as a result will decrease in number and vigor. The plant composition will change dramatically in response to the lowering of the water table. This further decrease in woody vegetation and change in vegetative composition will increase bank instability and cause a decline in the system in a spiralling fashion.

Null Hypotheses

Ho1: No relationship exists between the history of land use and current fluvial geomorphology. (Objectives 1 and 2)

Ho2: There is no difference between years in bankfull width/depth ratios and entrenchment ratios. (Objective 4)

Ho3: Water table levels are not correlated with creek entrenchment ratios. (Objective 5)

Ho4: Water table levels are not correlated with width/depth ratios. (Obj. 5)

Ho5: Entrenchment ratios do not change with differences in riparian corridor vegetation structure. (Objective 6)

Ho6: Width/depth ratio does not change with differences in riparian corridor vegetation structure. (Objective 6)

LITERATURE REVIEW

Stream Classification

Over the years there has been an ongoing debate over the existence, usefulness and possible field identification of a bankfull discharge. In studying streams, it is important to develop a frame of reference or common ground from which to compare. This is made difficult by the nature of streams since they are so variable from year to year, month to month and even day to day. Their behavior is dependent on many factors. The concept of a dominant or effective discharge has risen from the search for a single discharge to represent the variable regime of flows (Andrews 1980, Dunne and Leopold 1978, Dury 1976, Leopold 1974, Wolman and Miller 1960, Knighton 1984). The assumption that stream channels are self-formed is strongly supported by the concept of a dominant discharge. This would be the discharge primarily responsible for the formation of the stream channel (Andrews 1980, Dunne and Leopold 1978, Dury 1976, Leopold 1974, Wolman and Miller 1960, Andrews 1983, Emmett 1975, USDA Forest Service 1985). Those streams which are not self-formed (ie. bedrock channels; those significantly altered by man through major dams, reservoirs, diversions or urbanization; potholes) are subject to a different set of controls (USDA Forest Service 1985). A self-formed channel would conceivably be large enough to handle modest flows but not the larger infrequent flows (Dunne and Leopold 1978).

Flows that exceed the capacity of the channel will flow onto the relatively flat surface adjacent to the stream called the floodplain. The floodplain is the depositional feature of the channel which is built upon during high flows when the water velocity is decreased on the overflow surface and deposition of sediment occurs (Dunne and Leopold 1978, Emmett 1975). Floodplains can have different definitions for different professions. The one given above is utilized by fluvial geomorphologists while a more general definition of simply the valley flat is used by engineers (Dunne and Leopold 1978, Leopold 1974, Stream Systems Technology Center 1993). It is important to identify the difference between the floodplain being built under the present climatic regime and abandoned floodplains or terraces (Dunne and Leopold 1978, Nolan et al. 1987, Stream Systems Technology Center 1993, Woodyer 1968, Williamson et al. 1992). The flow which just fills the banks without overflow would conceivably be this dominant or effective discharge and has been equated to the term bankfull (Andrews 1980, Dunne and Leopold 1978, Dury 1976, Leopold 1974, Wolman and Miller 1960, Andrews 1983, Emmett 1975, USDA Forest Service 1985).

There have been several arguments put forth that dispute the bankfull discharge as being the most effective discharge in the formation of channels (Harvey 1969, Nolan et al. 1987, Pickup and Warner 1976, Knighton 1984). Nolan et al.(1987) and Pickup et al.(1976) both found that bankfull discharge was larger than the most effective discharge and thus less frequent. Knighton (1984) reported that bankfull has been found to be both too large and too small to be the effective discharge as well as the right size for predictions in some studies. The explanation for these differences may come from drainage size (Wolman and Miller 1960, Knighton 1984), or from climatic differences, in particular temperate vs. arid climates (Wolman and Gerson 1978, Wolman 1955). Harvey (1969) argued that channel formation is a far more complex process than can be explained by the occurrence of a single dominant flow. He submitted that vegetation and discharge regime are important factors overlooked by the bankfull proponents.

Following the line of argument that a single most effective flow exists, the frequency of such a discharge is important for planning purposes and predicting stream patterns. It needs to be examined to determine whether that flow is one of high-magnitude and low frequency or one of low-magnitude and high frequency (Nolan et al. 1987, Wolman and Miller 1960, Wolman and Gerson 1978). A specific return interval of 1.5 years (Andrews 1980, Dunne and Leopold 1978, Leopold 1974, Wolman and Miller 1960, Woodyer 1968, Knighton 1984) or 1.58 years (Dury 1976) has been presented as the estimated frequency of bankfull floods. This means that bankfull can be expected every year or every other year, and corresponds to a relatively frequent event. Williams (1978) found that even though the rivers studied had an average return interval of 1.5 years on the annual flood series, the range was from 1 to 32 years indicating a wide range of variability. This suggests that the 1.5 year flood will not represent bankfull discharge in all cases. Knighton (1984) found that a link can be established between dominant, most effective and bankfull discharges with a return interval of 1-2 years but also recognized that there were limitations to that link. He concluded by stating "Bankfull discharge is not necessarily of constant frequency or the most effective flow. Channel form is the product not of a single formative discharge but of a range of discharges which may include bankfull and of the temporal sequence of flow events. However, the bankfull channel is the one reference level which can reasonably be defined and it remains intuitively appealing to attach morphologic significance to bankfull flow." (p.96).

Despite Knighton's (1984) statement that bankfull can be reasonably defined, Williams (1978) identified ten different definitions of bankfull used in the literature. He then added an eleventh of his own. Knighton (1984) himself admitted that one of the limitations to the use of bankfull was the difficulty of defining it in the field. Williams (1978) compared five of the definitions he felt were the strongest and eliminated the other six for various reasons. Two of the definitions were related to depositional surfaces: 1) The height of the valley flat (Dury 1976, Woodyer 1968); 2) The level of the active floodplain (Andrews 1980, Dunne and Leopold 1978, Hedman and Osterkamp 1982, Leopold 1974, Nolan et al. 1987, Riley 1972, Wolman and Miller 1960, Woodyer 1968, Emmett 1975, Knighton 1984, Leopold et al. 1964, USDA Forest Service 1985, Williamson et al. 1992, Wolman and Leopold 1957). The other three required measurement of cross sections: 1) The elevation at which the width/depth ratio of the cross section becomes a minimum (Harvey 1969, Pickup and Warner 1976, Beschta and Platts 1986, Hey and Thorne 1986, Williamson et al. 1992, Wolman 1955); 2) The stage corresponding to the first maximum of the Riley (1972) bench index; 3) The stage corresponding to a change in the relation of cross-sectional area to top width (Williams 1978). Vegetation limits have also been used in defining bankfull in the field (Dunne and Leopold 1978, Harvey 1969, Riley 1972, Emmett 1975, USDA Forest Service 1992).

The large number of definitions available, and the difficulty of applying those definitions in the field has been recognized by many (Harvey 1969, Stream Systems Technology Center 1993, Knighton 1984, Leopold et al. 1964, Gregory and Walling

1973). Harvey (1969) argued that floodplain surfaces yield bankfull stages too high, and that vegetation limits and break in slope yield stages too low. He used the stage where width/depth ratio is at a minimum because he felt that it yielded a stage in between the others that best represented the bankfull stage and he was able to apply it consistently on all cross sections. This method has been used by others as well (Pickup and Warner 1976, Beschta and Platts 1986, Hey and Thorne 1986, Williamson et al. 1992, Wolman 1955), but it has severe limitations when dealing with recently incised channels since it is dependent on channel shape (Pickup and Warner 1976, Riley 1972). The definition of bankfull as mean high water line has also been the subject of several boundary dispute lawsuits (Huber 1995).

Wahl (1984) and Hedman and Osterkamp (1982) modified the traditional bankfull slightly in their assessment of the geometry of stream channels. They both identified three geomorphic reference levels namely within-channel bars, active channel section and main channel section. The main channel section corresponds with the definition of bankfull at the level of the floodplain or the stage at which overbank flooding occurs. This measure was discarded from use due to the inconsistency of the floodplain on some streams. They used instead, the active channel for measurements and discussion. The active channel was at a lower stage than bankfull and defined by break in slope and the lower limit of vegetation. It has been argued by some that this is also the definition of bankfull (Dunne and Leopold 1978, Harvey 1969, Riley 1972, Emmett 1975, USDA Forest Service 1992). This example helps to illustrate the inconsistency and difficulties faced by those who intend to use bankfull in delineating streams. The Forest Service (1985) approach was perhaps the most appropriate. In field identification of bankfull, hydrologists rely on several indicators rather than just one. A combination of the limit of perennial vegetation, elevation of depositional features (floodplain), change in grain size, break in slope and others gives the observer a reference level. The Forest Service recognized the need to make several cross-sectional measurements rather than a single cross section.

Rosgen (1994) developed a morphological classification of natural rivers that was designed in response to the need to categorize river systems by their morphology. Anyone working with river systems recognizes the need to predict river behavior from its appearance, to be able to extrapolate from one system to a similar one, and to have a consistent and reproducible frame of reference with which to work. Rosgen recognized that in order to satisfy these needs, his system must utilize measurable morphological features. One such feature could be bankfull width and depth. As outlined above, the problem lies in identifying bankfull in the field. The morphological classification of natural rivers (Rosgen 1994) uses measures of channel gradient, sinuosity, bankfull width/depth ratio, dominant particle size of bed and bank materials and entrenchment of channel. It placed a great deal of emphasis on the entrenchment ratio which is dependent on bankfull width. This system has been used by many researchers since its development in the early 1980's (Swanson 1988, USDA Forest Service 1992, Manning and Padgett 1992, Hudak and Ketcheson 1992, Petersen et al. 1992, Carlson et al. 1992).

Bankfull would be a useful concept if it could be consistently applied. The need for a reference level has been well demonstrated. The morphological classification of natural rivers (Rosgen 1994) provided a method by which river systems can be compared. However, consistency and repeatability are the keys to the success of such a system, and those have yet to be demonstrated.

History

Objectives 1 & 2 dealt with historical land uses. The following discussion describes the documented relationships:

Grant County

To begin this section on history, I will use a quote from a 1902 publication of the Western Historical Publishing Company titled An Illustrated History of Baker, Grant, Malheur and Harney Counties: "The accuracy and completeness of such a work depends not alone on the conscientiousness and care of the compilers, but more especially upon the amount and quality of the materials which *happen* to have been preserved... knowing how treacherous and deceptive the memory frequently proves." (p.v). This is highly applicable to my compilation of history as well, as I relied heavily on the memories of the people who were there and who heard the stories of others who lived before them.

To speak of the history of Bear and Silvies Valleys, one must start with the history of Grant County. This County in Eastern Oregon was first visited by Europeans involved in the fur trade and by explorers (often these men were one and the same). Then, in 1862, gold was discovered in Canyon Creek by prospectors headed for Florence, Idaho. The first to find gold on the creeks and rivers did not feel that the John Day Valley would ever be settled because the weather was too harsh (they did not know that the winter had been an extreme one and that the spring of 1862 was unusually cold) and there was an ever constant threat of trouble with Indians. The first attempts at horticulture were failures which served to confirm the feelings that the area was unsuited for agriculture. "Agriculture they considered out of the question entirely, and notwithstanding the abundance of luxuriant bunchgrass covering each hill from base to crest and spreading out profusely over valleys, even Oregonians thought that stockraising could never be profitably engaged in, owing to the supposed length and severity of the winters." (Western Historical Publishing Company 1902 p.387). However, further experiments with vegetables and fruit trees were successful and the settlement process began. The hillsides of "luxuriant bunchgrass" (Rand 1981; p.86) were first utilized by horses and mules which were an essential part of life in those days. Cattle were slowly being brought into the valley and then sheep, in great numbers. The first homesteads in the county were taken by B.C. Trowbridge and William Wilson in the John Day Valley on July 16, 1862 (Western Historical Publishing Company 1902). The towns of Canyon City and John Day gradually increased in size as the mining industry flourished. In the fall of 1862 there was an estimated four or five thousand people in the valley (Western Historical Publishing Company 1902), but they did not all remain, the census from 1890 totaled 5,080 people in the entire county. In 1882, there occurred a switch from cattle to sheep in the county. The sheep were much more suited to the conditions of the rangeland since the profusion of bunchgrasses had decreased dramatically. The authors also refer to thousands of horses that had gone wild in the area and which were breeding at will. References to the condition of the rangelands and the stream channels were also made by the Western Historical Publishing Company (1902). Apparently by the turn of the century, the rangelands had deteriorated to the point that the land was better able to support populations of hardy sheep rather than cattle, and the stream channels had taken the severe toll of twenty years of gold mining. In 1884, an effort was made to remove the county seat in Canyon City to the Harney valley area. The citizens of the Harney valley argued that mining was nearly played out in the Canyon City area and that "the narrow strip of land along the John Day was already too much impoverished for successful agriculture, and unable to furnish enough cereals, vegetables and beeves for home consumption of the sparse population". (Western Historical Publishing Company 1902 p.397). In 1885 a cloudburst in the northern part of the county washed out gullies thirty feet wide and twenty-five feet deep. In 1886, a similar cloudburst did some damage to Canyon City.

Turn of the century philosophy had a strong emphasis on settlement. Western Historical Publishing Company (1902) quoted an article published in "West Shore" (source not given) on February 15, 1885 which described Grant County as the largest and agriculturally least developed county in Oregon. The article bemoans the fact that vast ranges are being used by the stockmen which should be divided up into smaller farms and ranches. "Were the vast bands of cattle grazing within the limits of the county divided among two thousand, instead of two score owners, each with his family occupying a small, well-cultivated farm, the population and assessable value of property would be increased tenfold and the region would enjoy a prosperity it has never known" (Western Historical Publishing Company 1902 p.400). The article refers to Illinois and Iowa as the vision for the landscape of the county. One of the biggest complaints about the "stockmen" was that they were often absentee and thus taxes collected from them and their operations were minimal. The article estimates a total of 181,000 cattle (under the ownership of only eight ranches), 15,000 to 20,000 horses and 120,000 to 150,000 sheep in the county (it might be useful to be reminded at this point that the Grant County of 1885 was rectangular shaped extending approximately 200 miles from Umatilla County to the Nevada line and 90 miles wide (Western Historical Publishing Company 1902) containing an area of about 18,000 square miles). The 1885 to 1900 period was generally a prosperous one in the county with more and more land being put into agriculture as the settlers came in, and favorable rainfalls produced substantial crop yields. One result of this was an overcrowding of the rangelands as the cattle barons were forced off of the settled land. The new settlers often brought with them livestock of their own which increased the pressure on the rangelands and the valley bottoms as well. Also of interest is that in the late 1890s Grant County was connected to Baker County by telephone services.

Bear Valley

Bear Valley was one of the areas that was described in the above mentioned 1885 article as prime land for settlement. In 1880 Martin A. Lucas was said to have gone to stock raising in Bear Valley where he owned one half section. In 1883 W.S. Southworth took out a homestead in Bear Valley and in 1885 a post office was established at his place with his wife, Mrs. Minnie Southworth, the postmistress. The post office was named for Judge Seneca Smith as Minnie's sister-in-law was Mrs. Seneca Smith (McArthur 1982). In the 1890 census of Grant County, the population of Bear Valley was reported at 188, most of these being homesteaders as it wasn't until the 1920s when the Hines Lumber Company built a mill in Seneca that the town itself supported many people (Herberger 1995). Among the first settlers in the valley were the Strattons, the Herbergers, the Lowes, the Lincolns and the Sprouls (Grant County Oliver Museum 1983, Herberger 1995). Many of the homesteads were taken after 1916 when the stockgrower's act was passed through Congress allowing a 640 acre homestead rather than the original 160 acres (Scharff 1995). There were many changes to be seen in this little valley in the years to come. Irrigation ditches were put in, beavers were taken out, the timber industry came and brought with it railroad grades and people. Meadow ground was improved for haying by "clearing willows and grubbing sagebrush" (Grant County Oliver Museum 1983), and every homestead came with a complement of domestic animals, particularly horses, dairy cattle and pigs.

Electricity came to the valley in 1947. Meadow foxtail (*Alopecurus pratensis*) was introduced in the 1950s to increase forage production and proceeded to take over the valley. Other species introductions were Kentucky bluegrass (*Poa pratensis*), Crested wheatgrass (*Agropyron cristatum* and *A. desertorum*) and Timothy (*Phleum pratense*). Some of the earliest Crested wheatgrass seedings in Oregon can be found on the Southworth ranch in Bear Valley (Buckhouse 1995). John Scharff, the first ranger on the Prairie City (Bear Valley) Forest Service district, remembers the valley as being much more open than today with mostly large "yellow-bellied" ponderosa pine (*Pinus ponderosa*) with a stand of bunchgrasses underneath (Scharff 1995).

Silvies Valley

Silvies Valley too was listed in 1885 (Western Historical Publishing Company 1902) as an area of bottom land that had not yet reached its potential for inhabitance. In 1890 the population of this valley was listed at 192, with most of the valley being occupied principally by stock ranches. The Silvies River had been discovered many years before when, in 1826, Peter Skene Ogden sent a trapping party into central Oregon. Antoine Sylvaille was the head of this party and returned with the story of a river very rich with beaver and it was given the name of Sylvaille. The anglicized version of this, "Silvies", is still in use today (McArthur 1982). Peter Skene Ogden visited and trapped this river at least three times on his journeys through the Snake Country. He recorded several beaver trapped, and some antelope were seen. However, he only worked the lower portion of the river up to Emigrant Creek (Hudson's Bay Record Society 1961, Hudson's Bay Record Society 1971) which is well below my research area. This valley and river has been a popular location for trappers through the years. Wayne Negus (1990), spent a winter there in the early 1930s and hit what he called a "fur pocket" of muskrat. He went back to John Day with over 900 muskrat pelts, several mink, badger, coyotes and bobcats. The beaver had long since been trapped out of the valley (Negus 1990).

Oliver Ranch

There is a log cabin at the base of the "bald hills" on the Oliver ranch that is said to have been the winter headquarters of a cook and hired man of an outfit out of Winnemucca. These two men were responsible for putting up supplies for the upcoming summer when a group of cowboys would trail yearlings into the lush meadows of Bear Valley to fatten. I have not been able to determine the time period that this was occurring but I suspect it was prior to 1862 as there is no mention made of it in the journals of the miners from Canyon City around that time.

Joseph Cayton Oliver I came to Grant County as a young man in 1866 and worked in the mines before going into partnership with Augustus and Elizabeth Gregg in the dairy business. Augustus Gregg passed away in 1878 and Joseph married Elizabeth in 1879. They bought land four miles east of John Day and continued their dairy business. It was here that they started to add beef cattle to the operation. The two youngest children from that marriage, Herman and Frank Oliver went into partnership with their father. The ranch gradually expanded, and sheep were added to the ranch. Sometime between 1880 and 1898, they expanded into Bear Valley. Their property surrounded a homestead so they bought it almost out of necessity, then "Immediately every other piece of land there was homesteaded and offered to us as soon as the owners had title." (Oliver 1961 p.99). Their private ground up there was used as spring pasture then the livestock went into the forest for the summer while they hayed the meadows. The livestock were wintered in the John Day Valley up until the early 1970s. Herman Oliver, in his book Gold and Cattle Country, talks about being responsible for 1200 head of sheep and 300 head of cattle up in Bear Valley at the age of 13. That would have been the year 1898. Around the turn of the century, the head ditches were dug and the dams constructed for the purpose of irrigating the meadows adjacent to Bear Creek. These meadows have been managed that way since the beginning. Frank Oliver's son, Joe (J.C.II), took over the ranch in the 1940's. In 1964, the Biggs ranch was purchased by the Oliver ranch which put the entire stretch of Bear Creek from where it emerged from the forest to where it crossed under the highway under their ownership. The Biggs' had managed the upper meadows the same way (haying followed by aftermath grazing) but had not had any livestock for a few years prior to the sale. The lower two meadows which are currently under summer use have only been that way for 10 years. Previous to that they were early spring use pastures. The Oliver ranch does not fertilize or burn (except feed grounds on occasion) and the only willow control comes in the form of the swather driver in the summer. The lower pastures have not had willows on them in the memory of J.C. Oliver III, the present owner and manager of the Bear Valley ranch. Bear Creek is a perennial stream that often runs more than the Silvies River, into which it drains.

Lemcke Ranch

In 1914, Fred Lemcke came from Iowa to manage a ranch in Bear Valley where he met and married Edith Hanna. They homesteaded one place and in 1916, they added to it the ranch that Fred was managing. The diversion dams for irrigation from Scotty Creek went in between then and 1920. Around 1926, the Hines Lumber Company built a railroad from Burns into Bear Valley and a mill in Seneca (Grant

County Oliver Museum 1983). This changed the face of Bear Valley - it brought people, and the timber industry to this tiny little settlement. The ability to sell timber enabled some of the ranchers to pay off their ranches much more quickly. The Lemcke ranch was the end of the western line of the railroad and served as a railhead for sheep for twenty years. Fred and Edith were able to pay for the ranch by renting their ground for two or three days to the sheep owners waiting to ship their sheep. This line came out in 1946 but the grade remains. Fred and Edith's son, Bob, married Florence Erickson in 1948 and started taking over the operation of the ranch.

The Scotty meadows were grazed in the spring and then again in the fall until the early 1980s (when Bob and Florence's son, Jim took over) when they started grazing them in the summer for two or three short grazing periods. Small portions of this pasture have been hayed the last two years but that was the first time in its history (Lemcke 1994). Current management has experimented with burning a little but only in small patches. Scotty Creek was named for a pioneer sheep man, Scotty Hay, who had a camp and cabin on the stream (McArthur 1982). There has been some trapping in the past for beaver and marten. Scotty Creek runs perennially through the Scotty meadow but often dries up below before it reaches the Silvies River. The ranch is currently owned by D.R. Johnson of Riddle, Oregon.

Holliday Ranch

In the late 1890s or early 1900s, John Herberger purchased land in Bear Valley. In the early 1900s his son Brad took over the ranch. The Herberger family originally ran sheep but later switched to cattle. The meadows were irrigated (if there was enough water), then hayed with horse drawn equipment, and the aftermath was grazed by steers that came off the forest. The steers were grass fattened on the aftermath and buyers would come look at them in the meadow (Herberger 1995). The irrigation was aided by the beavers in the area which helped them spread the water (Herberger 1995). The Herberger's raised several horses in the time they had the ranch, these were run on the sagebrush flats. Clyde Holliday bought the ranch in 1963 (Holliday 1995). From 1964 to 1968, the existing dams were rebuilt and gully plugs were put in the sloughs to catch runoff and diverted irrigation water. The Herberger pastures were originally hayed but since about 1967, they have been used in the summer as yearling meadows. The irrigation ditches have not been maintained since the livestock have been using the pastures in the summer, although the dams are still used to create duck habitat. Scotty Creek does dry up down in these meadows due to a number of factors (diversions higher up, drought, filling of water trucks)(Holliday 1995). There are almost no willows in the Herberger pastures. Aerial photos from 1956 show more willow in the upper portion of the pastures but very few in the lower half. Speculation is that clearing practices in the past (although Jerry Herberger remembers "lots" of willows) may have caused the loss of them and the current grazing practices along with the lack of gravel beds precludes re-establishment.

Ponderosa Ranch

This ranch has had a most colorful history. In the early 1960s, John Cawrse bought up most of the homesteads in the valley (an estimate of 60 was made by Garth Johnson, present manager of the ranch) and in two years was running 3000 head of cattle on his ranch (Holliday 1995). In 1963, he and his family were tragically killed in a plane crash and the ranch was bought by Harry Pons who also owned several other ranches in the Burns area. Mr. Pons raised longhorn cattle and many other exotic animals (Holliday 1995). Steve Miller, the manager of the ranch at the time, was responsible for 2850 head of bison (at the peak), as well as elk, deer (white-tailed, black-tailed, mule, red, fallow), exotic sheep, zebras, tapir, and South American antelope (Miller 1995). These were run mostly together in a 5000 acre "wildlife field", with 9.5 foot high fences, that was on the west side of the valley. The meadows were flood irrigated starting in March when the ice went off of the river and the ditches and sloughs could be filled, then they were hayed (Miller 1995). Mr. Pons also built some lakes that were stocked for fishing for the children. Clifford Wolfwinkle acquired the ranch in about the early 70s and was the first to bring "dudes" to the ranch (Miller 1995). The ranch was purchased about 1976 by a Grazing Association which was subsidized by a low interest loan and turned into a yearling operation with some cows as well. Then, Traveller's Insurance Company owned it for about a year before it was purchased by Oren and Fleming in 1988. For the last twenty years, the meadows containing our research plots have been grazed in the summer on a short duration/ rotation basis (Johnson 1995).

The railroad that followed the river (and crossed it several times) came in the late 1920s (Hankins 1995). The fill for this grade was likely scraped from the meadows (Miller 1995) which would have implications on the vegetation and hydrologic function of the system. The dams went in before 1930, many of the ditches were dug by the homesteaders (Miller 1995). Beaver were at one point (1820s) very abundant on the river as well as muskrat and some mink. About 25-30 years ago there was some seeding of crested wheatgrass (Johnson 1995). Current management burns stagnated willow patches about every 10 years (Johnson 1995).

Ho1

It is clear, through the review of historical literature that a strong relationship between settlement history and current fluvial geomorphology exists.

STUDY AREA

Location

The study area is located in south central Grant County, Oregon. Grant County is situated in the Central Blue Mountains of east-central Oregon and lies between 44 and 45 north latitude and 118 and 120 west longitude (Gaither 1981). Portions of three streams in the Silvies River drainage were used for the study. These streams are the Silvies River (in the Silvies Valley), Bear Creek and Scotty Creek (both in Bear Valley). Four cooperating ranches were involved as the research was conducted on private property: Oliver Ranch, Holliday Ranch, Ponderosa Ranch, and the 96 Ranch (which changed ownership during the course of the study, it is referred to as the Lemcke ranch in this thesis).

Climate

Average summer temperature in Bear Valley is 13.75° C, average winter temperature is -4.87° C. The mean maximum temperature of 26.7°C occurs in Bear Valley in July and August. In January the mean minimum temperature is -13.1°C. However, extreme temperatures range from 37.8°C to -44.4°C. The mean annual precipitation is 33.2 cm with the majority of it coming in the form of snow. Mean annual snowfall is 161.8 cm. There is a small peak of rainfall in the months of May and June with July being the driest month. Thunderstorms are common in the summer months and although not contributing a large amount to the total precipitation, they can be very influential in terms of flash floods and inputs to an

Table 1. Climatological data for Seneca, OR. 1961-1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Mean temperature (C)													
Maximum	0.69	3.71	6.82	11.39	16.12	21.36	26.88	26.68	21.33	15.29	6.48	1.29	13.25
Minimum	13.13	-10.38	-6.81	-3.97	-0.64	2.44	3.16	2.03	-2.43	-6.02	-6.97	-11.39	-4.51
Mean	-6.22	-3.34	0.00	3.71	7.75	11.88	15.03	14.36	9.52	4.64	-0.24	-5.05	4.31
Extreme temperature													
Maximum	12.22	16.11	21.11	27.22	31.11	35.00	35.56	37.78	35.00	31.67	20.56	17.22	37.78
Minimum	-40.56	-44.44	-26.67	-15.00	-11.11	-8.33	-6.11	-7.22	-14.44	-20.56	-35.00	-44.44	-44.44
Precipitation (cm)													
Monthly mean	3.27	2.62	2.97	2.51	3.40	2.82	1.40	2.21	1.65	2.24	3.78	4.24	33.15
Snowfall (cm)													
Monthly mean	29.41	24.05	19.69	7.47	2.49	0.13	0.00	0.00	0.00	2.95	20.01	42.24	161.82

otherwise dry system. Table 1 lists the monthly and annual mean temperature and precipitation data from 1961-1990 for Seneca, Oregon which is situated in the south central part of Bear Valley. Figure 1 shows the relationship between temperatures and precipitation in the valley. Although Silvies Valley does not have a weather station, its climate is slightly milder and drier.

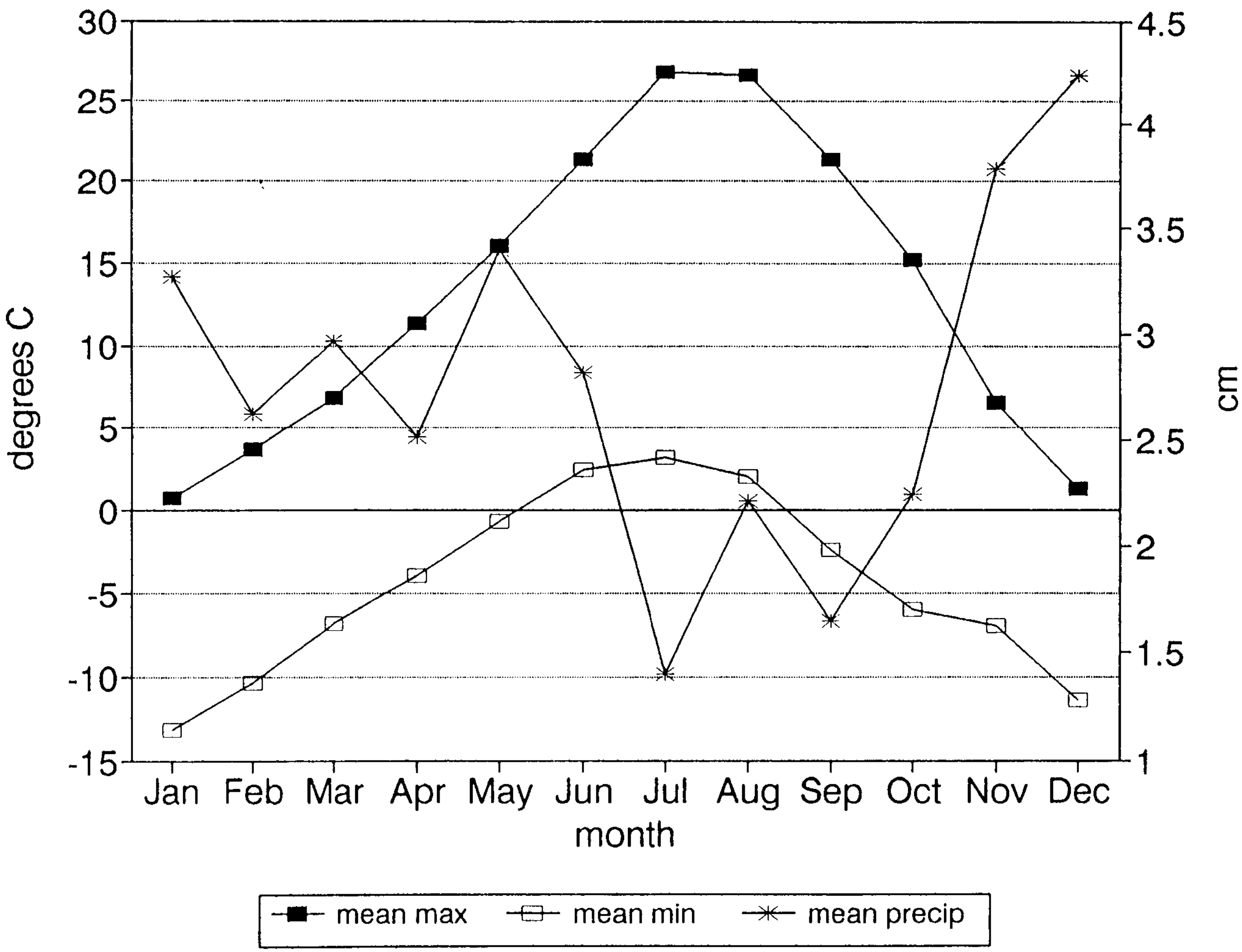
Geology

Bear Valley is bordered to the north by the Strawberry Mountain range of the Blue Mountains. This range rose up in the late Miocene (20 million years ago) through violent volcanic activity coupled with uplift along the John Day and other faults. It is estimated that the cones reached heights similar to Mt. Hood in the Oregon Cascades (USDI, Geological Survey 1974). The highest peak in the range today is Strawberry Mt. at 2,755 m (9,038 ft) (Gaither 1981). The valley bottom is covered with the Strawberry volcanic deposits (USDI 1974).

Soils and Vegetation

The soils on the project area are dominated by two series: Silvies silty clay loam and Damon silty clay loam. These two soils are very similar, the main difference being that the Silvies soil has a higher clay content. They are poorly drained, formed in mixed alluvium. These soils are found with slopes of 0 to 5 percent at elevations of 1158 to 1524 m (3800 to 5000 feet). The typical profile is a black (moist) clay for 120 cm with neutral pH (Silvies) and black (moist) silty clay loam about 46 cm then very dark grayish brown (moist) silty clay loam about 51 cm thick with a substratum

Figure 1. Average temperature and precipitation for Seneca, Oregon (1961-1990).



of very dark grayish brown silt loam to 127 cm or more (Damon). The Damon soil is also neutral throughout and is mottled below 66 cm. Depth to sand or gravel is more than 100 cm. Damon permeability is moderately slow while the Silvies is slow. Available water holding capacity is 18 to 25 cm. Effective rooting depths are 75 to 100 cm (and deeper for water loving plants). These soils are subject to surface water tables for most of the spring.

The range site guides list this area as wet and semi-wet mountain meadows. The typical "original" plant community as described by the SCS Range Site guide for the John Day Land Resource Area (1965) for the semi-wet meadow is composed of 25% redtop (*Agrostis alba*), 15% tufted hairgrass (*Deschampsia caespitosa*), 10% each slender wheatgrass (*Agropyron trachycaulum*), sod-forming bluegrasses (*Poa pratensis* and *P. sandbergii*), and meadow rushes (*Juncus* spp.). Other grasses do occur as well. Perennial forbs such as cow clover (*Trifolium involucratum*), vetch (*Vicia americana*), cinquefoil (*Potentilla gracilis*), yarrow (*Achillea millefolium*), aster (*Aster occidentalis*), buttercup (*Ranunculus* spp.), geranium (*Geranium* spp.), and dandelion (*Taraxacum officinale*) make up about 10%. An occasional shrub such as shrubby cinquefoil (*Potentilla fruiticosa*), golden currant (*Ribes aureum*), rose (*Rosa* spp.), willow (*Salix* spp.) and silver sagebrush (*Artemisia cana*) may occur.

The wet meadow has a similar diversity, but a different composition. The typical original plant community is as follows: 30% tufted hairgrass, 10% each Nevada bluegrass (*Poa nevadensis*), redtop and meadow sedges (*Carex* spp.), 30% other grasses, sedges and rushes. 10% is perennial forbs such as cow clover, cinquefoil, aster, buttercup, strawberry (*Frageria* sp.), groundsel (*Senecio* sp.), and avens (*Geum* *campanulatum*). An occasional shrub such as snowberry (*Symphoricarpos albus*), rose, golden currant, willow or aspen (*Populus tremuloides*) may occur. Both of these plant communities (semi-wet and wet meadow) are very tolerant of low temperatures.

It should be noted that with the introduction of meadow foxtail (*Alopecurus pratensis*) the plant communities described above will never be the same as the original condition. Meadow foxtail is a total dominant in the wetter areas of the semi-wet production type. Current research has identified four major plant communities in the meadows (Stringham 1994). These four are: wet meadow, semi-wet meadow (high production), semi-wet meadow (low production) and dry meadow. Preliminary species composition data from Stringham (1994) are as follows:

1. wet community dominated by sedges, rushes and sloughgrass (*Beckmannia syzigachne*), also present are Kentucky bluegrass, annual forbs, clover, Tufted hairgrass, Timothy, meadow foxtail, other grasses and perennial forbs;

2. semi-wet (high production) strongly dominated by meadow foxtail, also present are sedges, rushes, clover, Kentucky bluegrass, annual forbs, tufted hairgrass, potentilla, timothy, and dandelion;

3. semi-wet (low production) dominated by Kentucky bluegrass, also present are timothy, meadow foxtail, sedges, annual forbs, rushes, dandelion, potentilla, smooth brome (*Bromus inermis*), clover, yarrow, other grasses, and perennial forbs and silver sagebrush (*Artemisia cana*);

4. dry dominated by Kentucky bluegrass, also present are annual forbs, yarrow, smooth brome, pussytoes (*Antennaria* spp.), meadow foxtail, sedges, sandberg's bluegrass, potentilla, mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*),

lupine, junegrass, squirreltail, wheatgrass, Idaho fescue, timothy, crested wheatgrass, rushes, strawberry, buckwheat, dandelion, clover, green rabbitbrush (*Chrysothamnus viscidiflorus*), other grasses and forbs.

METHODS

Experimental Design

The stream segments to be classified were grouped into "treatments" based on the riparian corridor vegetative structure. Emphasis was placed on the woody component of the corridor vegetation since it is hypothesized that woody vegetation is a strong stabilizer of stream channels. The primary woody plant found along the riparian corridor was willow. At least seven different species of willow were identified (Sanders 1995).

Treatments:

1) herbaceous riparian corridor vegetation (HERB);
2) discontinuous, clumped woody riparian corridor vegetation (CLUMP);
3) continuous woody riparian corridor vegetation (WOODY).

Replication:

Each treatment was replicated four times. The replicas were located as follows:

1) The herbaceous treatment was replicated twice on Scotty Creek, in separate pastures, and twice on Bear Creek, in the same pasture.
2) Discontinuous woody was replicated twice on Scotty Creek in the same pasture, and twice on Silvies River, in separate pastures.
3) Continuous woody was replicated four times on Bear Creek, in separate pastures.

Experimental Units:

100 meter by 100 meter experimental units were randomly located within the pastures by Stringham (1994) for the purpose of riparian ecology research with this same project. The creek runs approximately through the middle of these units. In order to allow for potential correlation of data between the two researchers (Stringham and the author), the stream classification work was undertaken within the experimental units delineated by Stringham. The random starting point for the location of the unit within the pasture was chosen by a computer program written by Stringham. The experimental units are located as follows:

1) 6 units are on Bear Creek (HERB 3 & 4, WOODY 1,2,3 & 4)

2) 4 units are on Scotty Creek (HERB 1 & 2, CLUMP 3 & 4)

3) 2 units are on Silvies River (CLUMP 1 & 2).

Stream Classification

The system used followed the classification key of natural rivers published in Catena (Rosgen 1994) (Figure 2). The following criteria are used in developing the stream type:

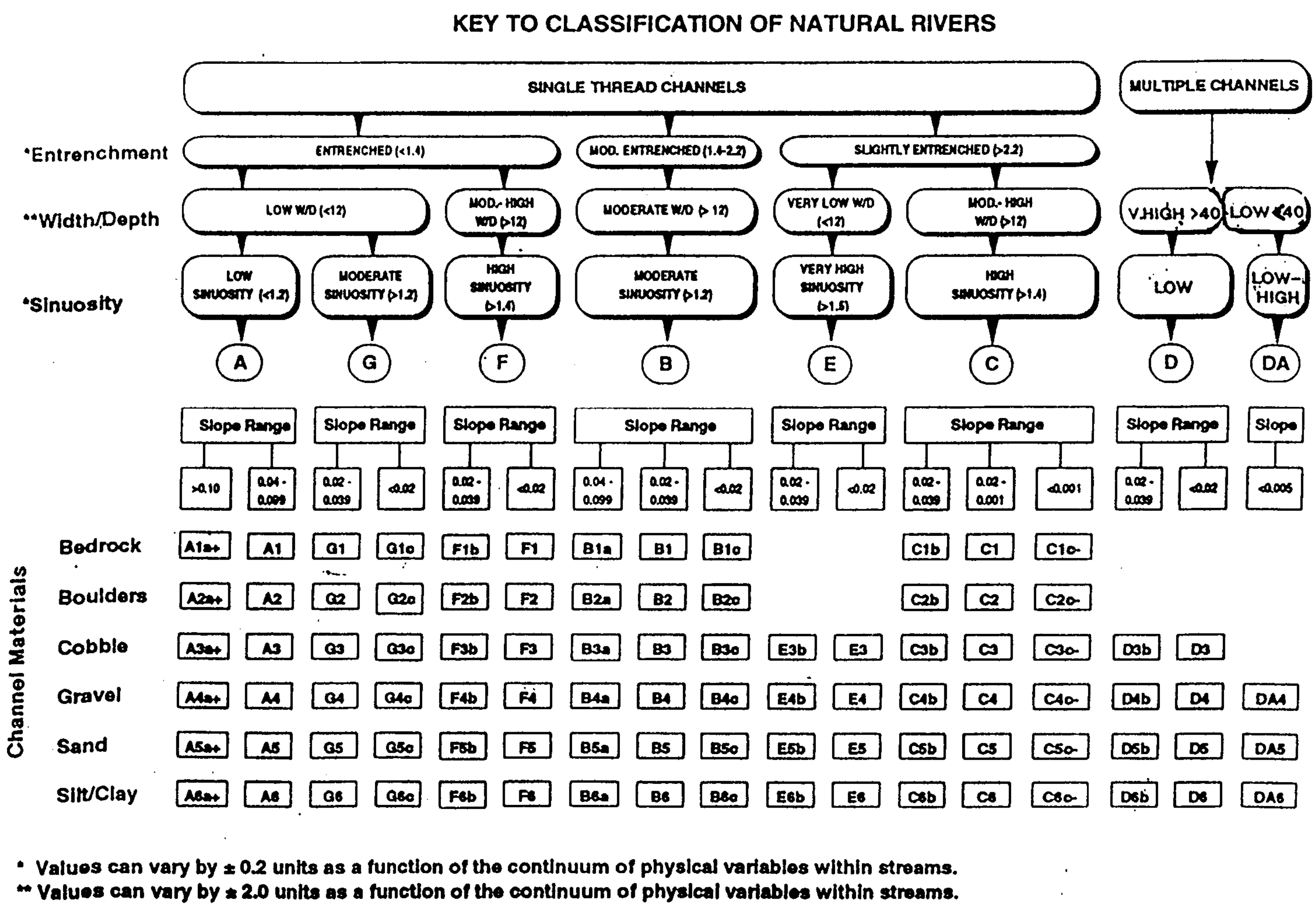
1) Single Thread vs. Multiple Channel

Single thread channels exist on the experimental units.

2) Entrenchment Ratio

Entrenchment Ratio is defined as the floodprone width of the stream divided by the bankfull width. Floodprone width is defined as the

Figure 2. Classification key of natural rivers developed by David L. Rosgen. (source: Rosgen 1994 p. 180)



water level at 2 * the maximum depth of the stream at the bankfull stage (Rosgen 1994).

3) Width/Depth Ratio

Width/Depth Ratio measurements are taken from the bankfull stage.

4) Sinuosity

Sinuosity is the ratio of channel length to valley length, or in this case to experimental unit length.

5) Gradient or Slope Range

The gradient of the water surface at bankfull is measured on the reach being classified. Each experimental unit will be considered a reach.

6) Channel Materials

Dominant size class of the channel materials is determined. The range in size is from bedrock to silt/clay.

Classification of Experimental Units:

To classify each experimental unit, ten transects (called creek stations) were established in 1993 within the boundaries of the unit if possible. The transects were located no less than 10 meters from each other. Pools, riffles and straight reaches were proportionally represented. If all transects could not be located within the unit, the remaining stations were located alternately upstream and downstream of the unit until 10 were established.

At each transect measurements were taken in 1993 and 1994 of:

1) bankfull, baseflow, top bank widths and depths

2) floodprone width

3) channel materials.

<u>Bankfull measurements:</u>

Bankfull was located by imitating the Forest Service (1985) description. Multiple markers were looked for, including active floodplain, break in slope, vegetation changes, and change in bed particle size. Once established on one bank, a tape was run across to the opposite bank and levelled to locate the bankfull stage on the other bank. With the tape taut, measurements were taken of width and depth. Depth measurements were taken at the deepest spot, along the tape, if that spot was not an obvious hole.

<u>Baseflow measurements:</u>

Baseflow width and depth were measured in the month of September. Although these measurements are not part of the classification scheme, they were used to establish base level, and in the analysis of water table relationships.

<u>Top bank measurements:</u>

These measurements were taken on channels that were obviously incised. If bankfull stage appeared to lie at some point below the top of an obvious bank, the width and depth of the top bank was also measured. This measurement aided in cross section drawing.

Floodprone width:

Floodprone width (the width at water level 2* max bankfull depth) (Figure 3), was determined by running a level tape at a height of 2* bankfull depth. If the width was obviously greater than three times the width of the bankfull channel (ie. potentially the entire valley bottom), it was noted as such and not physically measured, but visually estimated. At that point the entrenchment ratio becomes greater than 2.2 which denotes slightly entrenched in the classification scheme (Rosgen 1994).

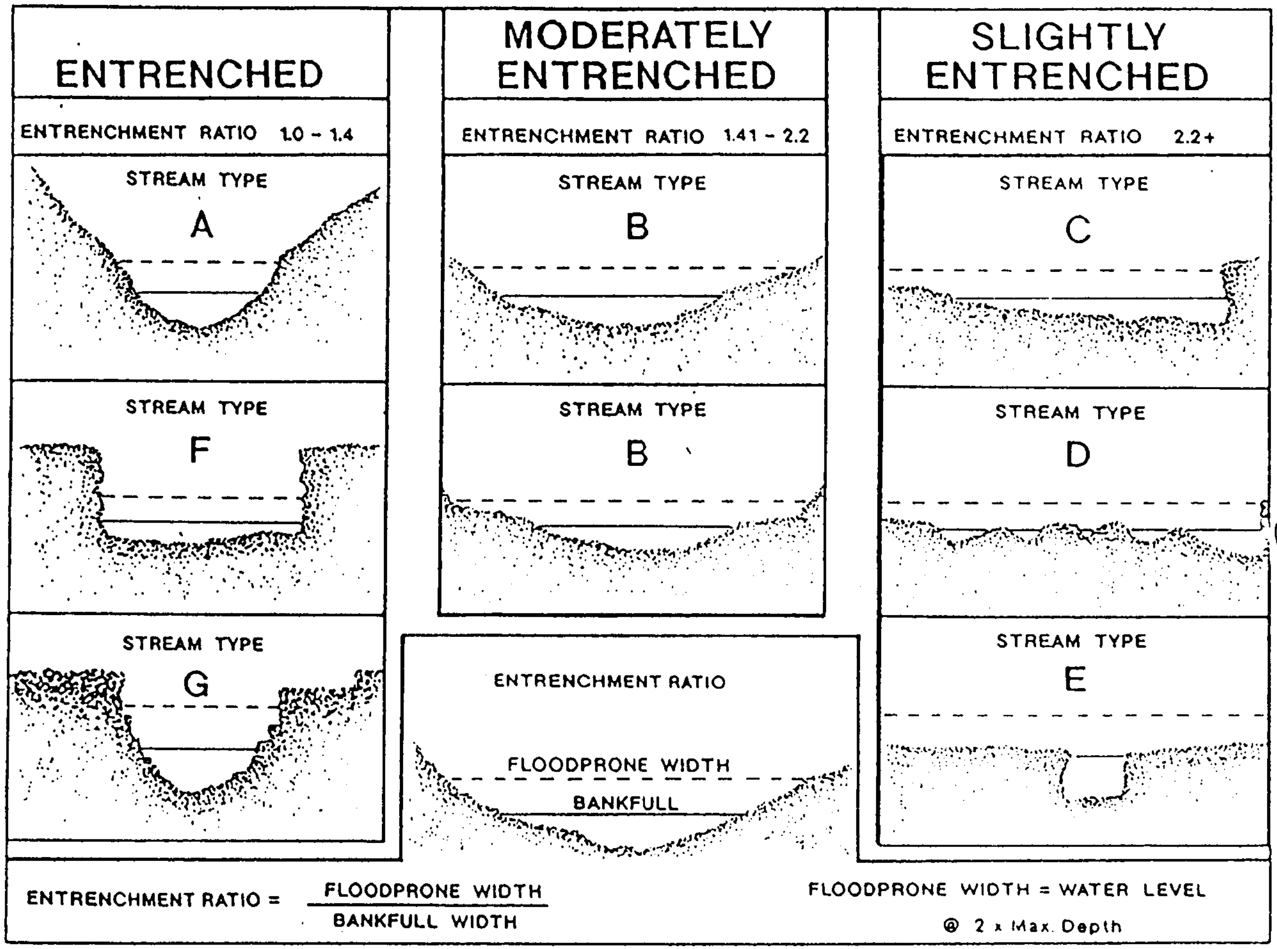
Sinuosity:

The distance the stream travelled from station 1 to station 10, as well as the linear distance between stations was measured in the field. The travel distance divided by the linear distance gives the sinuosity ratio. Aerial photos from a 1988-89 flight by the Soil Conservation Service were used to compare the sinuosity of the whole pasture to that of the experimental unit within that pasture.

Gradient:

A theodolite was used to measure the gradient of the water surface at baseflow from station 1 to station 10. Corrections to the bankfull stage from the measurements at those stations gave the water surface slope at bankfull.

Figure 3. Examples and calculations of channel entrenchment developed by David L. Rosgen. (source: Rosgen 1994 p. 182)



Channel materials:

Channel materials were determined by the Wolman Pebble Count method (USDA Forest Service 1992). Using this method, the stream was walked at each cross section starting and ending at bankfull stage. The particle under the toe at each step was put into a size class. One hundred particles were sampled per unit and a size class distribution was obtained to find dominant substrate size, defined as the median particle size (50% of particles are that size or smaller).

Depth to Water Table

Depth to water table was measured using water wells. The wells were constructed from 3/4" PVC pipe with 7/64" diameter holes drilled from bottom to within 6" of the top. The tops of the wells were capped with a 3/4" PVC cap which had a 7/64" hole drilled through the top.

Installation of Wells:

Using a gas powered auger, 2 inch diameter holes were drilled into the ground. One half inch minus gravel was placed in the bottom of the hole until the desired well depth was reached. The well was inserted and one half inch minus gravel was packed around the well to within six inches of the surface. The remaining six inches was packed with clay augured from the hole.

Placement of Wells:

Five transects of four wells each were located perpendicular to the stream. I am using the well closest to the stream (the "A" well) in my research analysis. The transects were located on both sides of the creek in an alternate fashion. The location of the first transect was randomly assigned by east vs. west end of the experimental unit, north vs. south side of the creek, and odd or even creek station. From that point, both side of the creek and creek station were alternated to locate the remaining transects. Within the transect, the first well was located within one meter of the stream channel. This well was placed to a depth of 120 cm or base level (of the creek), whichever was greater.

Measurement Schedule:

Depth to water table was measured every ten days from June 18 to September 10, 1994. In the units that were significantly effected by irrigation, the wells were measured on a three day rotation when the irrigation water was turned off until the water table stopped dropping quickly at which point a ten day schedule was resumed for those wells.

Historical Information

Historical information was collected from the following sources:

1) interviews with local residents
2) literature search of the Grant County Library and OSU Kerr Library for historical documents, diaries and history books of the area.

3) local USDA Forest Service office and Soil Conservation Service office

4) Oregon State University Extension Service (Grant County office)

5) Grant County Historical Society

Data Analysis

1. A t-test was used to compare the differences of unit means of width/depth ratios and entrenchment ratios from 1993 to 1994 (Ho2).
2. Multiple linear regression analysis was used to test the relationship between entrenchment ratios and water table depth, entrenchment ratios and width/depth ratios, width/depth ratios and water table levels (Ho3 and Ho4).
3. The nested experimental design gives the following analysis of variance (ANOVA) table to compare the treatment means of width/depth ratio and entrenchment ratio (Ho5 and Ho6).

ANOVA

Source of Variation	Degrees of freedom
Treatment (3)	2
Units with treatment (Error term)	9
Samples (n=10)	12*9 = 108
	119

RESULTS AND DISCUSSION

Objectives 3,4,5 & 6 dealt with the stream classification, repeatability of measurements, water table and vegetation structure relationships of the stream segments.

The results of the measured parameters and the resultant stream classification for the twelve experimental units are given in Table 2. The values listed were used to follow through the classification key of natural rivers (Figure 2). For example, in 1993, HERB 1 (a single thread channel, as are all of the other segments) had a measured entrenchment ratio of 8.801 which placed it in the "slightly entrenched" category. A width/depth ratio of 7.129 put it in the "very low w/d" category. The next level has only one choice for the very low w/d category: "very high sinuosity >1.5". HERB 1 had a measured sinuosity of only 1.34, however, Rosgen allows the use of a "continuum concept" which assigns a + or - 0.2 units for the sinuosity and entrenchment ratios (+ or - 2.0 for width/depth). The continuum concept allowed the 1.34 sinuosity ratio to be acceptable here (since with continuum, the range is 1.3 to 1.7 for sinuosity). This established the segment as an "E" stream. The gradient of 0.0039 and the silt/clay channel materials assigned the number "6" for a resultant "E6" classification. If the continuum concept does not encompass the measured value the first time the concept is required, then one must back up in the key and apply it earlier if possible. In some cases, such as WOODY 4, the segment defied classification. In 1993, the entrenchment ratio was 5.34 ("slightly entrenched"), the width/depth ratio was 8.782 ("very low w/d"), but the sinuosity of 1.1 did not fit, even

Table 2. Results of stream classification from 1993 and 1994.

Stream segment	Year	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Gradient	Channel Materials	Classification
HERB 1	1993	8.801	7.129	1.34	0.0039	silt/clay	E6
	1994	8.055	8.465	1.34	0.0039	silt/clay	E6
HERB 2	1993	5.059	7.097	1.25	0.0025	silt/clay	E6
	1994	3.703	6.962	1.25	0.0025	silt/clay	E6
HERB 3	1993	4.128	10.588	1.64	0.00029	silt/clay	E6
	1994	3.886	12.625	1.64	0.00029	silt/clay	C6c-
HERB 4	1993	2.84	10.819	1.33	0.00038	gravel	E4
	1994	2.498	11.985	1.33	0.00038	silt/clay	C6c-
CLUMP 1	1993	4.581	10.145	1.79	0.00019	gravel	E4
	1994	4.613	11.767	1.79	0.00019	gravel	E4
CLUMP 2	1993	2.795	11.614	1.43	<0.001	gravel	E4
	1994	2.533	12.801	1.43	<0.001	gravel	C4c-

Table 2. Continued

Stream segment	Year	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Gradient	Channel Materials	Classification
CLUMP 3	1993	18.640	3.234	1.62	0.0027	silt/clay	E6
	1994	20.977	3.083	1.62	0.0027	silt/clay	E6
CLUMP 4	1993	12.154	4.501	1.95	0.0023	silt/clay	E6
	1994	12.802	3.846	1.95	0.0023	silt/clay	E6
WOODY 1	1993	44.453	7.528	1.7	<0.001	silt/clay	E6
	1994	46.756	7.762	1.7	<0.001	sand	E5
WOODY 2	1993	70.071	6.391	1.89	<0.001	silt/clay	E6
	1994	70.265	7.438	1.89	<0.001	gravel	E4
WOODY 3	1993	56.535	6.911	1.8	0.0016	sand	E5
	1994	56.610	7.156	1.8	0.0016	gravel	E4
WOODY 4	1993	5.340	8.365	1.1	0.0044	gravel	E4
	1994	1.671	8.316	1.1	0.0044	gravel	G4c

with the continuum concept. Going back earlier in the key, the continuum concept did not work there either (the entrenchment ratio and the width/depth ratio were not close enough to the values to fit another category using continuum) so I chose to ignore the sinuosity discrepancy. The gradient of 0.0044 and gravel channel materials gave an "E4" classification. In 1994, the measurement of bankfull was lower (for reasons that will be speculated about later), and the entrenchment ratio was lowered to 1.671 ("moderately entrenched") but the width/depth ratio was 8.744 which did not fit the "moderately entrenched" width/depth category of >12 (even with the continuum concept). Going back in the key and applying the continuum concept to entrenchment, it did fit in the "entrenched" category, "low w/d" category and "low sinuosity" category, but, the gradient of 0.0044 did not fit slope ranges of the low sinuosity category, so, backing up one last time and using continuum, the "moderate sinuosity" category, slope and gravel channel materials resulted in a "G4c" classification.

Ho2

The entrenchment and width/depth ratios (Ho2) were found to be significantly different between 1993 and 1994 ($p=0.000163$ for entrenchment and $p=0.0208$ for width/depth from a t-test on the differences of the averages of the units). This is evident in the fact that four of the stream segments were totally reclassified in 1994 from their 1993 classification (ie: a different letter classification was assigned). Three of the four reclassifications (HERB 3, HERB 4 and CLUMP 2) were a result of the width/depth ratio changing significantly between years and the WOODY 4 reclassification was a result of a change in the entrenchment ratio. It must be noted that there were no apparent physical changes in the field that brought about these changes in classification, merely the author's location of bankfull in the field. The actual entrenchment of WOODY 4 did not change from 1993 to 1994, but the location of a different bankfull in 1994 (despite trying to repeat the measurement at the exact same locations) resulted in a different entrenchment ratio in the calculations. This is the same reason that the width/depth ratio changed for the other three reclassifications, the estimated location of bankfull differed in 1994. This illustrates the importance of correctly locating bankfull in the field for this classification system to work consistently. As a result of the imprecise methods, the analysis of the potential relationships between bankfull width/depth ratio, entrenchment ratio and water table as well as the treatment differences have come under question and can be found in Appendix A to be used only as direction for future research.

Four segments (HERB 4, WOODY 1,2 & 3) also changed the number portion of the classification meaning that the channel material technique was inconsistent as well. I see this as a minor problem in relation to the bankfull problem as the channel materials can be measured much more definitively than bankfull.

The major problem for me in using this system was field identification of bankfull. The morphological classification of natural rivers (Rosgen 1994) hinges on bankfull measurements as the reference flow. This is a common reference used by many people working with stream systems from many different disciplines. However, a review of the literature revealed an ongoing debate over the existence, usefulness and possible field identification of bankfull (Harvey 1969, Stream Systems Technology Center 1993, Knighton 1984, Leopold et al. 1964). As many as eleven different definitions were found and the argument that it doesn't even exist (at least not consistently) looms behind it all. Studies have shown that use of the 1.5 year flood is too large for the flow that just fills the channel, and others have found it to be too small (Knighton 1984). Using the idea that bankfull is not necessarily of a universal return period, but that it is simply the flow that just fills the channel, the bounds of the active channel must be defined. That is precisely where I ran into problems. On channels that are not entrenched, the top of the bank (and thus bankfull) was easy to locate, however, on an incised channel, the point on the bank where bankfull lies was not easily located. It has been suggested that it is more of an art than a science, which does not bode well for research purposes. The Forest Service (1985) suggested looking for multiple factors in locating bankfull in the field. The level of the active floodplain, a break in slope, a change in grain size and the limit of perennial vegetation were suggested indicators that I found to be the most consistent in the field, and the easiest to locate. After becoming comfortable with this, I still had my doubts about the repeatability of the measurements which were confirmed by the results of the statistical analysis that showed a difference.

Annual variation in precipitation added to the complexity of this measurement. The two years that I collected field data were very different precipitation years. 1993 was an historically wet year and 1994 was very dry. Stream segments that were running 10 to 15 cm deep at low flow in 1993 dried up completely by mid-August in 1994. There were no major morphological changes in the stream reaches from 1993 to 1994, but the measurements that I took reflected the bias of the dry year, despite looking for an unbiased bankfull. The implications of locating bankfull at a lower spot in 1994 (drawn down by the lower flow in September of 1994 than 1993) is to decrease entrenchment ratios by decreasing floodprone widths (as seen on WOODY 4) and to increase width/depth ratios (as seen on HERB 3 & 4 and CLUMP 2).

Ho3 and Ho4

Due to the imprecision found in the bankfull measurement, the results of the following analyses are only an indicator of potential trends and not conclusive. They may suggest direction for future research.

There was no relationship found between water table levels and entrenchment ratios (Ho3) for either the early (June) water table measurement ($p=0.6963$) or for the late (September) measurement ($p=0.6966$). Water table levels were found to be related to width/depth ratios (Ho4). The relationship was stronger for the late measurement of water table in September ($p=0.0055$) than for the early measurement in June ($p=0.0295$). It was estimated that an increase in width/depth ratio of 1 resulted in an increase in depth to water table of 2.24 cm in June and 3.06 cm in September. Low flow measurements were also taken in September of 1994. These were found to be highly related to water table levels ($p<0.001$). It was estimated that an increase in low flow width/depth ratio of 1 resulted in an increase in depth to water table of 2.75 cm.

Ho5 and Ho6

Due to the imprecision found in the bankfull measurement, the results of the following analyses are only an indicator of potential trends and not conclusive. They may suggest direction for future research.

The variance between replicas was found to be significantly greater than the variance between treatments which means that there is no treatment effect for either entrenchment ratios (Ho5) or for width/depth ratios (Ho6). If there was more variance between treatment than replica, then it could be concluded that the grouping of treatments based on woody vegetation structure was justified. These results however, suggest that the presence of woody vegetation alone does not influence stream channel characteristics enough to warrant grouping on that basis. This tells me that there are many factors involved in the present shape of stream channels, and although woody vegetation is one factor, it is only one.

CONCLUSIONS

It has become clear to me through this research that there are many factors involved in successful management, be it livestock, business or people. In order to understand the present, and plan for the future, a knowledge of the past is not only helpful but essential to avoid some costly mistakes. In his book, The Background of Ecology: concept and theory, Robert P. McIntosh (1985) sums this up quite well: "Ignorance of the past makes for redundance at best and confusion at worst" (p.ix). I have attempted to give an overview of the history of the research areas in terms of past management and have found it to be a daunting task. Records are scarce and poorly organized and memories are inherently (not intentionally) biased. I make this a call for organized record keeping, to allow us to learn from the mistakes, and successes already made, for I feel it is necessary if we are to continue to live on the land for generations to come.

My attempt at stream classification illustrates challenges yet to be resolved. The difficulty in locating bankfull and the resulting differences between years was too great to ignore. On a conceptual basis, the morphological classification of natural rivers (Rosgen 1994) works reasonably well - however, as a quantitative tool which requires exacting precision and consistent repeatability, it is frustratingly imprecise. My results indicate that bankfull cannot be measured for these streams.

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APPENDIX

Appendix Table 1.1 Field data for HERB 1, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	2.75	0.42	6.548	2.10	0.28	40	14.545
2	3.67	0.42	8.738	2.30	0.25	13	3.542
3	3.47	0.42	8.262	2.40	0.20	13	3.746
4	3.00	0.37	8.108	2.40	0.20	13	4.333
5	3.11	0.62	5.016	1.87	0.40	13	4.180
6	3.34	0.43	7.767	1.80	0.22	15	4.491
7	1.92	0.68	2.824	1.81	0.39	60	31.250
8	1.83	0.61	3.000	1.95	0.32	24	13.115
9	5.76	0.55	10.473	3.30	0.15	31	5.382
10	3.80	0.36	10.556	2.40	0.17	13	3.421
Average	3.265	0.488	7.129	2.233	0.258	23.5	8.801

Sinuosity Ratio = 1.34
Water Surface Slope = 0.0039

Appendix Table 1.2 Field data for HERB 1, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	2.82	0.42	6.714	0	0	40	14.184		
2	3.85	0.38	10.132	0	0	13	3.377	83	140
3	3.55	0.35	10.143	0	0	13	3.662		
4	3.50	0.38	9.211	0	0	13	3.714	14	51
5	3.04	0.38	8.000	0	0	13	4.276		
6	3.35	0.41	8.171	0	0	15	4.478	127	169
7	2.03	0.71	2.859	0	0	60	29.557		
8	1.80	0.53	3.396	0	0	24	13.333	54	63
9	5.45	0.38	14.342	0	0	15	2.752		
10	4.44	0.38	11.684	0	0	5.4	1.216	2	40
Ave	3.383	0.432	8.465	0	0	21.14	8.055		

Sinuosity Ratio = 1.34
Water Surface Slope = 0.0039

Appendix Table 2.1 Field data for HERB 2, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	3.17	0.74	4.284	2.70	0.54	23	7.256
2	5.47	0.64	8.547	1.85	0.32	27	4.936
3	5.60	0.50	11.200	4.65	0.20	19	3.393
4	3.49	1.03	3.388	2.45	0.89	20	5.731
5	3.42	0.97	3.526	3.02	0.73	20	5.848
6	3.35	0.81	4.136	3.00	0.61	20	5.970
7	5.25	1.12	4.688	4.85	0.78	20	3.810
8	5.81	0.46	12.630	3.95	0.38	25	4.303
9	5.00	0.37	13.514	3.30	0.64	25	5.000
10	4.60	0.91	5.055	3.07	0.64	20	4.348
Average	4.516	0.755	7.097	3.284	0.573	21.9	5.059

Sinuosity Ratio = 1.25
Water Surface Slope = 0.0025

Appendix Table 2.2 Field data from HERB 2, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	3.15	0.68	4.632	0	0	23	7.302		
2	5.47	0.59	9.271	0	0	27	4.936	63	137
3	5.54	0.54	10.259	0	0	15.5	2.798		
4	2.49	0.76	3.276	0	0	9.5	3.815	28	108
5	3.13	0.74	4.230	0	0	11	3.514		
6	3.63	0.68	5.338	0	0	9.6	2.645	51	115
7	3.80	0.60	6.333	0	0	13	3.421		
8	4.35	0.46	9.457	0	0	8.5	1.954	13	69
9	3.93	0.43	9.140	0	0	18	4.580		
10	3.15	0.41	7.683	0	0	6.5	2.063	99	152
Ave	3.864	0.589	6.962	0	0	14.16	3.703		

Sinuosity Ratio = 1.25
Water Surface Slope = 0.0025

Appendix Table 3.1 Field data for HERB 3, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	6.28	0.71	8.845	5.53	0.38	17	2.707
2	7.03	0.50	14.060	4.50	0.19	17	2.418
3	9.27	0.59	15.712	6.55	0.24	20	2.157
4	5.63	0.69	8.159	4.95	0.42	23	4.085
5	6.27	0.52	12.058	5.05	0.25	45	7.177
6	8.05	0.68	11.838	5.00	0.33	20	2.484
7	4.90	1.18	4.153	4.39	0.80	30	6.122
8	8.35	0.97	8.608	8.02	0.61	20	2.395
9	7.50	0.62	12.097	6.65	0.38	50	6.667
10	6.52	0.63	10.349	5.44	0.33	33	5.061
Average	6.980	0.709	10.588	5.608	0.393	27.5	4.128

Sinuosity Ratio = 1.64
Water Surface Slope = 0.00029

Appendix Table 3.2 Field data for HERB 3, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	6.10	0.64	9.531	4.90	0.37	17	2.787	48	78
2	7.15	0.41	17.439	3.60	0.135	17	2.378		
3	7.37	0.32	23.031	5.75	0.20	9.27	1.258	80	113
4	5.65	0.65	8.692	4.58	0.355	23	4.071		
5	6.20	0.52	11.923	3.49	0.205	45	7.258	69	89
6	7.52	0.53	14.189	3.89	0.26	13.4	1.782		
7	4.77	0.79	6.038	4.25	0.71	30	6.289	57	78
8	8.21	0.74	11.095	7.97	0.55	15	1.827		
9	7.26	0.57	12.737	6.00	0.32	50	6.887	43	92
10	6.25	0.54	11.574	4.70	0.26	27	4.320		
Ave	6.648	0.571	12.625	4.913	0.3365	24.667	3.886		

Sinuosity Ratio = 1.64
Water Surface Slope = 0.00029

Appendix Table 4.1 Field data for HERB 4, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	5.86	0.59	9.932	5.64	0.41	16.11	2.749
2	7.14	0.85	8.400	5.85	0.65	30	4.202
3	6.45	0.61	10.574	4.25	0.44	12	1.860
4	5.71	0.62	9.210	3.7	0.43	13.3	2.329
5	7.72	0.79	9.772	5.57	0.5	20	2.591
6	5.39	0.66	8.167	4.6	0.43	19.65	3.646
7	4.94	0.54	9.148	3.6	0.3	20.3	4.109
8	6	0.57	10.526	4.02	0.3	16	2.667
9	6.75	0.47	14.362	4.22	0.26	16	2.370
10	9.05	0.5	18.100	4.95	0.23	17	1.878
Average	6.501	0.620	10.819	4.640	0.395	18.036	2.840

Sinuosity Ratio = 1.33
Water Surface Slope = 0.00038

Appendix Table 4.2 Field data for HERB 4, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	5.91	0.6	9.850	4	0.34	13	2.200		
2	7.06	0.8	8.825	4.75	0.6	44	6.232	40	54
3	6.36	0.47	13.532	3.55	0.31	10	1.572		
4	4.77	0.55	8.673	3.08	0.36	12	2.516	37	82
5	7.15	0.61	11.721	5.15	0.41	12	1.678		
6	5.16	0.58	8.897	3.66	0.35	16	3.101	24	48
7	4.34	0.44	9.864	2.7	0.2	10	2.304		
8	4.98	0.4	12.450	3.15	0.22	10	2.008	62	103
9	5.63	0.34	16.559	3.3	0.17	10	1.776		
10	8.18	0.42	19.476	4.42	0.2	13	1.589	70	143
Average	5.954	0.521	11.985	3.776	0.316	15	2.498		

Sinuosity Ratio = 1.33
Water Surface Slope = 0.00038

Appendix Table 5.1 Field data for CLUMP 1, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	12.35	1.43	8.636	10.05	0.85	90	7.287
2	14.24	1.43	9.958	10.58	0.75	30	2.107
3	10.41	1.63	6.387	8.77	1.05	100	9.606
4	9.08	1.01	8.990	6.95	0.57	20	2.203
5	8.02	0.86	9.326	8.26	0.54	70	8.728
6	9.38	1.07	8.766	8.35	0.78	44	4.691
7	11.37	1.17	9.718	8.98	0.62	24	2.111
8	8.72	0.75	11.627	8.30	0.37	28	3.211
9	10.17	0.62	16.403	6.75	0.25	28	2.753
10	8.03	0.69	11.638	6.76	0.31	25	3.113
Average	10.177	1.066	10.145	8.375	0.609	45.900	4.581

Sinuosity Ratio = 1.79
Water Surface Slope = 0.00019

Appendix Table 5.2 Field data for CLUMP 1, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/9/94 (cm)
1	11.38	1.07	10.636	9.22	0.61	90	7.909		
2	12.12	0.92	13.174	9.85	0.52	24	1.980	123	134
3	9.84	1.16	8.483	8.10	0.76	100	10.163		
4	8.32	0.74	11.243	5.10	0.35	14.5	1.743	67	86
5	7.97	0.82	9.720	7.62	0.30	70	8.783		
6	8.99	0.98	9.173	8.45	0.55	44	4.894	104	111
7	10.05	0.81	12.407	8.08	0.37	24	2.388		
8	8.79	0.72	12.208	0	0	28	3.185	69	95
9	9.30	0.59	15.763	0	0	22	2.366		
10	7.73	0.52	14.865	0	0	21	2.717	42	87
Ave	9.449	0.833	11.767	5.642	0.346	43.75	4.613		

Sinuosity Ratio = 1.79
Water Surface Slope = 0.00019

Appendix Table 6.1 Field data for CLUMP 2, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	11.00	0.93	11.828	10.00	0.66	25	2.273
2	9.89	1.36	7.272	8.68	0.89	29	2.932
3	10.16	0.90	11.289	9.25	0.58	32	3.150
4	10.17	0.80	12.713	9.00	0.50	30	2.950
5	10.80	1.00	10.800	10.30	0.80	40	3.704
6	13.60	1.28	10.625	12.50	0.92	35	2.574
7	15.66	1.03	15.204	11.30	0.73	35	2.235
8	10.15	0.90	11.278	9.68	0.67	25	2.463
9	7.78	0.60	12.967	7.13	0.37	20	2.571
10	7.42	0.61	12.164	7.18	0.33	23	3.100
Average	10.663	0.941	11.614	9.502	0.645	29.400	2.795

Sinuosity Ratio = 1.43
Water Surface Slope = -0.12

Appendix Table 6.2 Field data for CLUMP 2, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	10.59	0.65	16.292	3.55	0.1	11.5	1.086		
2	8.97	1.07	8.383	4.43	0.37	29	3.233	69*	98*
3	9.7	0.75	12.933	0.89	0.04	32	3.299		
4	10.16	0.73	13.918	0	0	30	2.953		
5	10.7	0.99	10.808	5.3	0.3	40	3.738	53	91
6	12.43	1.01	12.307	9.6	0.44	35	2.816		
7	13.7	0.99	13.838	5.75	0.36	24	1.752	74	108
8	9.9	0.8	12.375	6.39	0.17	13	1.313		
9	7.65	0.56	13.661	1.33	0.02	19	2.484		
10	7.15	0.53	13.491	0	0	19	2.657	58	92
Average	10.095	0.808	12.801	3.724	0.18	25.25	2.533		

Sinuosity Ratio = 1.43
Water Surface Slope = -0.12
* average of two wells both located at station 2 on opposite sides of the stream

Appendix Table 7.1 Field data for CLUMP 3, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	2.06	0.53	3.887	1.41	0.40	9.8	4.757
2	1.80	0.73	2.466	1.73	0.37	62	34.444
3	2.14	0.53	4.038	1.71	0.30	25	11.682
4	2.18	0.62	3.516	1.38	0.32	35	16.055
5	1.95	0.62	3.145	1.10	0.30	30	15.385
6	1.44	0.75	1.920	1.26	0.42	60	41.667
7	2.40	0.84	2.857	1.42	0.52	30	12.500
8	2.26	0.70	3.229	1.10	0.36	50	22.124
9	2.22	0.67	3.313	1.41	0.27	25	11.261
10	2.42	0.61	3.967	1.91	0.23	40	16.530
Average	2.087	0.660	3.324	1.443	0.349	36.7	18.640

Sinuosity Ratio = 1.62
Water Surface Slope = 0.0027

Appendix Table 7.2 Field data for CLUMP 3, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	2.07	0.63	3.286	0.79	0.21	50	24.155		
2	1.93	0.72	2.681	0.75	0.23	62	32.124	36	65
3	1.8	0.52	3.462	0.8	0.14	25	13.889		
4	2.2	0.62	3.548	1.27	0.2	35	15.909	48	58
5	1.85	0.61	3.033	0.7	0.11	30	16.216		
6	1.4	0.64	2.188	1.15	0.24	60	42.857	44	71
7	1.83	0.81	2.259	1.31	0.4	30	16.393		
8	2.34	0.7	3.343	0.91	0.2	50	21.368	49	75
9	2.19	0.68	3.221	1.03	0.15	25	11.416		
10	2.59	0.68	3.809	1.9	0.1	40	15.444	58	73
Ave	2.02	0.661	3.083	1.061	0.198	40.7	20.977		

Sinuosity Ratio = 1.62
Water Surface Slope = 0.0027

Appendix Table 8.1 Field data for CLUMP 4, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	2.83	0.45	6.289	2.75	0.34	23.1	8.163
2	3.19	0.70	4.557	2.75	0.58	58	18.182
3	2.83	0.56	5.054	0.98	0.50	43	15.194
4	1.53	0.75	2.040	1.40	0.67	19	12.418
5	2.22	0.32	6.938	1.88	0.22	8	3.604
6	2.97	0.65	4.569	1.77	0.49	29	9.764
7	2.74	0.64	4.281	1.39	0.33	24	8.759
8	2.87	0.83	3.458	1.77	0.58	25	8.711
9	2.23	0.55	4.055	1.59	0.54	46	20.628
10	2.11	0.56	3.768	1.70	0.41	34	16.114
Ave	2.552	0.601	4.501	1.798	0.466	28.6	12.154

Sinuosity Ratio = 1.95
Water Surface Slope = 0.0023

Appendix Table 8.2 Field data for CLUMP 4, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	2.39	0.52	4.596	1.55	0.40	10	4.184	22	29
2	3.23	0.74	4.365	2.23	0.53	58	17.957		
3	3.25	0.65	5.000	1.03	0.44	43	13.231		
4	2.14	0.74	2.892	1.22	0.57	19	8.879	30	54
5	2.33	0.35	6.657	1.57	0.18	7.8	3.348		
6	2.18	0.70	3.114	1.50	0.50	29	13.303	36	62
7	1.77	0.61	2.902	1.19	0.40	24	13.559		
8	2.28	0.64	3.563	1.51	0.40	47	20.614	6	39
9	1.80	0.78	2.308	1.24	0.54	46	25.556		
10	1.76	0.60	2.933	0.99	0.40	34	19.318	4	28
Ave	2.313	0.633	4.309	1.403	0.436	31.78	15.210		

Sinuosity = 1.95
Water Surface Slope = 0.0023

Appendix Table 9.1 Field data for WOODY 1, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	8.9	1.09	8.165	5.88	0.78	686	77.079
2	6	1.09	5.505	5.63	0.84	686	114.333
3	7.85	1.2	6.542	6.72	0.9	550	70.064
4	6.78	0.91	7.451	6.69	0.64	50	7.375
5	5.48	0.74	7.405	4.74	0.42	60	10.949
6	6.28	0.74	8.486	5.69	0.46	80	12.739
7	5.3	0.78	6.795	4.56	0.57	70	13.208
8	6.93	0.66	10.500	5.67	0.46	90	12.987
9	6.18	0.98	6.306	5.83	0.7	686	111.003
10	6.42	0.79	8.127	5.58	0.58	95	14.798
Average	6.612	0.898	7.528	5.699	0.635	305.300	44.453

Sinuosity Ratio = 1.7
Water Surface Slope = -0.02

Appendix Table 9.2 Field data for WOODY 1, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	8.30	1.05	7.905	5.35	0.72	686	82.651	28	92
2	5.80	1.00	5.800	5.63	0.75	686	118.276		
3	7.10	1.05	6.762	6.50	0.83	550	77.465	49	77
4	6.67	0.82	8.134	4.07	0.53	50	7.496		
5	5.30	0.70	7.571	4.58	0.33	60	11.321	63	81
6	6.30	0.63	10.000	5.65	0.34	80	12.698		
7	4.94	0.74	6.676	4.73	0.49	70	14.170	67	103
8	6.20	0.60	10.333	5.38	0.44	90	14.516		
9	6.05	0.96	6.302	5.67	0.65	686	113.388	56	79
10	6.10	0.75	8.133	5.31	0.52	95	15.574		
Ave	6.276	0.83	7.762	5.287	0.56	305.3	46.756		

Sinuosity Ratio = 1.7
Water Surface Slope = -0.02

Appendix Table 10.1 Field data for WOODY 2, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	7.74	1.12	6.911	7.17	0.91	686	88.630
2	7.65	1.45	5.276	6.30	1.06	686	89.673
3	7.50	0.95	7.895	6.90	0.76	686	91.467
4	7.50	1.47	5.102	7.39	1.15	686	91.467
5	7.92	1.98	4.000	7.45	1.59	686	86.616
6	6.40	1.09	5.872	5.56	0.83	90	14.063
7	7.15	1.43	5.000	6.65	1.00	300	41.958
8	6.35	0.78	8.141	6.50	0.63	686	108.031
9	7.22	1.00	7.220	6.99	0.70	340	47.091
10	8.15	0.96	8.490	4.90	0.53	340	41.718
Average	7.358	1.223	6.391	6.581	0.916	518.600	70.071

Sinuosity Ratio = 1.89
Water Surface Slope = 0.0

Appendix Table 10.2 Field data for WOODY 2, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	7.66	1.09	7.028	6.38	0.68	686	89.556	64	104
2	6.66	1.09	6.110	5.95	0.82	686	103.003	59	107
3	7.17	0.85	8.435	6.53	0.51	686	95.676		
4	7.00	1.27	5.512	6.90	0.91	686	98.000		
5	7.06	1.37	5.153	6.80	1.08	686	97.167	50	97
6	5.76	1.14	5.053	4.60	0.68	90	15.625		
7	6.60	1.15	5.739	5.77	0.76	300	45.455	55	111
8	6.36	0.74	8.595	5.93	0.38	686	107.862		
9	6.90	0.79	8.734	6.65	0.44	340	49.275	78	112
10	7.57	0.54	14.019	5.80	0.30	7.8	1.030		
Average	6.874	1.003	7.438	6.131	0.656	485.38	70.265		

Sinuosity Ratio = 1.89
Water Surface Slope = 0.0

Appendix Table 11.1 Field data for WOODY 3, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	4.06	0.78	5.205	3.67	0.42	270	66.502
2	5.17	0.73	7.082	5.31	0.50	250	48.356
3	6.01	0.64	9.391	3.80	0.24	250	41.597
4	5.42	0.51	10.627	3.88	0.28	35	6.458
5	5.92	1.06	5.585	5.65	0.55	500	84.459
6	5.30	0.83	6.386	4.93	0.51	110	20.755
7	4.63	1.07	4.327	4.56	0.87	500	107.991
8	6.90	1.00	6.900	6.20	0.65	500	72.464
9	5.03	0.80	6.288	4.79	0.50	500	99.404
10	4.32	0.59	7.322	4.20	0.24	75	17.361
Average	5.276	0.801	6.911	4.699	0.476	299.000	56.535

Sinuosity Ratio = 1.8
Water Surface Slope = 0.0016

Appendix Table 11.2 Field data for WOODY 3, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	3.94	0.68	5.794	3.44	0.31	270	68.528	97	110
2	5.25	0.73	7.192	5.15	0.42	250	47.619		
3	6.27	0.73	8.589	2.88	0.21	250	39.872	90	113
4	5.48	0.53	10.340	3.40	0.16	35	6.387		
5	5.53	0.92	6.011	5.43	0.49	500	90.416	40	83
6	5.34	0.73	7.315	4.80	0.37	110	20.599		
7	4.82	0.90	5.356	4.68	0.62	500	103.734		
8	6.95	0.89	7.809	4.74	0.51	500	71.942	44	61
9	5.01	0.79	6.342	4.64	0.45	500	99.800	79	96
10	4.36	0.64	6.813	1.91	0.15	75	17.202		
Ave	5.295	0.754	7.156	4.107	0.369	299	56.610		

Sinuosity Ratio = 1.8
Water Surface Slope = 0.0016

Appendix Table 12.1 Field data for WOODY 4, 1993

	bankfull		width/depth	baseflow		floodprone	entrenchment
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio
1	4.00	0.54	7.407	3.40	0.32	9.91	2.478
2	6.50	0.52	12.500	5.50	0.28	7.7	1.185
3	5.09	0.63	8.079	3.40	0.43	7.4	1.454
4	4.77	0.65	7.338	4.07	0.33	85	17.820
5	4.77	0.63	7.571	4.37	0.32	85	17.820
6	5.90	0.42	14.048	4.90	0.19	12.09	2.049
7	5.05	0.49	10.306	4.20	0.28	7.5	1.485
8	3.91	0.60	6.517	3.48	0.29	7.48	1.913
9	3.90	0.74	5.270	2.53	0.44	7.25	1.859
10*	4.71	1.02	4.618	4.25	0.73	85	18.047
Average	4.877	0.580	8.782	3.983	0.320	25.481	5.340

Sinuosity Ratio = 1.1
Water Surface Slope = 0.0044
* deep pool outlier that was rejected from the analysis because it was not representative of the reach

Appendix Table 12.2 Field data for WOODY 4, 1994

	bankfull		w/d	baseflow		floodpr	entrench	depth to water table	
Station	width (meters)	depth (meters)	ratio	width (meters)	depth (meters)	width (meters)	ratio	6/18/94 (cm)	9/10/94 (cm)
1	3.66	0.49	7.469	3.45	0.26	9	2.459	65	96
2	6.50	0.57	11.404	5.37	0.25	7.8	1.200		
3	4.80	0.63	7.619	3.45	0.40	6.8	1.417	96	101
4	3.97	0.56	7.089	4.07	0.31	6.42	1.617		
5	4.39	0.51	8.608	4.27	0.28	6.44	1.467	73	97
6	5.38	0.45	11.956	4.69	0.18	10.3	1.914		
7	4.83	0.47	10.277	3.95	0.25	6.91	1.431	89	112
8	3.70	0.48	7.708	3.80	0.22	7.52	2.032		
9	4.20	0.64	6.563	2.27	0.35	6.31	1.502	73	115
10*	4.60	1.03	4.466	4.27	0.71	85	18.478		
Average	4.603	0.533	8.744	3.924	0.278	7.50	1.671		

Sinuosity Ratio = 1.1
Water Surface Slope = 0.0044
* deep pool outlier that was rejected from the analysis because it was not representative of the reach

Appendix Table 13.1 Particle Size Distribution using Wolman Pebble Count Technique

1993	HERB 1	HERB 2	HERB 3	HERB 4
silt/clay*	63	80	62	44
sand**	2	0	0	3
gravel***	35	20	38	53
median particle size	silt/clay	silt/clay	silt/clay	gravel
1994				
silt/clay	79	100	66	57
sand	0	0	1	0
gravel	79	0	33	43
median particle size	silt/clay	silt/clay	silt/clay	silt/clay

* < .05mm
** .05 - 2mm
*** 2mm - 8cm

Appendix Table 13.1 continued

1993	CLUMP 1	CLUMP 2	CLUMP 3	CLUMP 4
silt/clay*	30	46	77	84
sand**	6	0	6	7
gravel***	64	54	17	9
median particle size	gravel	gravel	silt/clay	silt/clay
1994				
silt/clay	35	41	72	84
sand	0	2	3	5
gravel	65	57	25	11
median particle size	gravel	gravel	silt/clay	silt/clay

* < .05mm
** .05 - 2mm
*** 2mm - 8cm

Appendix Table 13.1 continued

1993	WOODY 1	WOODY 2	WOODY 3	WOODY 4
silt/clay*	58	64	48	35
sand**	4	0	24	4
gravel***	38	36	28	51
cobble****	0	0	0	10
median particle size	silt/clay	silt/clay	sand	gravel
1994				
silt/clay	47	48	43	11
sand	6	2	5	1
gravel	47	50	52	80
cobble	0	0	0	8
median particle size	sand	gravel	gravel	gravel

* < .05mm
** .05 - 2mm
*** 2mm - 8cm
**** 8 - 60cm