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Application of the United States Army Corps of Engineers wetland delineation field indicators within subalpine zone wetlands of western Montana

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APPLICATION OF THE UNITED STATES ARMY CORPS OF ENGINEEERS WETLAND DELINEATION FIELD INDICATORS WITHIN SUBALPINE ZONE WETLANDS OF WESTERN MONTANA

by

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presented in partial fulfillment of the requirements

for the degree of

Master of Science

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Application of the United States Army Corps of Engineers Wetland Delineation Field Indicators Within the Subalpine Zone of Western Montana

Director: Paul L. Hansen PLH

This study, conducted in 1997 and 1998, examined the correlations between the 1987 Army Corps of Engineers Wetlands Delineation Manual wetland field indicators of wetland hydrology, hydrophytic vegetation, and hydric soils within wetlands in the subalpine zone of western Montana. The methods as outlined in the 1987 Corps Manual used in the determination of jurisdictional wetland status and in wetland boundary delineation, may produce inconsistent and inaccurate jurisdictional wetland approximations in problem area wetlands. It is important that the 1987 Corps Manual methods be tested in problem area wetlands. I used the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types as described in *The Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) to locate study sites which held similar subalpine characteristics. At these sites I found only 44 percent of the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type plots and 6 percent of the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type plots to be jurisdictional wetlands. Weighted Average vegetation plot scores correlated modestly to the seasonally high water table ($rho = 0.644$, $p < 0.01$) within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, and very low ($rho = 0.094$, p = not significant) within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type. Weighted average vegetation plot scores correlated modestly with the depth to redox soil features ($rho = 0.439$, $p < 0.01$) and the thickness of the A horizon ($rho = -0.499$, $p < 0.01$) within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, and very low ($rho = -0.241$, p = not significant; and $rho = 0.285$, $p = < 0.10$) within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type. The depth to the seasonally high water table correlated strongly with the depth to redox soil features ($rho = 0.702$, $p < 0.01$) and modestly with the thickness of the A horizon ($rho = -0.520$, $p < 0.001$) within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, and very low ($rho = 0.147$, p = not significant; and $rho = -0.213$, p = not significant) within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type. Within all sites, only seasonally high water tables within 15 cm (5.91 in) of the soil surface for at least 7 consecutive days had a significant correlation to the weighted average vegetation plot scores ($rho = 0.511$, $p < 0.10$). Within the subalpine zone for these habitat types, the 1987 Corps Manual indicators of vegetation composition are not good indicators of the seasonally high water table. The wetland scientist should rely upon the presence and depth of redoxomorphic soil features when attempting to determine the seasonally high water table. The need for the regionalization of wetland field indicators is discussed, as well as opportunities for further research.

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INTRODUCTION

As society has come to recognize the value of this nation's wetlands, the methods of defining wetlands and their boundaries has become critical to their conservation and protection (Roman and others 1985; Hansen and others 1995). Although the 1977 Clean Water Act (33 CFR 330.2) originally protected wetlands from dredging and filling in the U. S., it wasn't until the 1987 *Corps of Engineers Wetlands Delineation Manual* (hereafter, the 1987 Corps Manual; Environmental Laboratory 1987) that the methods for the federal determination of a site's jurisdictional wetland status and delineation of the wetland boundary were published. The methods outlined in the 1987 Corps Manual stated that wetland determinations are to be accomplished through the thorough examination of water, substrate, and biota (Environmental Laboratory 1987; National Research Council 1995). The protection and regulation of wetlands in the United States requires that the methods as outlined in the 1987 Corps Manual produce accurate, consistent, and repeatable field determinations over the wide range of wetland ecologies (National Research Council 1995).

However, the frequency and duration of saturation required for wetland formation and maintenance has not yet been summarized by region. The lack of information regarding the fundamental hydrologic requirements for regional jurisdictional wetlands has been described as the "serious weakness in the scientific foundation for wetland delineation" (National Research Council 1995). Furthermore, the reliability of of soil, vegetation, and hydrology field indicators as defined by the 1987 Corps Manual is not known for most regions, and there is a current need for regional hydrologic studies to clarify how vegetation and soil characteristics are related to different hydrological regimes (National Research Council 1995). Finally, the National Research Council identified the use of regional information specific to particular kinds of wetlands as the "most desirable" approach to the building of a "robust empirical foundation for regulatory practice" (National Research Council 1995).

Before discussing how these gaps in wetland delineation science may be filled, I will first provide some background information on the wetland characterization methods described in the 1987 Corps Manual.

Wetland Delineation

The 1987 Corps Manual defines jurisdictional wetlands as such:

> Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

To determine if an area meets this definition, the 1987 Corps Manual applies a three-parameter approach which requires the examination of soils, vegetation, and hydrology features. A wetland is considered jurisdictional and protected by law under the Clean Water Act (33 CFR 330.2) if positive indicators of wetland hydrology, hydric soils, and hydrophytic vegetation, are present. Wetlands are commonly referred to as either jurisdictional wetlands or functional wetlands. While all three indicators are required to be present in a jurisdictional wetland, a functional wetland needs to have present only one of the three indicator criteria (Cowardin and others 1979). Many functional wetlands do not meet jurisdictional requirements, however, due to the greater accumulation of water at or near the soil surface, they perform many of the functions of a wetland. It is the prevailing view that the functional wetland is a wetland as defined by science, and the jurisdictional wetland is a wetland as defined by law.

Both definitions rely upon the same three wetland field indicators: wetland hydrology, hydric soils, and hydrophytic vegetation. Whenever the jurisdictional wetland status of a site is in need of determination, the field delineator uses the methods for determination as outlined in the 1987 Corps Manual. These methods rely upon the ecological correlations between wetland hydrology and the formation of hydric soils features, and hydrophytic plant communities. These same correlations are then relied upon to delineate a single ecologically sound boundary separating wetland from upland (Environmental Laboratory 1987). A discussion of each parameter follows.

Hydrology— Recurrent, sustained saturation of the upper part of the substrate is the driving force behind the formation and maintenance of wetlands (Carter 1986; LaBaugh 1986; van der Valk and others 1994; Doss 1995). The 1987 Corps Manual requires direct evidence of saturation or inundation at a frequency and duration indicative of wetland hydrology which is currently defined as 5 percent or 14 days of the growing season, but this evidence is difficult to obtain (National Research Council 1995). For the field delineator, the direct observation of the water table through the use of perforated wells, nested piezometer units, or stream gage stations is not practical (Wetlands Research Program 1993; Carter 1994; Light and others 1993; National Research Council 1995). Presently, the indirect indicators of wetland hydrology such as debris drift lines, and water marks, are commonly used as evidence of flooding or saturation (Carter and others 1994; National Research Council 1995). However, these indirect hydrologic indicators convey little about the frequency, duration, or timing of inundation or soil saturation (Light and others 1993; Davis and others 1996). To this point, it is the quantification of wetland hydrology that provides the most difficulty to the delineation of wetlands (Carter 1986; Busch and others 1992; Skaggs and others 1994; National Research Council 1995).

Soils—The examination of wetland soil characteristics is a powerful indicator of a site's hydrology. It is well accepted that the saturation of pore space in soils by water decreases the movement of oxygen (Megonigal and others 1993). Respiratory oxygen demand of plant roots and soil organisms deplete oxygen levels and suppress redox potential creating anaerobic conditions. By definition, hydric soils are soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part (Pickering and Veneman 1984; Megonigal and others 1993; Skaggs and others 1994). Continuous or frequent anaerobisis will create distinctive redoxomorphic features characteristic to wetland soils (Pickering and others 1984; Environmental Laboratory 1987; Light and others 1993; National Research Council 1995).

Hydric soils indicators are commonly used to find the depth to the seasonally high water table. The most accurate measures of hydric soils conditions involve monitoring soil moisture, soil O_2 content, or redox potential (Megonigal and others 1993; Davis and others 1996). Since these methods are impractical to routine wetland delineation, hydric soils are often identified by the presence of a low-chroma matrix, mottles, and/or a surface horizon high in organic matter (Faulkner and Patrick 1992; Megonigal and others 1993). Although the examination of the soil profile is often the most reliable field technique for the characterization of the moisture regime, saturation is not always necessarily a prerequisite for mottling formation (Pickering and Veneman 1984; Megonigal and others 1993). Thus, in different soil types certain indicators are more applicable than others. Current Federal guidelines for hydric soils indicators for different soil types are outlined in the 1987 Corps Manual, and in *Field Indicators of Hydric Soils in the United States Version 3.2* (USDA 1996).

Vegetation—The presence of hydrophytic vegetation is often the first indicator used by the wetland scientist to assess a site's wetland status using the 1987 Corps Manual. Hydrophytic vegetation is defined as macrophytic plant life growing in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content (Tiner 1991). Soil waterlogging acts as a selective factor for species which have specialized adaptations for survival under anaerobic conditions (Light and others 1993; Mitsch and Grosselink 1993). The presence of a species in a wetland depends on that species' tolerance for saturation within the root zone, and hydrophytes have special morphological, metabolic, and life history adaptations which allow them to live in anaerobic conditions (Hook 1984;

Tiner 1991; Carter and others 1994). Thus, by examining a site's vegetation community the field delineator can attempt to determine if hydrology indicative of saturated conditions where anaerobisis has depleted soil oxygen and created reducing conditions exists upon that site (Tiner 1991).

Because vegetation is considered a characteristic feature of wetlands, the U.S. Fish and Wildlife Service in cooperation with the United States Army Corps of Engineers, the Environmental Protection Agency, and the United States Department of Agriculture Natural Resource Conservation Service has published the *National List Of Plant Species That Occur In Wetlands* (Reed 1988). This list divides the United States into separate regions: the two regions that cover Montana are Region 4 (North Plains Region) and Region 9 (Northwest Region).

In the Reed (1988) list, plants are separated into five basic wetland ecological indicator status groups which are based on a plant species frequency of occurrence in wetlands. The five groups are: 1) obligate wetland plants (OBL) that occur almost always (estimated probability > 99 percent) in wetlands under natural conditions; 2) facultative wetland plants (FACW) that usually occur in wetlands (estimated probability 67-99 percent), but occasionally are found in non-wetlands; 3) facultative plants (FAC) that are equally likely to occur in wetlands or non-wetlands (estimated probability 34-66 percent), 4) facultative upland plants (FACU) that usually occur in non-wetlands (estimated probability 67-99 percent), but occasionally are found in wetlands (estimated probability 1-33 percent); and, 5) obligate upland (UPL) plant species which occur almost always (estimated probability > 99 percent) in non-wetlands under natural conditions.

There are currently two commonly used methods for evaluating whether a vegetation community is considered hydrophytic wetland vegetation, both of which use the Reed (1988) descriptors. The first method uses a dominance ratio which considers a plant community hydrophytic if more than 50 percent of the dominant species have a wetland indicator status of OBL, FACW, or FAC (Environmental Laboratory 1987). The dominant species are those with > 20 percent canopy cover within each of the tree, sapling, shrub, herb, woody vine, and bryophyte vegetation layers (Environmental Laboratory 1987). A second method uses a weighted average of the indicator status of all species in the community. The Reed (1988) indicators are assigned numerical values (OBL=1, FACW=2, FAC=3, FACU=4, UPL=5), and an average score is calculated with species weighted by abundance (Federal Interagency Committee for Wetland Delineation 1989; hereafter, the 1989 Manual). A plant community is considered hydrophytic if the weighted average index is less than 3.0 (Wentworth and Johnson 1986). The 1989 Manual considers both of these techniques to be equivalent, but tests have shown that the methods can produce different determinations of the hydrophytic plant community (Davis and others 1996).

The Fidelity of Wetland Field Indicators

Boundary Determination—Several techniques for characterizing wetland hydrology and vegetation communities exist, and different soil features are more appropriate for different regions of the U. S. Which techniques are most accurate? Only a few studies have simultaneously measured vegetation, hydrology, and soils features in forested wetlands and subsequently tried to correlate their relationship to the determination of wetland boundary delineation across the wetland ecotone (Allen and others 1989).

The results of these studies have shown confounding relationships between the three wetland field indicators (Anderson and others 1980; Allen and others 1989; Schmalzer and Hinkle 1992; Carter and others 1994). In north Florida, Light and others (1993) found hydrophytic plant communities on soils that were not hydric. Golet and others (1993) found no change in facultative dominated vegetation communities over a transition from hydric to nonhydric soils. Roman and others (1985) found boundary determinations based upon soil gleying in transitional wetlands to encompass hydrologically dry sites. Using direct hydrology measurements, Carter and others (1994) located jurisdictional vegetation boundaries above and below boundaries determined through soils and hydrology investigations alone. Thus, application of Federal parameters in ecotones is problematic (Davis and others 1996).

Problem Areas—Though this research has shown the difficulties in applying the 1987 Corps Manual most wetland areas can be accurately delineated a majority of the time (National Research Council 1995). However, the reliability of the three wetland field indicators is tenuous in the wetland types defined as problem areas by the 1987 Corps Manual. A problem area is a wetland in which of one or more indicators may periodically be lacking due to normal seasonal or annual variability (Environmental Laboratory 1987). Problem areas include: prairie potholes; facultative upland-dominated evergreen forested wetlands; highly variable, seasonal wetlands; wetlands on glacial deposits; slope wetlands; riparian ecosystems; and permafrost wetlands (Environmental Laboratory 1987; National Research Council 1995). The lack of recognition of the unique ecological characteristics (i.e. the indicators of wetland hydrology, hydric soils, and hydrophytic vegetation) of the wetlands of Montana, especially for those problem area wetlands, has led to difficulties in wetland delineation in this region.

Current delineation methods were developed in the southeastern United States hardwood bottomlands which are generally temperate, and characterized by long, humid summers and mild winters. This fact makes the 1987 Corps Manual field indicators most applicable there (Carter and others 1994; National Research Council 1995). Problems in delineation stem from the vagueness of the wetland definition itself, and in establishing "measurable and testable criteria for the three parameters" (Carter and others 1994). To this point, the National Research Council (1995) recently noted that "much of the controversy over wetland delineation can be reduced to a single question: which characteristics can be used to identify wetland ecosystems and distinguish them from other ecosystems?" For accurate wetland identification and delineation the fidelity of wetland indicators needs to be tested within identified problem areas at a regional scale (National Research Council 1995).

Subalpine Wetlands

In the Intermountain West, wetlands in the subalpine zone are not uncommon. Subalpine is defined as the vegetative zone dominated by the *Abies lasiocarpa* (subalpine fir) series in Western Montana located from approximately 1,525 m (5,000 ft) to 2,440 m (8,800 ft) (Pfister and others 1977; Lackschewitz 1991). Using the 1987 Corps Manual definition, subalpine wetlands are problem area wetlands. These systems have short growing seasons due to a Cryic soil temperature regime (growing season of June 1 through August 30), are often found on wet seep slopes, and tend to have wide ecotonal gradations between wetland and upland. Each of these properties cause the positive correlations between the presence of wetland hydrology and the formation of hydric soils and hydrophytic vegetation communities to be less reliable to the field delineator (National Research Council 1995). The following sections address the ecological properties of subalpine wetlands which affect the applicability of the 1987 Corps Manual methods.

Temperature and Saturation—The respiration rates of plants, animals, and soil microbes are directly affected by soil temperature, as the rate of respiration generally doubles with each increase of 10 °C (18 °F) (Ping 1987; Buol and others 1989). Since the demand for oxygen in a soil is highly dependent on temperature, seasonal and monthly differences in temperature have a marked effect upon the rate of chemical and biological changes that take place in the soil as the result of flooding or anaerobic conditions (Chapin and others 1991; Light and others 1993).

In subalpine soils, plant and microbial respiration rates are depressed, and flooded soils take longer to become anaerobic as temperatures are low (Jackson and Drew 1984). Thus the soil temperature during a flooding event will play a significant role in the rate of development of anaerobic soil conditions and the subsequent development of hydric soils and hydrophytic vegetation indicators. The term "saturation threshold" addresses these issues and is defined as the minimal period of time needed to cause reducing or anaerobic conditions (Environmental Laboratory 1987). The 1987 Corps Manual states that saturation or inundation shall only be relevant to periods within the growing season, as "metabolic processes of soil microorganisms, plant roots, and animals are negligible" outside of this period (National Research Council 1995). Does this hold true for the subalpine zone? If it does not, what are the implications?

Growing Season Debate—The sensitivity of plants to saturated conditions as well as the effects of temperature on oxygen depletion, change the saturation threshold for different regions. Each ecological region has an unique growing season to which the saturation threshold is attached. The 1987 Corps Manual places the temperature threshold for determination of beginning of the growing season at greater than 5 °C (41 °F) measured at 50 cm (19.7 in) below the soil surface. This is difficult to measure and subsequently the mean frost-free portion of the year has been substituted to determine the growing season (Environmental Laboratory 1987). Using the frost-free period does not accurately characterize the soil temperatures and potential for biological activity during frost-prone months (Magney 1993). In particular, this threshold fails for wetland communities in cold regions, such as the subalpine zone of Western Montana (National Research Council 1995).

For example, Barrow, Alaska averages 16 frost-free days a year, but averages 91 days with a mean daily temperature above freezing (National Research

Council 1995). In equatorial alpine communities and in midaltitude alpine plant communities, subfreezing temperatures often occur early in the growth period (Billings and Bliss 1959; Chapin and Shaver 1985; National Research Council 1995). Studies in coastal British Columbia have shown that in many years biological activity occurs over a period exceeding the growing season limit set by the mean frost-free period (National Research Council 1995). These obvious discrepancies in the definition are recognized in the 1987 Corps Manual but no regional adjustments for these problems have been recommended (National Research Council 1995).

Soil and Plant Responses. Recent research has shown that soil microorganisms active during the winter months may play a key role in promoting plant activity during or before the spring snowmelt (Brooks and others 1997). In the past, most research into respiratory activity has been limited to the spring and summer months as it was thought that rates of winter decomposition and respiratory activity are minimal in frozen or snow covered soils (Brooks and others 1997). However, studies in the 1980's showed that substantial losses of leaf litter during the winter months of (from 50 to 90 percent of the annual litter fall) was not uncommon (Coxson and Parkinson 1987). Research in the aspen woodland forests in southwestern Alberta indicated that large pulses of N_20 occurred in several types of subarctic soils during spring thaw, and that most of the microbial activity occurred at depths below the thaw line or during periods when the entire soil profile was frozen (Coxson and Parkinson 1987). It is now thought that consistent snow cover on alpine soils insulates the soil from extreme air temperatures and allows heterotrophic activity to continue through much of the winter . This can be compared to sites with minimal snow cover and frozen soils where production of N_20 does not begin until snowmelt (Brooks and others 1997).

Thus, soil microbes are active in arctic and temperate wetlands where the temperature is below biological zero. In a Wyoming subalpine meadow soil microbes were found to oxidize > 25 percent of the estimated annual carbon fixation at soil temperatures between 0.5 °C (32.9 °F) and 1.5 °C (34.7 °F) (Sommerfeld and others 1993). Bacterial respiration in tundra soils continues down to -6.5 °C (20.3 °F) or -7 °C (19.4 °F), and some taiga soil microbes have greater respiration rates at 4 °C (39.2 °F) than at 20 °C (68 °F) (National Research Council 1995). Walker and others (1989), found during the examination of Pergelic Cryaquepts and Histic Pergelic Cryaquepts, that although saturated for most of the growing season, some soils only entered a reducing state once frozen and the plants were dormant. Most importantly in relation to subalpine forested wetlands, reducing conditions, low redox potentials, and methane emissions due to microbial activity in saturated soils have been found to occur at temperatures below biological zero outside of the defined growing season (National Research Council 1995).

It is now thought that microbial activity in snow-covered soils plays a key role in the N and C nutrient cycling before many plants become active. It was previously thought that soil temperature and moisture were the controlling factors in these cycles, it now is understood that within these cold soils the main controlling factor is a source of organic matter (Coxson and Parkinson 1987; Christensen and Tiedje 1990; Brooks and others 1996). This would help explain why N levels beneath alpine snowpack are highest just prior and during snowmelt, when most plants have yet to become active (Mullen and others 1998). In association with microbial activity during winter months it has also been found that some plant species are also active before the period which is considered the growing season.

Obviously, a single definition for the period considered to be the growing season is not applicable to the wide range of wetland sites found within the United States (National Research Council 1995). Within the subalpine zone the main problem with the current growing season definition is its inflexibility to account for regional plant and microbial adaptation to cooler temperatures (Chapin and others 1991). Plant growth in the alpine environment is limited by multiple stresses including high winds, low temperature, low nutrient availability and soils moisture (Walker and others 1994). These factors do result in lower levels of primary productivity and phytomass in alpine systems as compared to other systems (Walker and others 1994).

Although snow cover generally minimizes photosynthetic activity during the early stages of snowmelt, these same soils are insulated from extreme air temperatures (Brooks and others 1996). This may explain how some alpine plant species adapt to cooler conditions and they have been found to remain physiologically active at soil temperatures outside the period defined as the growing season (Bedford and others 1992). The often studied alpine herb *Ranunculus adoneus* (snow buttercup) takes advantage of cold soils by developing arbuscular mycorrihzal fungal root structures late in the previous years growing season. Thus, this herb can utilize the early season flush of N before new roots have become active (Mullen and others 1998). In an area of permafrost wetlands soils in Alaska, mean annual soil temperatures in the saturated zone rarely exceed 0 °C (32 °F) for the warmest weeks, creating a biological zero (< 5 °C [< 41 °F]) growing season of 0 days. However, the roots of Arctic plants are found to grow below biological zero, and photosynthesis rates are "significant" at -4 ° C (24 °F) (Tieszen and others 1980). Arctic, montane, and temperate plant species grow, and compete under snow cover, and some evergreen shrubs photosynthesize even when their root zone is frozen (Billings and Bliss 1959; Egerton and Wilson 1993; National Research Council 1995). Overall, at least 20 different plant species grow under snowpack at temperatures below 0 °C (32 °F), and even in northern hardwood forests, spring-flowering herbs can develop leaves in partial snow cover (National Research Council 1995).

Problems Using the 1987 Corps Manual in Subalpine Wetlands—The criteria for wetland hydrology proposed by the 1987 Corps Manual are an attempt to define the depth and duration of saturation which will produce anaerobic conditions in the upper part of the soil profile, thus producing indicative wetland features (Skaggs and others 1994). As discussed here, wetlands in the subalpine zone pose unique problems to the assumptions associated with the soil, vegetation, and hydrology correlations used in the 1987 Corps Manual. The 1987 Corps Manual defines the growing season for Cryic soils as June 1 through August 30, but does this accurately represent the period of microbial and plant activity? Thus I raise these questions: What is the saturation threshold in Cryic soils? Will the plant community accurately reflect this hydrology? What hydric soil features will form and under which hydrologic regimes will they form?

The methods in the 1987 Corps Manual assume that strong relationships exist between soil saturation and wetland indicators. Obviously, these relationships are not uniform across the wide range of soils, climates, and wetland types in the United States (National Research Council 1995). Before the 1987 Corps Manual can be confidently applied in subalpine wetlands, correlations between hydrological regimes and the various methods used to characterize the vegetation community and hydric soils features need to be quantified.

BACKGROUND, OBJECTIVES, AND HYPOTHESES

Background

Montana is unique in that we have the only state-wide operational riparian and wetland ecological site classification: *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995). In this document a total of 113 "types" are identified for Montana representing 69 habitat types and 44 community types. This state-wide ecological site classification system provides land managers a tool for classifying riparian and wetland sites. Within this classification is an approximation of jurisdictional wetland status for all of the 133 types. This approximation was developed to give land managers an uncomplicated process for identifying potential jurisdictional wetland and riparian areas associated with these types (Hansen and others 1995). This information however, is not a substitute for an on-site wetland determination.

Recently, to provide users of the Hansen and others (1995) classification a more accurate approximation of jurisdictional wetland status, the Second Approximation of Jurisdictional Wetland Status for all types within the *The Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) was initiated. In a Montana Riparian and Wetland Association (MRWA) review of the 113 types, eight habitat types (ht) and one community type (ct) were given preference as having dubious wetland status and important contemporary management concerns. These types were to be given special consideration in the Second Approximation of Jurisdictional Wetland Status.

They are :

Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador tea) ht

Abies lasiocarpa/Streptopus amplexifolius (subalpine fir/twisted stalk) ht

Pinus ponderosa/Cornus stolonifera (ponderosa pine/red-osier dogwood) ht

Fraxinus pennsylvanica/Prunus virginiana (green ash/chokecherry) ht

Populus trichocarpa/Cornus stolonifera (black cottonwood/red-osier dogwood) ct

Salix geyeriana/Calamagrostis canadensis (geyer willow/bluejoint reedgrass) ht

Artemisia cana/Agropyron smithii (silver sagebrush/western wheatgrass) ht

Sarcobatus vermiculatus/Agropyron smithii (black greesewood/western wheatgrass) ht

Agropyron smithii (western wheatgrass) ht[1]

All of these types are considered to fall within the 1987 Corps Manual definition of a problem area. Current delineation methodologies incorporate some regional elements, such as the regional hydrophyte list and supplements to the hydric soils list. However, the fidelity and reliability of most wetland field indicators is not known for specific regions, and is especially troublesome in known problem areas (National Research Council 1995). To this point, it is the recommendation of the National Research Council (1995) that "hydrologic features associated with flooding or saturation should be calibrated regionally for specific wetland types to facilitate more consistent delineation."

In January 1997 I began the task of completing the Second Approximation of

[1] Taxonomic nomenclature follows Hitchcock and Cronquist (1973) for all taxa.

Jurisdictional Wetland Status study. Specifically, I selected the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types from the MRWA list, to explore regionally specific wetland field indicator relationships within the subalpine zone problem area.

Goals and Objectives

In 1997 I used the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types from the *Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) to locate wetland sites within the subalpine zone of Western Montana that exhibit similar characteristics. I chose these two habitat types due to their importance to the Second Approximation of Jurisdictional Wetland Status, and their location in the subalpine zone which may complicate the correlations between wetland field indicators (National Research Council 1995). In 1997 and 1998 I measured hydrology, vegetation, and soils indicators within these selected sites. In September 1998 I approximated the jurisdictional wetland status of the two habitat types, and then analyzed the relationships between the three 1987 Corps Manual wetland field indicators.

The goal of my study was to: Test the regional applicability of 1987 Corps Manual wetland delineation methods within the subalpine zone of western Montana.

The specific objectives of my study study were as follows:

1) Aid in the Second Approximation of Jurisdictional Wetland Status of the Hansen and others (1995) riparian and wetland types by determining the federal jurisdictional wetland status of the *Abies lasiocarpa/Ledum glandulosum* (Subalpine Fir/Labrador Tea) and *Abies lasiocarpa/Streptopus amplexifolius* (Subalpine Fir/Twisted Stalk) habitat types (Hansen and others 1995) using direct hydrology measurements in association with vegetation and soil surveys.

2) Determine the strength of correlations between commonly used field indicators of soils, vegetation, and hydrology used for boundary delineation in Western subalpine riparian and wetland zones, and lend insight to the applicability of wetland delineation methods in the Western subalpine riparian and wetland zones.

3) Recommend techniques for the regional testing of wetland parameters for different wetland types throughout the West.

Hypotheses

To address objective two, I tested three hypotheses. They are as follows:

1. H_O: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types there is a strong correlation between hydrophytic vegetation plot scores and wetland hydrology.

H_a: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types there is not a strong correlation between hydrophytic vegetation and wetland hydrology.

Rejection Rule: Reject H_o if the calculated correlation coefficient $|rho_c| < 0.70$.

2. H_o: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types there is a strong correlation between hydric soil features and hydrophytic vegetation.

H_a: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types there is not a strong correlation between hydric soil features and hydrophytic vegetation.

Rejection Rule: Reject H_o if the calculated correlation coefficient $|rho_c| < 0.70$.

3. H_o: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum*

glandulosum (subalpine fir/Labrador tea) habitat types there is a strong correlation between wetland hydrology and hydric soil features.

H_a: In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types there is not a strong correlation between wetland hydrology and hydric soil features.

Rejection Rule: Reject H_o if the calculated correlation coefficient $|rho_c| < 0.70$.

The rejection rule for hypotheses three, four, and five was predetermined by the author. A calculated correlation coefficient (rho) of greater than 0.70 is considered the break-point between a modest correlation (rho > 0.40) and a strong correlation (rho > 0.70) (Fowler and Cohen 1990). My experience in wetland delineation and familiarity with the strong correlations exhibited between the three wetland field indicators in non-problem area wetlands, led me to use the strong correlation (rho > 0.70) as the rejection rule for the hypotheses regarding the wetland indicator relationships I tested within subalpine wetlands.

GENERAL ECOLOGY OF THE *ABIES LASIOCARPA/LEDUM GLANDULOSUM* (SUBALPINE FIR/LABRADOR TEA) AND *ABIES LASIOCARPA/STREPTOPUS AMPLEXIFOLIUS* (SUBALPINE FIR/TWISTED STALK) HABITAT TYPES AND STUDY AREA DESCRIPTION

Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador tea) Habitat Type

The *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type is a minor type at mid to high elevations in Western Montana (Hansen and others 1995). Significant populations are located in the western portion of the Flathead National Forest in the Tally Lake Ranger District, the Kootenai National Forest, and in the southern portions of the Bitterroot National Forest. The *Calamagrostis canadensis* (bluejoint reedgrass) phase represents the wet phase while the *Ledum glandulosum* (Labrador tea) phase represents the drier phase of this wetland habitat type. The *Calamagrostis canadensis* (bluejoint reedgrass) phase is associated with low gradient streams and wet meadows. The *Ledum glandulosum* (Labrador tea) phase is associated with hillsides that are typically only wet in the spring and/or early summer.

Figure 1 shows the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type *Ledum glandulosum* (Labrador tea) phase on a moderate slope in the Bitterroot National Forest. Figure 2 is representative of the *Calamagrostis canadensis* (bluejoint reedgrass) phase bordering a wet meadow at the base of a slope dominated by *Picea englemannii* (Englemann spruce), *Abies lasiocarpa* (subalpine fir), *Carex* spp. (sedge) and *Ledum* *glandulosum* (Labrador tea).

Figure 1. *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type *Ledum glandulosum* (Labrador tea) phase.

Figure 2. *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type *Calamagrostis canadensis* (bluejoint reedgrass) phase.

Soils of the *Calamagrostis canadensis* (bluejoint reedgrass) phase are poorly to somewhat poorly drained and are generally Aquic Cryaquolls or Aquic Cryoborolls. The soils typically have thick organic layers over alluvium or glacial till. Soil textures are generally silty clay. These soils can generally be considered hydric. Soils of the *Ledum glandulosum* (Labrador tea) phase are moderately to well drained and classify as Humic Cryaquepts and Typic/Andic Cryoborolls. Soil textures are generally gravelly sands that have developed from quartzite substrates. Soils for this phase are generally non-hydric. These mid and upper elevation valley bottom settings are considered to have a cryic soil temperature regime (Sirucek and others 1995).

Pinus contorta (lodgepole pine), *Picea englemannii* (Englemann spruce), and *Abies lasiocarpa* (subalpine fir) are the dominant conifers of this type. The undergrowth is dominated by *Ledum glandulosum* (Labrador tea), *Calamagrostis canadensis* (bluejoint reedgrass), *Vaccinium scoparium* (grouse whortleberry), and *Menziesia ferruginea* (false azalea). Associated forbs of this habitat type include *Arnica latifolia* (broadleaf arnica), *Thalictrum venulosum* (western meadowrue), and *Senecio triangularis* (arrowleaf groundsel).

Water tables for the two phases of this habitat type are responsive to slope position. The *Calamagrostis canadensis* (bluejoint reedgrass) phase is usually found at the base of a slope seep area at the edge of the tree line in a wet meadow. Water tables are at the soil surface during the spring and typically do not drop below 50 cm (19.7 in) during the growing season. The *Ledum glandulosum* (Labrador tea) phase is found on steep slopes having spring seep areas, and at the base of seep slopes associated with the *Calamagrostis canadensis* (bluejoint reedgrass) phase. Water tables for the *Ledum glandulosum* (Labrador tea) phase are near the surface only for a short time during the early spring making for a mix of dry and wet site vegetation. This quality leads to the difficulty in the application of Federal wetland delineation procedures.

***Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) Habitat Type**

The *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type is a minor type at mid elevations from 1,250 m (4,100 ft) to 2,440 m (8,000 ft) in Western Montana (Hansen and others 1995). It occurs along slopes with seeps and subirrigated alluvial terraces, as well as along small streams. This type is represented by the *Menziesia ferruginea* (false azalea) phase and the *Streptopus amplexifolius* (twisted stalk) phase.

The *Menziesia ferruginea* phase is characterized by an open canopy structure dominated by *Picea* spp. (spruce) and *Abies lasiocarpa* (subalpine fir). The undergrowth is dominated by a dense shrub layer of *Menziesia ferruginea* (false azalea), *Vaccinium globulare* (globe huckleberry), and supports a variable assemblage of *Arnica latifolia* (broadleaf arnica), *Tiarella trifoliata* (trefoil foamflower), and *Clintonia uniflora* (queen's cup). The *Streptopus amplexifolius* (twisted stalk) phase supports a high coverage of wet site forbs and lacks the high shrub coverage typical of the *Menziesia ferruginea* (false azalea) phase. Shrub species present may include *Ribies lacustre* (swamp current), *Rubus parviflorus* (thimbleberry), and *Vaccinium globulare* (globe huckleberry). Characteristic herbaceous species include: *Thalictrum occidentale* (western meadowrue), *Senecio triangularis* (arrowleaf groundsel), *Galium triflorum* (sweetscented beadstraw), and *Streptopus amplexifolius* (twisted stalk).

Figure 3 shows the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, *Streptopus amplexifolius* (twisted stalk) phase at the edge of a high gradient stream. Figure 4 shows the dense undergrowth of this type.

Figure 3. *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, *Streptopus amplexifolius* (twisted stalk) phase.

Alluvial parent material is commonly associated with the *Streptopus amplexifolius* (twisted stalk) phase, with coarse fragment inclusions of granite, sandstone, argillite, quartzite, and mica schist. Sites of the *Menziesia ferruginea* (false azalea) phase are commonly found having a volcanic ash cap up to 33 cm (13 in). Soil textures vary little from silty clay loam to loam with coarse fragment content varying widely for both phases. These mid and upper elevation valley bottom settings are considered to have a cryic soil temperature regime (Sirucek and others 1995).

Figure 4. *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type *Menziesia ferruginea* (false azalea) phase.

Water tables for the *Menziesia ferruginea* (false azalea) phase are near the surface only during the early spring. Water tables for the *Streptopus amplexifolius* (twisted stalk) phase are also briefly near the soil surface during a short portion of the spring, but this phase encompasses significantly wetter sites. In the marginally wet site typically occupied by both of these phases, topography and slope position play key roles in the probability of surface saturation (Hansen and others 1995).

STUDY AREA

I conducted my work within 3 study areas located in the subalpine zone of Western Montana. Although I found sites containing the *Abies lasiocarpa/Ledum glandulosum,* (subalpine fir/Labrador tea) habitat type as far east as the Gallatin National Forest, near Bozeman, Montana, the majority of *Abies lasiocarpa/Ledum glandulosum,* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) sites are located in Western Montana (Hansen and others 1995). Thus for logistical purposes, I confined site selection to west of the Continental Divide within the state of Montana.

The three study areas are: 1) Darby Ranger District, Bitterroot National Forest; 2) Tally Lake Ranger District, Flathead National Forest, and; 3) Swan Lake Ranger District, Flathead National Forest. Study areas were selected with the assistance of Dean Sirucek of the Flathead National Forest, and Brad Cook, former research specialist at the Riparian and Wetland Research Program at the School of Forestry, University of Montana. A brief description of each study area follows.

Tally Lake Ranger District, Flathead National Forest

The 930,000 ha (2.3 million acre) Flathead National Forest is bordered by Canada to the north, Glacier National Park to the north and east, the Lolo National Forest to the south, the Kootenai National Forest to the west and the Lewis and Clark National Forest to the east. The Tally Lake Ranger District lies within Flathead County and is west of Whitefish, Montana.

Elevations range from 1,220 m (4,000 ft) to 2,000 m (6,560 ft).

Climate within the region is strongly influenced by Pacific maritime weather systems. Annual precipitation ranges from 40 cm (15.8 in) in the valley bottoms to 254 cm (100 in) at the highest elevations. The amount of precipitation received changes rapidly with elevation in mountainous areas due to the orographic precipitation process. Winters are cloudy, cool, and wet, as November, December, and January are the wettest months. The mountain areas receive about 80 percent of of their precipitation as snowfall (USDA 1985). Within the Tally Lake Ranger District, annual precipitation averages between 71 cm (27.9 in) to 78 cm (30.7 in) with snowfall averaging 254 cm (100 in) to 500 cm (197 in). Average winter low temperatures are -13 °C (8.6 °F) and average summer highs are 28 °C (82.4 °F) (USDA 1985).

Typical riparian and wetland vegetation in this area consists of *Picea* spp. (spruce), *Abies lasiocarpa* (subalpine fir), and *Pinus contorta* (lodgepole pine) in the overstory. Common shrub species include *Ledum glandulosum* (Labrador tea), *Cornus canadensis* (bunchberry), *Vaccinium globulare* (globe huckleberry), *Vaccinium scoparium* (dwarf huckleberry), *Alnus incana* (mountain alder), and *Linnaea borealis* (twinflower). *Calamagrostis canadensis* (bluejoint reedgrass), *Luzula hitchcockii* (smooth woodrush), *Carex scopularum* (Rocky Mountain sedge), are some of the common graminoids. *Arnica cordifolia* (heart-leaf arnica), *Clintonia uniflora* (queen's cup), *Dodecatheon jeffreyi* (tall mountain shooting star), *Lupinus* spp. (lupine), *Equisetum arvense* (common horsetail), *Senecio triangularis* (arrowleaf groundsel), *Tiarella trifoliata* (trefoil foamflower), and

Xerophyllum tenax (beargrass) are forbs commonly found is this subalpine area.

Parent materials for soil formation are predominantly metasedimentary rocks of the Precambrian Age Belt super-group. Major rock types are quartzite, siltite, and argillite, with some limestone. Much of the soils have a surface mantle of volcanic ash derived from the eruption of Mt. Mazama in Oregon about 6,700 years ago. Stream bottom soils form in alluvial and lucustrine deposits with glacial till parent materials (USDA 1985). These mid and upper elevation valley bottom settings are considered to have a cryic soil temperature regime (USDA 1985).

Darby Ranger District, Bitterroot National Forest

The 650,000 ha (1.6 million acre) Bitterroot National Forest, is located in west central Montana and east central Idaho. National Forest land begins above the foothills of the east and west sides of the Bitterroot River Valley in two mountain ranges. The Bitterroot Mountains on the west and the Sapphire Mountains on the east, while Lolo National Forest borders to the north. Elevation ranges from 976 m (3,201 ft) at the north end of the Bitterroot Valley to the highest point, Trapper Peak at 3,097 m (10,158 ft) to the south.

Macroclimate and microclimate differences greatly effect vegetation patterns within the mountainous topography of this region (Lackschewitz 1991). Mean July temperature is approximately 12 °C (53 °F) in the timberline zone at 2,440 m elevation, and 18 °C (65 °F) to 20° C (68 °F) at Darby, Montana. at 1,183 m (3,880 ft) elevation (Arno and Habeck 1972; Lackschewitz 1991). Although the

Bitterroot Valley bottomland only receives an average of 33 cm (13 in) of precipitation a year, timberline zones may receive 100 cm (39.4 in) to 130 cm (51.2 in), with snow accumulations of 1.5 m (4.9 ft) to 3 m (9.8 ft) in April in the subalpine zones (1,525 m [5,000 ft] to 2,684 m [8,800 ft]) (Pfister and others 1977, Lackschewitz 1991). On the microclimate scale, wind exposed ridgetops, north and south-facing slopes, cold air pockets, and the rugged topography act to create many niches for a variety of plant communities (Lackschewitz 1991).

Vegetation within riparian and wetland areas of the subalpine zone is characterized by *Picea* spp. (spruce), *Abies lasiocarpa* (subalpine fir), and *Pinus contorta* (lodgepole pine) in the overstory. Common shrub species include *Ledum glandulosum* (Labrador tea), *Cornus canadensis* (bunchberry), *Vaccinium globulare* (globe huckleberry), *Alnus incana* (mountain alder), *Menziesia ferruginea* (false azalea). *Calamagrostis canadensis* (bluejoint reedgrass), *Luzula hitchcockii* (smooth woodrush), and *Carex scopularum* (Rocky Mountain sedge) are some of the common graminoids. *Arnica cordifolia* (heart-leaf arnica), *Clintonia uniflora* (queen's cup), *Dodecatheon jeffreyi* (tall mountain shooting star), *Lupinus* spp. (lupine), *Mitella breweri* (Brewer's mitrewort), *Senecio triangularis* (arrowleaf groundsel), *Tiarella trifoliata* (trefoil foamflower), *Veratrum viride* (green false hellebore), and *Xerophyllum tenax* (beargrass) are forbs commonly found is this subalpine area.

Soils of the Bitterroot Range are derived from the Idaho batholith, a fault block of gneissic granite. Soils are generally shallow and stony, with only a moderate degree of horizon development. Soils developed from the Idaho batholith are strongly acidic in nature (Lackschewitz 1991). These mid and upper elevation valley bottom settings are considered to have a cryic soil temperature regime (USDA 1985).

Swan Lake Ranger District, Flathead National Forest

Part of the 930,000 ha (2.3 million acre) Flathead National Forest, the Swan Lake Ranger District is located in the Swan Valley, bordered by the Mission Mountains to the west and the Swan Range and the Bob Marshall Wilderness to the east. Elevations range from 1,220 m (4,000 ft) to over 2,440 m (8,000 ft).

Orographic precipitation greatly affect precipitation regimes in different elevations in this area. Annual rainfall in the valleys is approximately 70 cm (27.6 in), while the mountain tops receive approximately 250 cm (98.5 in) annually. Snowfall accounts for about 65 percent of the precipitation and ranges from 5 m (16.4 ft) to 20 m (65.6 ft) each year. Winter temperatures are low and average -15 °C (5 °F); summer highs are warm, averaging 27 °C (82 °F) (USDA 1985).

Typical riparian and wetland vegetation in this area consists of a wide variety of overstory species including, *Picea* spp. (spruce), *Abies lasiocarp*a (subalpine fir), *Abies grandes* (grand fir), *Pinus monticola* (western white pine), *Taxus brevifolia* (Pacific yew), *Thuja plicata* (western redcedar), *Betula papyrifera* (paper birch), and *Pinus contorta* (lodgepole pine). Common shrub species include *Cornus canadensis* (bunchberry), *Alnus incana* (mountain alder), *Linnaea borealis* (twinflower), *Cornus stolonifera* (red-osier dogwood), *Pachistima myrseinites* (mountain boxwood), *Ribies* spp. (currant), and

Symphoricarpos albus (snowberry). *Arnica cordifoli*a (heart-leaf arnica), *Smilacina racemosa* (false Solomin's-seal), *Streptopus amplexifolius* (twisted stalk), *Clintonia uniflora* (queen's cup), *Lupinus* spp. (lupine), *Equisetum arvense* (common horsetail), *Senecio triangularis* (arrowleaf groundsel), *Tiarella trifoliata* (trefoil foamflower), and *Xerophyllum tenax* (beargrass) are forbs commonly found is this lower subalpine area.

Bedrock consists of Precambrian mudstones to sandstones, with a predominance of calcarious strata. Soils in this area are derived primarily from partially calcarious glacial till and from volcanic ash of Mt. Mazama origin. Soils typical of *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types have a shallow O horizon, underlain with a shallow ash-grey A horizon, followed by a reddish brown andic B horizon, usually 10 cm (3.9 in) to 20 cm (7.9 in). thick (Antos 1977). Soils are very rocky and fairly well drained in riparian sites. These mid and upper elevation valley bottom settings are considered to have a cryic soil temperature regime (USDA 1985).

METHODS

The first objective was to approximate of the jurisdictional wetland status for the *Abies lasiocarpa/Ledum glandulosum*, (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. The second was to use these same two habitat types to determine the strength of the correlations which exist between hydrology, vegetation, and soils wetland field indicators of the 1987 Corps Manual within the subapline zone. A majority of the methods used while assessing these two objectives are similar; such as the methods used in the selection of study sites, the placement of transects, the installation of well units, and the collection of vegetation and soils data.

To avoid repetition, this Methods section is divided into four major headings. The first two headings, Study Site Selection, and Data Collection, describe methods which are common to both objectives one and two. Following these sections, are the headings titled: Methods Used in the Determination of Jurisdictional Wetland Status, and; Methods Used in the Determination of the Correlations Between Hydrology, Hydric Soils Indicators, and Hydrophytic Vegetation Communities.

Study Site Selection

After selecting the three study areas to conduct this research in, I then located representative stands of the *Abies lasiocarpa/Ledum glandulosum*, (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. To do this I consulted regional experts from the Flathead National Forest and the Bitterroot National Forest whom identified the best potential areas for locating the target habitat types. I then drove and hiked the most accessible areas and located three to five sites within each region which contained undisturbed stands of the target habitat types. Sites were delineated to contain a homogeneous stand of the desired habitat type, as well as parts of drier (upland) and wetter (lowland) types (Daubenmire 1959). I determined study site boundaries where a combination of vegetation, soil, hydrological, and landform features indicated breaks between the target habitat types and other types (Carter and others 1994). There are 11 study sites in all (Table 1).

Table 1. General study site descriptions

Site #	Study Area	Drainage	Contained Habitat Type(s)[1]
1	Tally Ranger District [2]	Griffin Creek	ABILAS/LEDGLA
2	Tally Ranger District	Griffin Creek	ABILAS/LEDGLA
3	Tally Ranger District	Griffin Creek	ABILAS/LEDGLA
4	Tally Ranger District	Griffin Creek	ABILAS/LEDGLA
5	Darby Ranger District [3]	Lost Horse Creek	ABILAS/LEDGLA;ABILAS/STRAMP
6	Darby Ranger District	Lost Horse Creek	ABILAS/LEDGLA;ABILAS/STRAMP
7	Darby Ranger District	Lost Horse Creek	ABILAS/LEDGLA;ABILAS/STRAMP
8	Swan Ranger District [4]	North Fork Lost Creek	ABILAS/STRAMP
9	Swan Ranger District	Porcupine Creek	ABILAS/STRAMP
10	Swan Ranger District	Porcupine Creek	ABILAS/STRAMP
11	Swan Ranger District	North Fork Lost Creek	ABILAS/STRAMP

[1] ABILAS/LEDGLA is the *Abies lasiocarpa/Ledum glandulosum*, (subalpine fir/Labrador tea) habitat type; ABILAS/STRAMP is the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type.

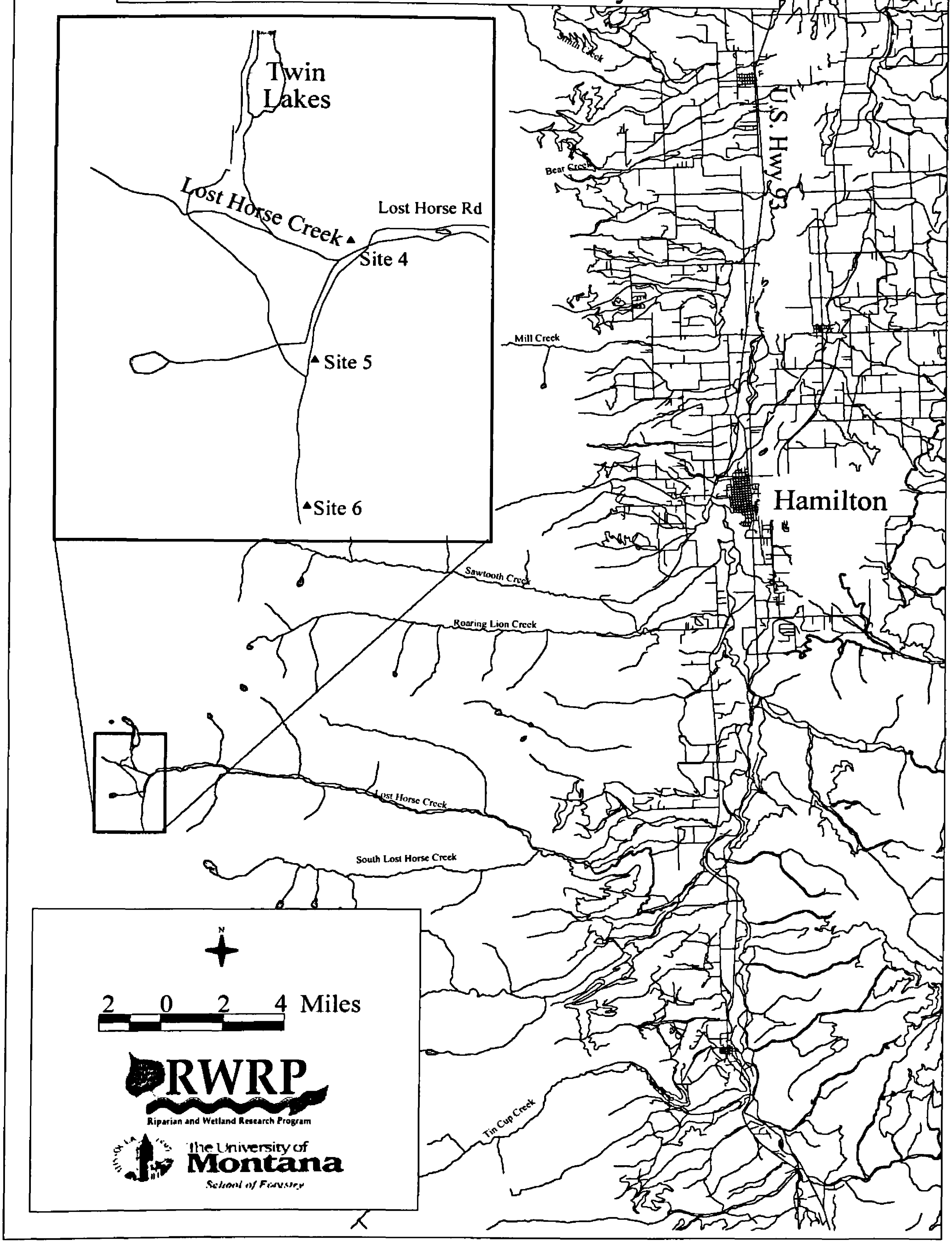
[2] The Tally Lake Ranger District,Flathead National Forest.

[3] The Darby Ranger District, Bitterroot National Forest.

[4] The Swan Lake Ranger District, Flathead National Forest.

The following maps show the location of all sites located in the Darby Ranger District (Figure 5), the Tally Lake Ranger District (Figure 6), and the Swan Lake Ranger District (Figure 7).

Figure 5. Darby Ranger District
Bitterroot National Forest Study Area



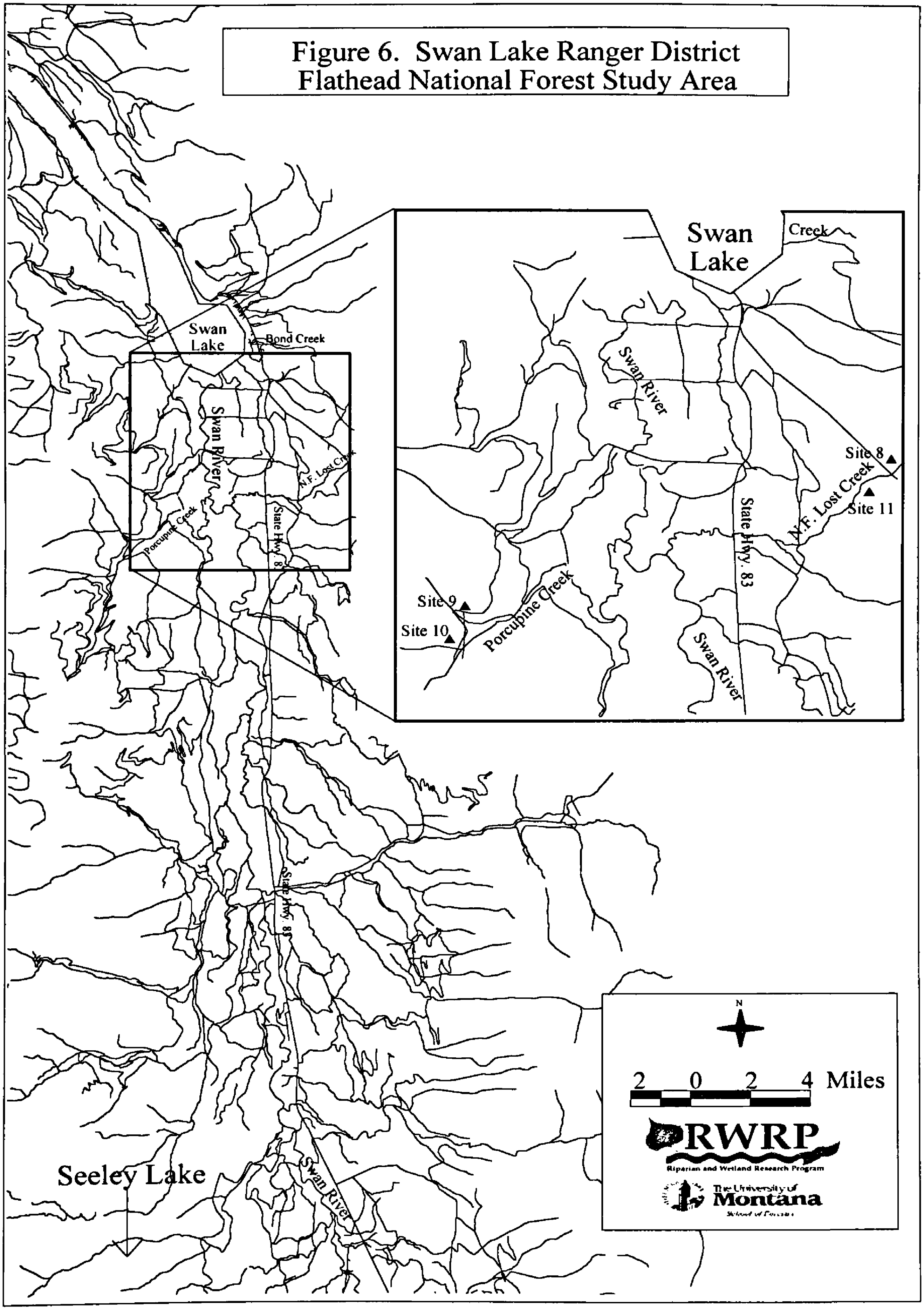
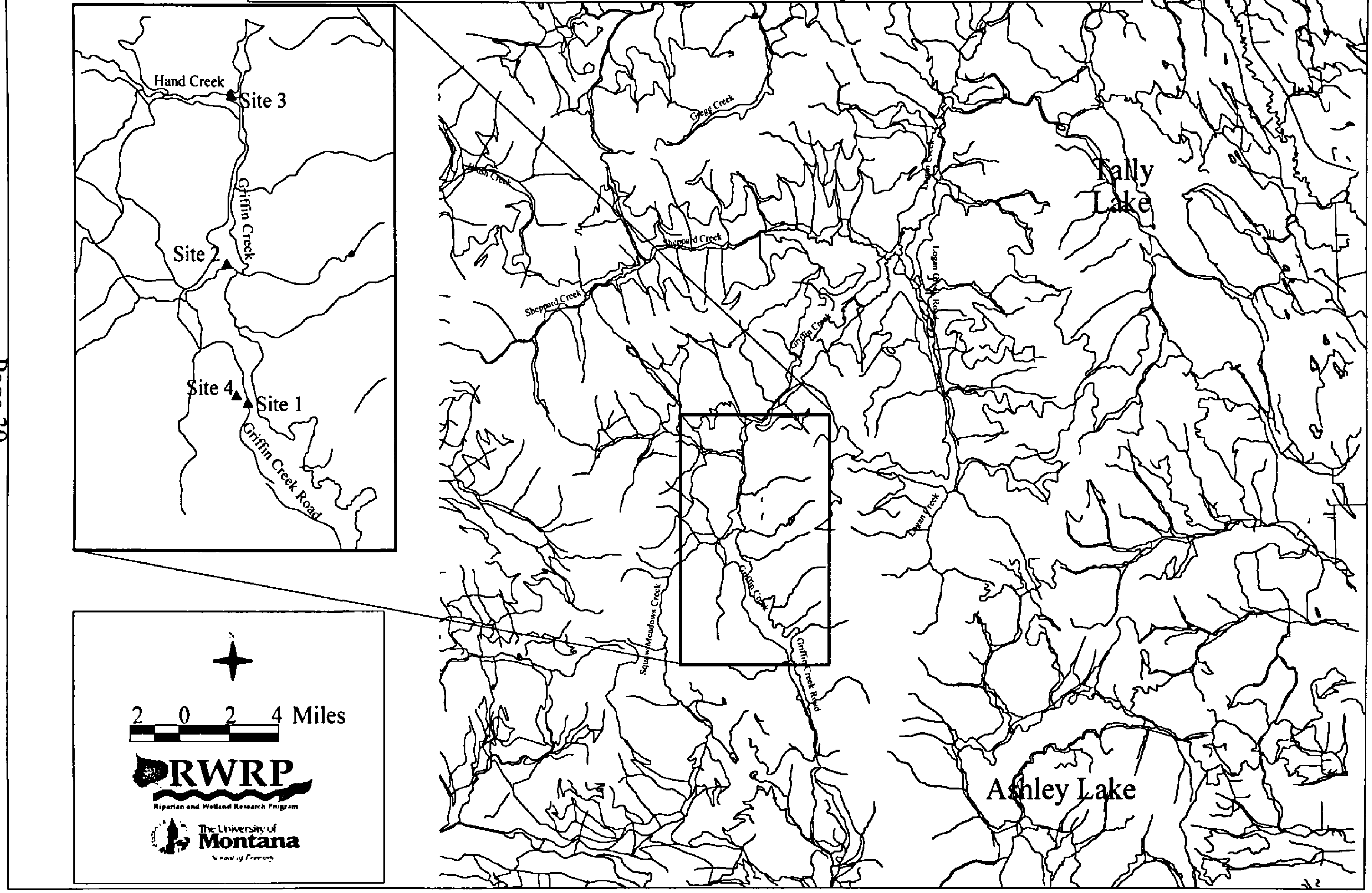


Figure 6. Swan Lake Ranger District Flathead National Forest Study Area

Figure 7. Talley Lake Ranger District
Flathead National Forest Study Area



Location of Study Sites One Through Four—Study sites one through four are located within the Tally Lake Ranger District, Flathead National Forest at about 1,700 m (5,576 ft). All four study sites are located on points of the Griffin Creek drainage, accessed by Griffin Creek Forest Road (FR) 538. In May 1997 I traveled FR 538 and located sites previously surveyed by Riparian and Wetland Research Program (RWRP) in 1993. I then used the methods for site selection and delineation as described above.

Location of Study Sites Five Through Seven—Study sites five, six, and seven are located within the Darby Ranger District, Bitterroot National Forest between 1,830 m (6,000 ft) and 2,050 m (6,724 ft). All study sites are located at points along Lost Horse Creek FR 429, approximately 32.1 km (20 mi) to 38.6 km (24 mi) west from Highway 93. In May 1997 I traveled FR 429 and located sites previously surveyed by RWRP in 1993. I then used the methods for site selection and delineation as described above.

Location of Study Sites Eight Through Eleven—Study sites eight through eleven are located within the Swan Lake Ranger District, Flathead National Forest. Two study sites are located on the Mission Mountain Range, west side of the Swan River valley in the Porcupine Creek drainage at 1,510 m (4,952 ft). Both sites are accessed by FR 10229. The two other study sites are located on the Swan Range east side of the Swan River valley in the North Fork Lost Creek drainage at about 1,490 m (4,887 ft). These sites are accessed by FR 680. In May 1997 I traveled FR 10229 and FR 680 and located sites previously surveyed by RWRP in 1993. I then used the methods for site selection and delineation as described above.

Data Collection

To address the study objectives and hypotheses I measured vegetation, soils, and hydrology characteristics at the 11 study sites. Although each objective and hypothesis of this study are unique, the methods of transect placement, the establishment of water table wells, and monitoring of the well units are generally the same.

Transect Placement—At each site I extended two to four line transects, depending on site dimensions, ranging in length from 30 m (98 ft) to 110 m (360 ft), from a hydrophytic vegetation community, through the ecotone, to an upland community (Anderson and others 1980; Carter and others 1994; Davis and others 1996). Transects were started from a random point within the wet community and oriented perpendicular to its boundary (Davis and others 1996). I determined the endpoints of each transect when a combination of vegetation, soil, hydrological, and landform features clearly indicated upland conditions (Carter and others 1994).

Collection of Hydrology Data— On each transect I installed by hand, three to four 1 m (3.28 ft) x 1.9 cm (0.74 in) perforated observation well units with polyethylene nose pieces designed by Aquatic Research Instruments, Leadore, ID. Well units could be easily driven into most substrates with a bronze slide hammer assembly. Wells were installed at points selected to represent distinct points on the wet to dry gradient and the total length and elevation range on each transect. For the variety of sites this distance between well units on the transects ranged from 5 m (16 ft) to 33 m (108 ft).

I monitored each of the well units bimonthly using a dipstick coated with Kolor Cut (Ransom and Smeck 1985; Carter and others 1994). The change in color of the Kolor Cut indicated the surface of free water in the well. The distance from the soil surface to this point was recorded, and the displacement of water in the well due to the dipstick was then corrected. A hydrograph representing seasonal water table levels was then created for each well. Water table levels for periods between measurements are considered to be directly related to the next closest measurement (Davis and others 1996). On the hydrograph this period is represented as a straight line connecting consecutive measurements.

Measurements were taken only for the period considered to be within the growing season, which is estimated for cryic soils as the period from June 1 to August 30 (Environmental Laboratory 1987). To more accurately estimate the growing season for the sites within each study region, I used the long-term seasonal temperature averages as reported by the nearest Western Regional Climate Center (WRCC) recording station (WRCC 1998). Growing season limits were defined by the dates of spring and fall freeze probabilities. This is a .5 probability of <-2 °C (28 °F) air temperatures or a killing frost (Skaggs and others 1994). For all three sites; the Tally Lake Ranger District (Fortine 1N, Montana WRCC Station # 1243139), the Darby Ranger District (Darby, Montana Station WRCC # 242221), and the Swan Lake Ranger District (Swan Lake, Montana WRCC Station #248087) the growing season remained June 1 to August 1.

Determination of the seasonally high water table. The 1987 Corps Manual considers wetland hydrology to exist if the water table is less than 30 cm (11 in) from the soil surface, for at least 14 consecutive days during the growing season or 5 percent of the growing season. Due to the brief growing season in subalpine environments, I used the 14 days period for hydrologic determinations, as 5 percent of the growing season equates to approximately 5 days. Due to low soil temperatures, 5 days of saturation is not likely to be long enough for an anaerobic state to be reached (National Research Council 1995). I then calculated the 14 day water table exceedence level for each well unit. For my purposes, the terms 14 day exceedence level, and the seasonally high water table are synonymous. This measure represents the highest water level continuously reached or exceeded for 14 consecutive days within the growing season in "normal" hydrological years based upon the bi-weekly readings taken during the growing season (Davis and others 1996). This is considered to be the minimum hydrological period required for wetland formation and maintenance (Davis and others 1996).

Two years of hydrological data are not adequate for predicting long term behavior of the water table (National Research Council 1995). I determined "normal" site hydrology based upon watershed hydrology for each study region. Water year recurrence intervals were calculated from the nearest stream gage station to each study region watershed. I collected yearly peak flow discharge (cfs) data from the United States Geological Survey Surface Water Retrieval web site (USGS 1998). Watershed hydrology for the 1997 and 1998 water years were to be considered "normal" if the probability of occurrence for the discharge data for that year fell within the 0.3 to 0.7 range

(Davis and others 1996).

Only the 1998 water year for the Tally Lake Ranger District as calculated from stream gage 12365000 on the Stillwater River near Whitefish, Montana fell within the normal range (see Appendix A for peak flow return interval calculations). Due to the abnormal water years of 1997 and 1998, for each well I calculated the 14 day 5 percent exceedence as the level for which the water table was closest to the surface of the soil as recorded in either 1997 and 1998. I used this 14 day 5 percent exceedence level for all further calculations. Since the 1997 water year was exceedingly wet, most of the calculated 14 day 5 percent exceedence levels were derived from the 1997 recordings. The 1998 water year was exceedingly dry and did not provide a reasonable set of water table data.

Collection of Vegetation Data—At each well unit, I collected vegetation cover class data using circular 18 m (59 ft) diameter plots placed parallel to slope gradient (Barbour and others 1987, Environmental Laboratory 1987). The well unit served as the center of the vegetation plot. I reduced plot size if the plot covered areas which were not representative of the area measured by the well.

Vegetation data collection followed the Intermediate-Level Onsite Determination Data Form (Environmental Laboratory 1987). I sampled vegetation in five distinct layers: 1) tree; 2) sapling; 3) tall shrub; 4) short shrub; and 5) herbaceous which follows the field methods as described in the 1987 Corps Manual (Table 2).

Table 2. Five vegetation survey layers for hydrophytic vegetation plot determinations

Layer	Type of Vegetation	Definition
Herbaceous	Herbaceous/Woody	< 5 m (1.64 ft)
Short Shrub	Woody Shrub	> 5 m (1.64 ft) < (1.5 m 4.92 ft)
Tall Shrub	Woody Shrub	> 1.5 m (4.92 ft)
Tree	Woody Tree	> 5 cm (2 in) DBH
Sapling	Woody Tree	< 5 cm (2 in) DBH

Again using the 1987 Corps Manual system, I then measured species importance in terms of percent canopy cover and the midpoint cover classes (Table 3).

Table 3. 1987 Corps Manual canopy cover classes used to measure importance of plant species

Canopy Cover Class	Range (% cover)	Midpoint (% cover)
1	0 - 5	2.5
2	6 - 25	15.0
3	26 - 50	37.5
4	51 - 75	62.5
5	76 - 95	85.0
6	96 - 100	98.0

Thus, for each vegetation strata, the presence of a species was recorded as was the cover class.

Collection of Soils Data—Analysis of hydric soils features is required in the three parameter approach defined in the 1987 Corps Manual. All soils examined in this study fall within the Cryic temperature regime. This determination was made by the professional judgment of the author and Riparian Landtype Inventory of the Flathead National Forest (Sirucek and others 1995).

Soil pits were excavated by shovel for analysis at points within each plot judged to be representative of plot topography and vegetation (Light and others 1996). Soil pits were dug near the well site but as not to interfere with well hydrology. Hydric soils features were recorded following the methods as outlined in the 1987 Corps Manual and the 1996 Field Indicators of Hydric Soils in the United States Version 3.2 (USDA 1996).

Summary—From the 11 sites sampled, 31 transects (see Appendix B for transect cross-sections) yielded 109 well points. Of the 109 well points, 49 were located in *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types, and 45 were located in *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type (Table 4).

Table 4. Distribution of well units located in the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea; ABILAS/LEDGLA) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk; ABILAS/STRAMP) habitat types, with reference to site and region

Region Site #	ABILAS/LEDGLA ht No. of Wells	ABILAS/STRAMP ht No. of Wells
Tally Lake Ranger District		
1	12	0
2	10	0
3	12	0
4	5	-
Darby Ranger District		
5	4	8
6	6	7
7	4	8
Swan Lake Ranger District		
8	0	7
9	0	8
10	0	1
11	0	8
Total	49	45

Methods Used in the Determination of Jurisdictional Wetland Status

The following methods are specific to objective one: The approximation of the jurisdictional wetland status for the *Abies lasiocarpa/Ledum glandulosum*, (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types.

Hydrology Determination—I used the 14 day exceedence level of the water table to determine if positive or negative wetland hydrology was present for each well site. Following 1987 Corps Manual methods, if the 14 day exceedence level was within 30 cm (11 in) of the soil surface, then the positive determination of wetland hydrology was given to the plot the well represented (Environmental Laboratory 1987).

Vegetation Determination—Following the determination of habitat type, I calculated the dominance ratio for each plot. The dominance ratio is calculated as the ratio of obligate-wetland, facultative-wetland, and facultative species, to facultative-upland, and upland (Reed 1988) dominant species (ie. >20 percent cover) in each of the five sampled layers. Using these 1987 Corps Manual methods, a plot was determined to have hydrophytic vegetation if 50 percent or greater of the dominant species were obligate-wetland, facultative-wetland, or facultative wetland species (Environmental Laboratory 1987).

Soils Determination—Soils for each site were classified to series and a positive or negative determination for hydric soils was then made based upon the presence of hydric soils indicators (Environmenal Laboratory 1987; USDA 1996).

Analysis—I calculated the percentage of total plots within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types which contained positive observations of all three wetland field indicators. These plots were determined to have a positive jurisdictional wetland status.

Methods Used in the Determination of the Correlations Between Hydrology, Hydric Soils Indicators, and Hydrophytic Vegetation Communities

The following methods describe the collection and calculation of vegetation, soils, and hydrology data specific to objective two and hypotheses one, two, and three: The determination of the strength of the correlations which exist between hydrology, vegetation, and soils wetland indicators of the 1987 Corps Manual. I collected several variables for each wetland field indicator in order to determine which methods were most appropriate to wetland delineation within the subalpine zone.

Hydrology Determination—To characterize site hydrology for each well unit, I calculated the 7 day, 14 day, and 21 day exceedence level. As a reminder, each exceedence level represents the the water table at the highest sustained point of saturation obtained for 7, 14, and 21 days respectively, during the growing season.

Vegetation Determination—The habitat type and dominance ratios were calculated for each plot as well as two other vegetation community descriptors: 1) weighted average (WA) index, and; 2) index average (INAV). The dominance ratio, weighted average index, and index average are all acceptable measures of Federal wetland vegetation community determinations (Eicher and others 1988).

Weighted average index algorithm. The weighted average index was used to assess the wetland status of each plot and each separate layer based upon the Reed (1988) wetland indicator category. For calculation purposes, each plant species present and its assigned wetland indicator category was represented by an ecological index number consisting of the integers 1 - 5 for the 5 wetland indicator categories obligate - upland (Table 5).

Table 5. Wetland indicator categories for plant species (Reed 1988), defined by the frequency of occurrence in wetlands

Wetland Indicator Category	Frequency of Occurrence in Wetlands	Ecological Index
Obligate	> 99%	1
Facultative Wetland	67% - 99%	2
Facultative	34% - 66%	3
Facultative Upland	1% - 33%	4
Upland	< 1%	5

Weighted average index is an average of the ecological index weighted by importance value which is the cover class midpoint (Light and others 1996). The weighted average algorithm is:

$$WAj = (\sum_{i=1}^{p} IijEi)/(\sum_{i=1}^{p} Iij)$$

where: WAj = weighted average for plot j

Iij = importance value of species i on plot j

Ei = ecological index for species i

p = number of species in plot j

The weighted average algorithm was used to compute a score for each sample plot and stratum within the plot indicating the plot's position on the wetland to upland gradient (Eicher 1988). Computed scores ranged from 1 to 5, with 1 representing obligate wetland plant communities and 5 representing upland plant communities. A score of less than 3.0 was considered to be an indication of wetland vegetation, while a score of greater than 3.0 was considered to be upland vegetation (Eicher 1988). As a general rule, any scores between 2.5 and 3.5 were considered ambiguous to this determination (Environmental Laboratory 1987).

Index average algorithm. An index average score was calculated for the entire plot, using all species present. As with the weighted average index, the index average uses species scores based upon the Reed (1988) indicator list. However, the index average does not use importance values in the calculation, and rather weights all species equally. The INAV algorithm is:

$$INAVj = \left(\sum_{i=1}^{p} Ei \right) / \, p$$

where: INAV j = index average for plot j

Ei = ecological index for species i

p = number of species in plot j

The index average scores are interpreted in the same manner as the weighted average index scoring system.

Soils Determination—1987 Corps Manual wetland field indicators commonly used in mineral to silt loam soils include the identification of a loamy mucky mineral layer within 15 cm of the surface, and/or distinct or prominent redox concentrations (Environmental Laboratory 1987). Only two hydric soils features were observed with enough frequency to be to be used in data analysis: 1) the depth to redoxomorphic features, and; 2) the depth of the organic A horizon. I found redoxomorphic features within 65 cm (25in) of the soil surface for 75 of the 95 study plots. Within these same plots, 14 of the 95 soil profiles had a 20 cm (8 in) to 40 cm (16 in) organic layer covering the mineral horizons.

The depth of the A horizon was measured as a layer above a mineral horizon and below the O horizon (Buol and others 1989). Depth to redoxomorphic features was measured as the depth from the soil surface (top of the O horizon) to a layer with distinct hydric features. This would be a layer with gleyed soil colors (as indicated by the gley page in the Munsell Soil Color Chart), or to layers with Munsell Soil Color Chart value 5 or greater and chroma 2 or less with 2 percent or more distinct or prominent redox concentrations as soft masses or pore linings. This layer must have been at least 5 cm (2 in) thick (Environmental Laboratory 1987; USDA 1996).

Summary of Variables—Table 6 lists all of the site variables collected for correlation analysis between the various hydrologic regimes, the measures of the vegetation community, and the formation of hydric soils indicators.

Table 6. Three wetland field indicators required for the delineation of wetland sites using the 1987 Corps manual, and related variables measured

Wetland Field Indicator	Measurement
Hydrology	7 Day Exceedence Level
	14 day Exceedence Level
	21 Day Exceedence Level
Vegetation	Habitat Type
	Dominance Ratio Plot
	Index Average Plot
	Weighted Average Plot
	Weighted Average Tree Layer
	Weighted Average Sapling Layer
	Weighted Average Tall Shrub Layer
	Weighted Average Short Shrub Layer
	Weighted Average Herbaceous Layer
Soils	Depth to Redox Feature
	Depth of A Horizon

Analysis—I could not assume a bivariate normal distribution nor homoscedasticity, and thus used the non-parametric Spearman Rank Order Correlation procedure to calculate all correlation coefficients (rho) within this study (Sheskin 1997). All correlation coefficients as calculated by the Spearman Rank Correlation procedure are evaluated with respect to the criteria which describes the strength of the correlation coefficient (rho) value.

Table 7. Strength of the correlation coefficient (rho) (Fowler and Cohen 1990)

Value of the coefficient (rho) (positive or negative)	Meaning
0.00 to 0.19	A very weak correlation
0.20 to 0.39	A weak correlation
0.40 to 0.69	A modest correlation
0.70 to 0.89	A strong correlation
0.90 to 1.00	A very strong correlation

Plot score method. In a preliminary test, I used the Spearman Rank Correlation procedure in StatView, a statistical computer package, to find the vegetation method (weighted average, index average, and dominance ratio) that best reflected the seasonally high water table (14 day exceedence level) for all plots within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. I tested for the best vegetation method before addressing hypotheses one, two, and three simply in order to reduce the number of variables involved in the correlation analysis.

The weighted average index score had the strongest correlation with respect to measures of the 7 day exceedence level, 14 day exceedence level, and the 21 day exceedence level (Table 8). Based upon these results, and to simplify the vegetation correlation analysis, I used the weighted average index method in all further vegetation correlations.

Table 8. Spearman Rank correlation coefficients between the 14 day exceedence level and weighted average, index average, and dominance ratio vegetation plot scores the for the *Abies lasiocarpa/Ledum glandulosum* and *Abies lasiocarpa/Streptopus amplexifolius* habitat types where hydrology was present. Note: Depths were measured as positive distances below the ground surface

Exceedence Level (n)	Weighted Average	Index Average	Dominance Ratio
7 Day (74)	0.555**	0.464**	-0.441**
14 Day (70)	0.471**	0.460**	-0.379*
21 Day (65)	0.391*	0.363*	-0.364*

* indicates significance at $P < 0.01$
** indicates significance at $P < 0.001$

Correlation analysis. I then used the Spearman Rank Correlation procedure in StatView to address hypotheses one, two, and three by determining the correlation coefficients between the following variables within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea), and *Abies* *lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types and their respective phases: 1) weighted average index for the plot and the strata, and the 14 day exceedence level; 2) weighted average index for the plot and the strata, and the corresponding hydric soils features, and; 3) hydric soils features, and the corresponding 14 day exceedence level. As a computed rho close to zero may be the result of a curvilinear relationship, I constructed scatterplots for all Spearman Rank Order calculations. No curvilinear relationships were found.

Assessment of Northwest (Region 9) Reed (1988) Wetland Indicator Values

The weighted average scores from each plot were used to calculate a set of averages for each individual species found in the collection of vegetation data within this study. This information was used to determine if any species listed by Reed (1988) for the Northwest Region might be incorrectly classified in terms of wetland indicator status. The calculation of species index averages follow the methods by Walker and others (1989) as follows:

(1) A species index average was calculated for each species according to the equation:

$$Ai = \frac{\sum_{m}^{m} WAj}{m}$$

where: Ai = the species index average value for species i

m = the number of plots which the species occurs

WAj = the weighted average for stand j

Individual Species' Water Table Calculations—To aid in the reevaluation of species' wetland indicator status the species' mean seasonally high water table was calculated as the mean 14 day exceedence level for all of the plots which the species appeared in. The calculation of each species' mean seasonally high water table follows:

$$WTi = \frac{\sum_{m}^{m} 14Dj}{m}$$

where: *WTi* = The mean seasonally high water table for species *i*

14Dj = the 14 day exceedence level for stand *j*

m = the number of plots which the species occurs

RESULTS

Jurisdictional Wetland Status of the Two Habitat Types

All hydrology, vegetation, and soils data from the 110 riparian and wetland sites within this study is available through the Riparian and Wetland Research Program web page. This information is currently located under the Jurisdictional Wetland Delineation Database as a sub-section of the voluminous RWRP Database which is currently located on the Internet at: http//www.rwrp.umt.edu.

Vegetation Plot Scores—Following the 1987 Corps Manual, a vegetation community is considered to be hydrophytic only if greater than 50 percent of the dominant species are obligate, facultative-wetland, or facultative. The plots contained within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type can generally be considered to have hydrophytic vegetation as the dominance ratio plot scores for the Reed (1988) wetland vegetation indicators have a mean plot dominance ratio of 0.575 (standard error = 0.030).

Interestingly, the two phases within this habitat type represent different hydrophytic vegetation communities. The *Calamagrostis canadensis* (bluejoint reedgrass) phase with a mean dominance ratio of 0.664 (standard error = 0.030) is more likely to have hydrophytic wetland vegetation. The *Ledum glandulosum* (Labrador tea/Labrador tea) phase however has a mean plot dominance ratio of 0.500 (standard error = 0.050), which makes the determination of hydrophytic vegetation rather ambiguous. Table 9 shows the mean dominance ratio plot scores for the *Abies lasiocarpa/Ledum* *glandulosum* (subalpine fir/Labrador tea) habitat type and the two associated phases.

Table 9. *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type with phases and the vegetation dominance ratio plot score

Habitat Type (n) Phase (n)	Dominance Ratio Plot Score Mean	Standard Error.	Minimum	Maximum
Abies lasiocarpa/Ledum glandulosum (50) (subalpine fir/Labrador tea)	0.575	0.030	0.160	0.990
Ledum glandulosum phase (27) (Labrador tea)	0.500	0.030	0.200	0.750
Calamagrostis canadensis phase (23) (bluejoint reedgrass)	0.664	0.050	0.160	0.990

The *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) plots had lower mean dominance ratio scores than the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, with a mean plot dominance ratio of 0.473 (standard error = 0.022) (Table 10).

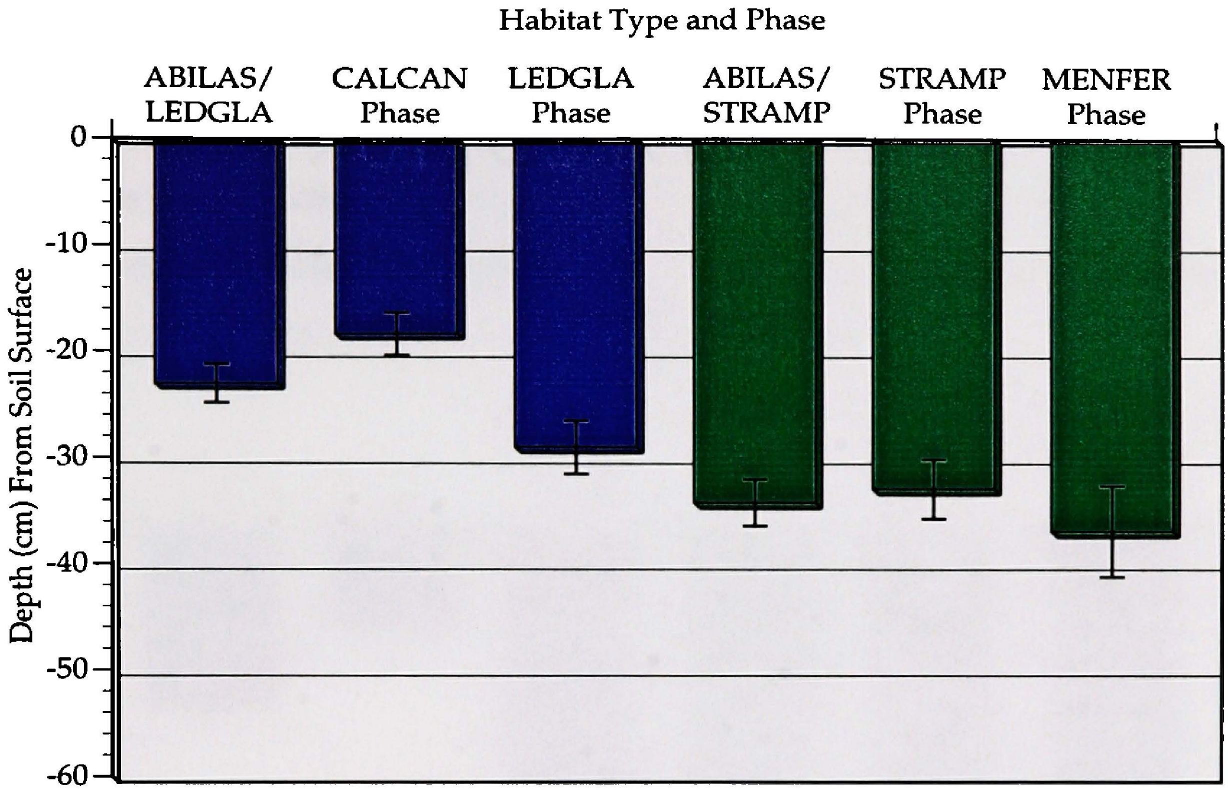
Table 10. *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type with phases and the vegetation dominance ratio plot score

Habitat Type (n) Phase (n)	Dominance Ratio Plot Score Mean	Standard Error	Minimum	Maximum
Abies lasiocarpa/Streptopus amplexifolius (45) (subalpine fir/twisted stalk)	0.473	0.022	0.160	0.830
Streptopus amplexifolius phase (32) (twisted stalk)	0.507	0.026	0.160	0.830
Menziesia ferruginea phase (13) (false azalea)	0.390	0.029	0.250	0.550

This is indicative of vegetation communities in a drier site. The *Streptopus amplexifolius* (twisted stalk) phase of this type had a mean dominance ratio score slightly above 0.500 (standard error = 0.026) which like the *Ledum glandulosum* (Labrador tea) phase of the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type is rather ambiguous to a jurisdictional determination of hydrophytic vegetation. The *Menziesia ferruginea* (false azalea) phase has distinctly non-hydrophytic vegetation with a mean plot dominance ratio of 0.390 (standard error = 0.029), and is thus considered non-wetland vegetation.

Hydric Soils—The *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type had a higher frequency of hydric soils features than the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type. In the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, 21 of 50 soil pits showed prominent redox features immediately below the A-horizon or within 25 cm (10 in) of the soil surface, to record a positive hydric soils determination.

The mean depth to redoxomorphic features was 23.02 cm (9.06 in) (standard error = 1.87 cm [0.74 in]). Within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, seven of the 45 plots showed prominent redoxomorphic features immediately below the A-horizon or within 25 cm (10 in) of the soil surface. The mean depth to redoxomorphic features was 34.20 cm (13.47 in) (standard error = 2.02 cm [0.80 in]) (See Appendix C for summary statistics of soil profile data) (Figure 8).

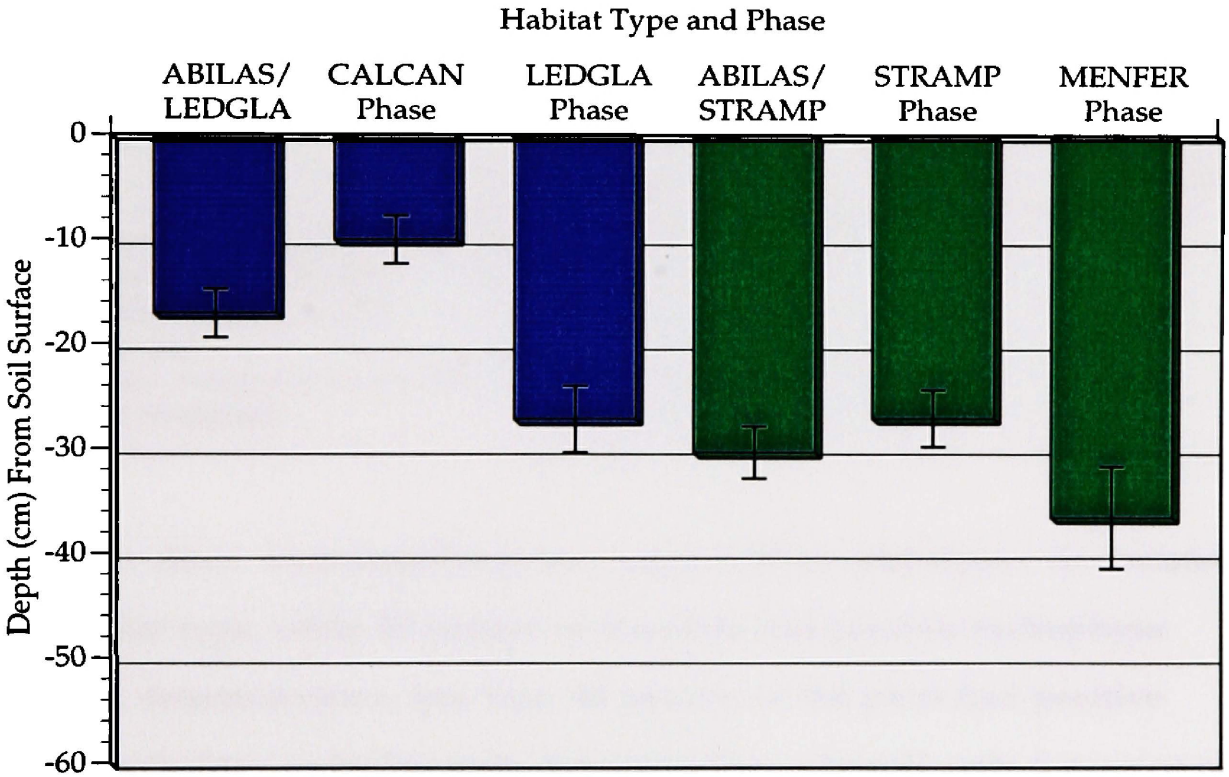


ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
CALCAN = *Calamagrostis canadensis* (bluejoint reedgrass)
LEDGLA = *Ledum glandulosum* (Labrador tea)
ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk)
STRAMP = *Streptopus amplexifolius* (twisted stalk)
MENFER = *Menziesia ferruginea* (false azalea)

Figure 8. Mean depth to redoxomorphic features for the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. Error bars represent the standard error of the mean.

Hydrology—In the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, 38 of 50 well units recorded a free water table within 75 cm (29 in) of the soil surface in either 1997 or 1998. Of the 38 positive observations, 30 well units had 14 day exceedence levels within the upper 30 cm (12 in) of the soil surface, and recorded a positive determination of wetland hydrology. The mean 14 day exceedence level was 17.09 cm (6.73 in) (standard error = 2.40 cm [0.94 in]). Figure 9 shows the mean depth to the seasonally high water table.

Within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, 32 of the 45 well units recorded positive hydrology in either 1997 or 1998. Of the 32 positive observations, 17 well units had 14 day exceedence levels within 30 cm (12 in) of the soil surface for a positive determination of wetland hydrology. The mean 14 day exceedence level was 30.38 cm (11.96 in) (standard error = 2.56 cm [1.00 in]).



ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
CALCAN = *Calamagrostis canadensis* (bluejoint reedgrass)
LEDGLA = *Ledum glandulosum* (Labrador tea)
ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk)
STRAMP = *Streptopus amplexifolius* (twisted stalk)
MENFER = *Menziesia ferruginea* (false azalea)

Figure 9. Mean 14 day exceedence level for the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. Error bars represent the standard error of the mean

Jurisdictional Wetland Status—For each well unit, wetland hydrology, hydrophytic vegetation, and hydric soils must be present to have a positive determination of jurisdictional wetland status (Environmental Laboratory

1987). Each of the three wetland field indicators were observed in over 50 percent of the plots in the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, however only 44 percent of these plots had all three indicators at this time for a positive plot determination of jurisdictional wetland status (Table 11).

Table 11. *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type and the percentage of positive jurisdictional wetland determinations for the three wetland field indicators (Environmental Laboratory 1987) and the entire plot

Habitat Type (n) Phase (n)	Hydrophytic Vegetation	Hydric Soil	Wetland Hydrology	Jurisdictional Wetland
Abies lasiocarpa/Ledum glandulosum (50) (subalpine fir/Labrador tea)	64%	54%	64%	44%
Ledum glandulosum phase (27) (Labrador tea)	48%	22%	37%	14%
Calamagrostis canadensis phase (23) (bluejoint reedgrass)	82%	91%	95%	78%

Within the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, while 55 percent of the plots had positive hydrophytic vegetation determinations, less than 40 percent of the plots had positive wetland hydrology or hydric soils determinations. Overall, only 6 percent of the plots had all three indicators at the same time to form a positive determination of jurisdictional wetland status (Table 12).

Table 12. *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type and the percentage of positive jurisdictional wetland determinations for the three wetland field indicators (Environmental Laboratory 1987) and the entire plot.

Habitat Type (n) Phase (n)	Hydrophytic Vegetation	Hydric Soil	Wetland Hydrology	Jurisdictional Wetland
Abies lasiocarpa/Streptopus (45) *amplexifolius* (subalpine fir/twisted stalk)	55%	15%	37%	6%

Table 12 (cont.)

Streptopus amplexifolius phase (32) (twisted stalk)	65%	21%	40%	9%
Menziesia ferruginea phase (13) (false azalea)	30%	0%	30%	0%

Testing the Wetland Indicator Correlations

Hydrophytic Vegetation Scores vs. Site Hydrology—Within this set of calculations, a significant positive correlation coefficient indicates that as the seasonally high water table moved closer to the soil surface the associated weighted average ecological index value moved closer to one. A negative coefficient indicates the inverse of this relationship. Correlations between vegetation weighted average index scores and the 14 day exceedence level for the relatively wet *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type resulted in a modest correlation for plot scores with rho = 0.644. Of the 5 sampled vegetation layers per plot, the herbaceous layer best reflected the plot hydrology (rho = 0.632) (Table 13). No correlation was reported for the tall shrub layer in the *Ledum glandulosum* (Labrador tea) phase as the sample size was not adequate.

Table 13. Spearman rank correlation coefficients between weighted average vegetation plot and strata scores and the 14 day exceedence value for the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type and phases, for plots where hydrology was present in 1997 or 1998 (Two plots were omitted as statistical outliers) Note: Depths to 14 day exceedence level were measured as positive distances below the ground surface

Strata	ABILAS/LEDGLA Habitat Type (n)	CALCAN Phase (n)	LEDGLA Phase (n)
Tree	-0.093 (36)	-0.209 (23)	-0.185 (15)
Sapling	0.075 (36)	0.175 (23)	0.343 (15)
Tall Shrub	0.336 (12)	0.313 (11)	–
Short Shrub	-0.213 (36)	0.048 (23)	0.338 (15)
Herbaceous	0.632*** (36)	0.508** (23)	0.206 (15)
Entire Plot	0.644*** (36)	0.512*** (23)	-0.271 (18)

Table 13 (cont.)

ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
CALCAN = *Calamagrostis canadensis* (bluejoint reedgrass) phase
LEDGLA = *Ledum glandulosum* (Labrador tea) phase
* indicates significance at P < 0.10
** indicates significance at P < 0.05
*** indicates significance at P < 0.01

Vegetation weighted average index plot scores and the 14 day exceedence level for the drier *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type were not correlated(rho = 0.094). The short shrub strata was the only layer to with a significant correlation with the 14 day exceedence level (rho = 0.337) (Table 14).

Table 14. Spearman rank correlation coefficients between weighted average vegetation plot and strata scores and the 14 day exceedence value for the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type and phases, for plots where hydrology was present in 1997 or 1998. Note: Depths to 14 day exceedence level were measured as positive distances below the ground surface

Strata	ABILAS/STRAMP Habitat Type (n)	STRAMP Phase (n)	MENFER Phase (n)
Tree	-0.191 (32)	-0.299 (21)	0.193 (11)
Sapling	-0.133 (32)	-0.279 (21)	0.396 (11)
Tall Shrub	0.101 (32)	-0.146 (21)	0.280 (11)
Short Shrub	0.337* (32)	0.381* (21)	-0.214 (11)
Herbaceous	0.012 (32)	-0.055 (21)	0.236 (11)
Entire Plot	0.094 (32)	-0.201 (21)	0.389 (11)

ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type
STRAMP = *Streptopus amplexifolius* (twisted stalk) phase
MENFER = *Menziesia ferruginea* (false azalea) phase.
* indicates significance at P < 0.10; ** indicates significance at P < 0.05; *** indicates significance at P < 0.01

For plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types, the correlations between vegetation plot scores and the seasonally high water table were rho = 0.094 and rho = 0.644 respectively. Therefore I reject $H_o(1)$ and accept $H_a(1)$ and conclude that there is not a strong correlation ($|rho| > 0.70$) between vegetation plot scores and plot hydrology.

Hydrophytic Vegetation Scores vs. Hydric Soils Features—Within this set of coefficients, a significant positive correlation between the weighted average ecological index values and the depth to redoxomorphic features indicates that as the depth to which redoxomorphic features moved closer to the soil surface, the weighted average scores mover closer to one. This makes sense as redoxomorphic soil features are the product of soil saturation (Megonigal and others 1993). A negative correlation in the relationship between weighted average score and the thickness of the organic A horizon indicates that as the thickness of the organic horizon increases the weighted average score decreases. This relationship also makes ecological sense as inundation and the reduction of soil oxygen restricts the decomposition of organic matter (Megonigal and other 1993). Within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, correlations between weighted average index plot scores and the two measured hydric soils features were modest. The thickness of the A horizon had the best correlation with the plot weighted average index vegetation scores with a rho = -0.499. The herbaceous and short shrub weighted average strata scores were the only strata to record significant correlations with either of the hydric soil features. Scores for the two layers ranged from weak to modest (Table 15).

Within the drier *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type, all of the correlations between vegetation weighted average scores and the hydric soils features were weak (Table 16). The tall shrub, short shrub, and herbaceous layers as well as the weighted average index plot score did record weak correlations with the relationship to the thickness of the A horizon.

Table 15. Spearman rank correlation coefficients between weighted average vegetation plot and strata scores, and soil features in the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type for plots where the soil feature was present

Strata	Depth to Redox (n)	Thickness of A Horizon (n)
Tree	-0.102 (39)	-0.081 (50)
Sapling	0.107 (41)	-0.036 (50)
Tall Shrub	-0.018 (13)	-0.348 (15)
Short Shrub	-0.347** (41)	0.141*** (50)
Herbaceous	0.544*** (41)	-0.473*** (50)
Entire Plot	0.439*** (41)	-0.499*** (50)

* indicates significance at P < 0.10
** indicates significance at P < 0.05
*** indicates significance at P < 0.01

Table 16. Spearman rank correlation coefficients between weighted average vegetation plot and strata scores, and soil features in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type for plots where the soil feature was present

Strata	Depth to Redox (n)	Thickness of A Horizon (n)
Tree	-0.052 (34)	0.123 (45)
Sapling	-0.127 (34)	0.214 (45)
Tall Shrub	0.024 (34)	-0.347** (45)
Short Shrub	0.130 (34)	-0.365** (45)
Herbaceous	-0.262 (34)	0.375** (45)
Entire Plot	-0.241 (34)	0.285* (45)

* indicates significance at P < 0.10
** indicates significance at P < 0.05
*** indicates significance at P < 0.01

Correlations for all plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types the correlation (rho) between hydric vegetation weighted average index plot scores, and hydric soil features were not greater than 0.70. Therefore I reject $H_o(2)$ and accept $H_{a(2)}$ and conclude that there is not a strong correlation ($|rho| > 0.70$) between hydric soil features and hydrophytic vegetation plot scores.

Hydric Soil Features vs. Site Hydrology—Within this set of correlations, a significant positive correlation between the seasonally high water table and the depth to which redoxomorphic soil features were found indicates that as the water table moved closer to the soil surface, the redoxomorphic features also moved closer to the soil surface. A negative correlation between the seasonally high water table and the thickness of the organic A horizon reflects the increasing thickness of the A horizon as the seasonally high water table is found nearer to the soil surface (Table 17).

Table 17. Spearman rank correlation coefficient between soil features and 14 day exceedence level in the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type and phases for plots where both the soil feature and hydrology were present. Note: Distance to redox feature and to the 14 day exceedence value were measured as positive distances from the top of the O horizon. (Two plots were omitted as statistical outliers)

Soil Feature	ABILAS/LEDGLA habitat type (n)	CALCAN phase (n)	LEDGLA phase (n)
Depth to Redox	0.702*** (48)	0.514** (23)	0.702** (25)
Thickness of A Horizon	-0.520*** (48)	-0.335 (23)	-0.393* (25)

ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
CALCAN = *Calamagrostis canadensis* (bluejoint reedgrass) phase
LEDGLA = *Ledum glandulosum* (Labrador tea) phase.
* indicates significance at $P < 0.10$
** indicates significance at $P < 0.05$
*** indicates significance at $P < 0.01$

Within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type, the depth to redoxomorphic features had a strong correlation with the seasonally high water table (rho = 0.702). The thickness of the A horizon had a moderate correlation with site hydrology (rho = -0.520).

The correlations between both measured hydric soil features and the 14 day exceedence level for the drier *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type and phases were very weak to weak, and not statistically significant (P > 0.10) (Table 18).

Table 18. Spearman rank correlation coefficient between soil features and 14 day exceedence level in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type and phases for plots where both the soil feature and hydrology were present. Note: Distance to redox feature and to the 14 day exceedence value were measured as positive distances from the top of the O horizon.

Strata Soil Feature	ABILAS/STRAMP Habitat Type (n)	STRAMP Phase (n)	MENFER Phase (n)
Depth to Redox	0.147 (32)	0.217 (21)	0.006 (11)
Thickness of A Horizon	-0.213 (32)	-0.247 (21)	-0.120 (11)

ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type
STRAMP = *Streptopus amplexifolius* (twisted stalk) phase
MENFER = *Menziesia ferruginea* (false azalea) phase
* indicates significance at P < 0.10
** indicates significance at P < 0.05
*** indicates significance at P < 0.01

In the sum of plots examined in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) and Abies *lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat types only the correlation (rho) between the 14 day exceedence level, and the depth to redoxomorphic features within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type was greater than 0.70. Therefore I accept $H_O(3)$ and conclude that within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type there is a strong correlation (rho = 0.702) between the depth to redoxomorphic soil features and the 14 day exceedence level. In all other cases I reject $H_o(3)$ and accept $H_a(3)$ and conclude that the correlations between hydric soil features and the 14 day exceedence level are not strongly correlated.

An Assessment of Northwest (Region 9) Reed (1988) Wetland Indicator Values

To assist in the reevaluation of the wetland indicator status for individual plant species new ecological indices were calculated and the mean seasonally high water table was calculated for every species which occurred in this study. If a calculated value of species index score deviated by at least 1.00 from the values determined by Reed (1988), then a review of that species' status is recommended. This deviation indicates that at least within this set of plots this species is occurring in samples with values that differ from its assigned value. This assessment does not indicate that the Reed (1988) classification is incorrect because it only reflects the species' distribution within the plots of this study. However, since a full deviation of 1.00 indicates a change in the wetland indicator status for any particular species a reassessment of the Reed (1988) listing should be undertaken.

The mean seasonally high water table depths calculated for each species is reported as the depth below the soil surface to which the mean seasonally high water table was located. As with the calculated index values, the mean seasonally high water table values are valid for only these select sites in which the species were recorded. Due to the ecological amplitude of many of these species these water table figures should be supplemented with water table data from a wider variety of sites.

Table 19 lists all the species which had their calculated index value differ by 0.50 or greater from the Reed (1988) value. A total of 69 species appeared in at least five of the 110 vegetation plots, 43 of which appear in this table. Species which deviated by 1.00 or more from the listed value are italicized in bold.

Table 19. Species with a calculated index score which differed by 0.50 from the assigned Reed (1988) value with a comparison to the species' Reed (1988) index value and mean seasonally high water table.

Lifeform *Species*	Reed (1988) Index Value	Calculated Index Value	Mean Seasonally High Water Table (cm)
Tree			
Abies lasiocarpa	4	3.15	24.3
Taxus brevifolia	4	3.47	24.0
Shrub			
Actaea rubra*	5	3.38	33.4
Alnus sinuata	2	3.24	28.3
Berberis repens*	5	3.55	25.6
Cornus stolonifera	2	3.23	28.1
Ledum glandulosum	2	3.05	17.0
Linnaea borealis	4	3.32	26.0
Menziesia ferruginea	4	3.20	27.5
Pachistima myrsinites*	5	3.43	32.5
Rhamnus purshiana*	5	3.41	29.1
Rosa woodsii	4	3.38	26.7
Rubus parviflorus	4	3.37	28.9
Spiraea betulifolia*	5	3.31	17.9
Graminoid			
Calamagrostis canadensis	2	2.83	14.1
Carex interior	2	2.56	10.8
Carex mertensii	2	2.84	7.4
Carex misandra	4	2.69	2.5
Carex scopulorum	2	2.73	4.6
Forb			
Adenocaulon bicolor*	5	3.53	23.0
Aralia nudicaulis	4	3.42	30.0
Arnica cordifolia*	5	3.21	27.0
Clintonia uniflora*	5	3.37	31.5
Dodecatheon jeffreyi	2	2.90	16.2
Equisetum sylvaticum	2	2.87	17.7

Table 19 (cont.)

Erythronium grandiflorum	3	2.79	14.9
Galium triflorum	4	3.07	21.5
Gentiana calycosa	2	2.85	11.4
Geum macrophyllum	2	2.62	3.28
Habenaria hyperborea*	5	2.76	9.35
Ligusticum tenuifolium	2	3.04	24.4
Listera cordata	2	3.07	21.1
Osmorhiza chilensis*	5	3.20	30.3
Pedicularis bracteosa*	5	2.94	12.2
Pteridium aquilinum	4	3.24	23.0
Pyrola asarifolia	4	3.29	28.6
Pyrola secunda	4	3.20	30.1
Pyrola uniflora	4	3.01	19.4
Senecio triangularis	2	3.03	24.7
Thalictrum occidentale	4	3.27	28.7
Tofieldia glutinosa	1	2.54	4.2
Trillium ovatum*	5	3.33	31.7
Veratrum viride	1	3.26	33.5
Xerophyllum tenax*	5	3.27	26.5

* indicates a provisional Reed (1988) value of 5.

Application of these methods to other areas of Montana may help facilitate a better approximation of a particular species' indicator status within Montana's subalpine wetlands. Because Montana has a wide range of climatic and habitat conditions, subregional indicators may be more precise (Walker and others 1988). Although these results show trends only for the species occurrence within these specific subalpine wetlands, certain species do stand out as in need of review.

Thirteen of the 21 species which had their calculated index value deviate by 1.00 or greater from the Reed (1988) value were those which were not listed and had a default ecological index value of five (upland). Two of these unlisted species *Habenaria hyperborea* (northern bog orchid) and *Pedicularis bracteosa*(bracted lousewort), both had calculated index values below 3.00, with respective mean seasonally high water tables of 9.35 cm (3.68 in) and 12.2

cm (4.80 in) below the soil surface. These two factors would indicate that these species should be regarded as either facultative (FAC) or facultative wetland (FACW). While these two species stand out as having the greatest deviation from the Reed (1988) listing, all 13 of the species which currently are not listed for the Northwest Region should have their wetland indicator status reevaluated.

Veratrum viride (false hellebore) and *Tofieldia glutinosa* (tofieldia) have a Reed (1988) listing of one (obligate) but had calculated ecological indices of 3.26 and 2.54 respectively. The mean water table calculated for *Veratrum viride* (false hellebore) was 26.5 cm (10.4 in), while *Tofieldia glutinosa* (tofieldia) occurred on sites with water tables near to the soil surface with a mean depth of 4.2 cm (1.6 in). A shallow mean seasonally high water table would seem to indicate that the original Reed (1998) value of one (obligate) may better reflect this species than the recalculated ecological index of 2.54.

The Spearman Rank Order Correlation procedure was used again to determine the relationship between the current Reed (1988) listing, the new calculated ecological index values, and the mean seasonally high water table for the species listed in Table 19. The rho calculated between the new ecological index values and the mean seasonally high water tables was strong at 0.757 ($p < 0.0001$), while the rho calculated between the current Reed (1988) listing and the mean seasonally high water tables was only moderate at 0.408 ($p < 0.01$). This indicates that the new index values calculated for this set of species is correlated stronger to the water tables associated with the sites in which these species were found than the current Reed (1988) listings.

DISCUSSION

Jurisdictional Wetland Determination

As the area separating wetland from uplands broadens, a wetland boundary line is difficult to determine (Carter and others 1994). Only a handful of studies have attempted to quantify the 1987 Corps Manual delineation methods within these difficult areas, and none of these studies have been conducted within the Rocky Mountain region (National Research Council 1995). One of the objectives of this study was to use habitat types that are commonly found within the wetland to upland ecotone within the subalpine zone problem area to identify features that may help the field delineator better delineate the extent of jurisdictional wetlands.

In the results I presented data showing that neither the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) or *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types have jurisdictional wetlands in greater than 66 percent of their sites (Table 11, Table 12). However, this data does not fully explain the ecological characteristics of those sites. Further examination of the wetland to upland ecotone and the ecology of these two habitat types will help shed more light into these results.

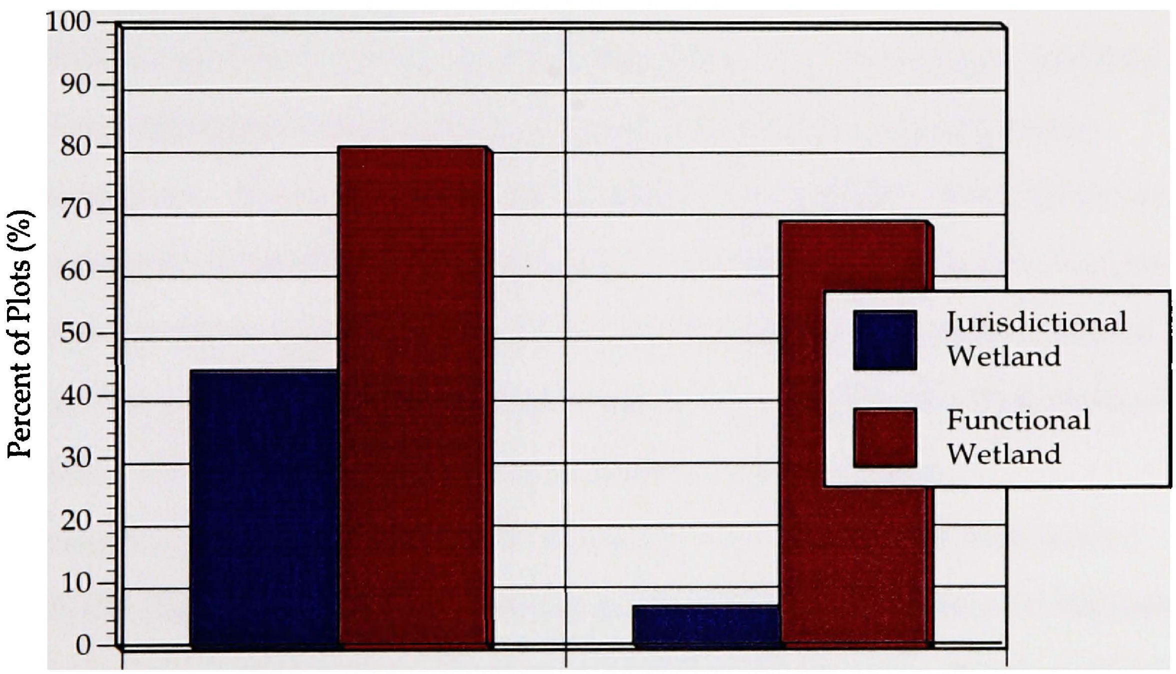
Determination of Jurisdictional Wetland Status Within The Wetland to Upland Ecotone—After measuring hydrology, vegetation, and soil characteristics within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types I found that each type had distinct ecological characteristics. First, the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type has much higher seasonal water tables than the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type (See Figure 9). Since hydrology drives the formation of hydric soil features and the establishment of hydrophytic vegetation communities, it makes sense that, in comparison, the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)habitat type had a much higher percentage of positive wetland indicators. In the field I found this type associated with the wet fringe of the wetland to upland ecotone, often near streamsides, in wet meadows, and the base of seep slopes.

The *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type and both of the phases associated within this type are only found on seep slopes or along the riparian fringe. I found this type associated with the upland end of the ecotone where surface water was infrequent or water tables rarely were near the surface. The sites are not inundated or saturated for a duration that would indicate wetland hydrology or produce distinguishing hydric soils features. The majority of vegetation communities associated with this type were not hydrophytic in nature.

Slope Position. From my field observations and review of the transect topography (see Appendix B for transect cross-sections), I found that the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type often occupies the toe slope position that had the tendency to retain the water table at or near the surface well into the growing season. These sites supported a predominance of hydrophytic vegetation communities (64 percent of the plots) and also produced hydric soil features (54 percent of the plots). I found *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type mostly near springs on 10 percent to 20 percent slopes. Many of these sites had water tables occurring within 75 cm (29 in) of the soil surface, hydrophytic vegetation, and soils indicators. But due to the ephemeral hydrology that was usually present only in the early growing season, the majority of these hillslope seep sites could not be considered jurisdictional wetlands because they did not have all three of the wetland field indicators at the same time.

It is not uncommon to find *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type near springs on 10 percent to 20 percent slopes. The conditions that apply to the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types of the same ecology apply to these types as well. Wetland scientists in this region should understand two points from this discussion: 1) the majority of hillside springs are not jurisdictional wetlands; and, 2) jurisdictional wetlands usually do not extend above the toe slope.

Functional and Jurisdictional Wetlands—Although I did find plots that meet the definition of a jurisdictional wetland within both of the studied habitat types, these habitat types cannot be confidently called jurisdictional wetlands. However, while working in these two habitat types the wetland ecologist must realize that these ***are*** functional wetlands. Remember that a functional wetland need only meet one of the three wetland indicator criteria (Cowardin and others 1979). Functional wetlands are sites that may meet jurisdictional criteria, but do perform wetland functions resulting from the greater amount of water that occupies that area as opposed to adjacent uplands. Thus wetland managers need to realize that although the wetland delineation boundary line stops at the point where one of the three indicators is absent, wetland functions may extend to areas well past that boundary line. This emphasizes the point that all jurisdictional wetlands are functional wetlands, but not all functional wetlands are jurisdictional wetlands (Hansen and others 1995). Figure 10 illustrates the discrepancy between the percentage of jurisdictional wetland and functional wetland determinations.



ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk)

Figure 10. Percentage of functional and jurisdictional wetland sites within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types

The sites occupied by these two habitat types are difficult to apply the 1987 Corps Manual wetland delineation techniques within. The surface water is rarely on site after spring snowmelt and visible signs of wetland hydrology, such as drift marks and water stained leaves, are rarely present. The vegetation communities are dominated by facultative upland species with pockets of facultative wetland species near seep areas. The majority of parent material associated with the soils are red to red/yellow in hue naturally mottled from andic surface horizons. This can easily confuse the reading of hydric soils features. The contrast between the two habitat types, their variable wetland hydrology, and their status as problem areas made them excellent areas for correlation analysis of their wetland field indicators.

Wetland Indicator Correlations

In the previous section, I made an approximation of jurisdictional wetland status of two subalpine habitat types in order to assist land managers in subalpine regions. From this work the questions then arise: What tools can the field wetland delineator rely upon when delineating a wetland boundary within these problem types? Is there a strong association between wetland hydrology, the presence of hydrophytic vegetation, and the development of hydric soils? Which 1987 Corps Manual methods for wetland characterization best apply to these in the cold, and flashy wetlands above 1,672 m (5,500 ft). After I determined the ecological characteristics of the two subalpine habitat types I then addressed these questions in the little studied subalpine wetlands of Western Montana.

The results of the Spearman Rank Order Correlation analysis showed three important trends: 1) weighted average index scores best relate to the seasonally high water tables in areas where the water table reaches within 15 cm (6 in) of the soil surface; 2) weighted average index scores best related similarly to the thickness of the organic A horizon as to the depth to redoxomorphic soil features; and, 3) redoxomorphic soil features are the best indicators of depth to the seasonally high water table. I now will discuss each of these trends.

Vegetation and Hydrology Relationships—Analysis of the relationship between weighted average index scores and the measure of the seasonally high water table showed that only within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type was there a significant correlation (rho = 0.644) between the two field indicators. This is noteworthy as I had determined that the seasonally high water table within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type was significantly closer to the soil surface than the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type.

To further explain these results I attempted to determine if the depth of the seasonally high water table made a difference as to the effectiveness of the weighted average scoring method. To do this I divided all 14 day exceedence level plots into 4 different depth ranges. I then looked for relational strengths with the associated weighted average vegetation plot score using the same Spearman Rank Order correlation procedure (Table 19). Looking at results from these correlations I inferred that only when saturation was within the rooting zone (within 30 cm [12 in] of the soil surface) was the weighted average method an affective tool for vegetation characterization. This is interesting as saturation within the rooting zone is most important to the composition and maintenance of the hydrophytic vegetation community

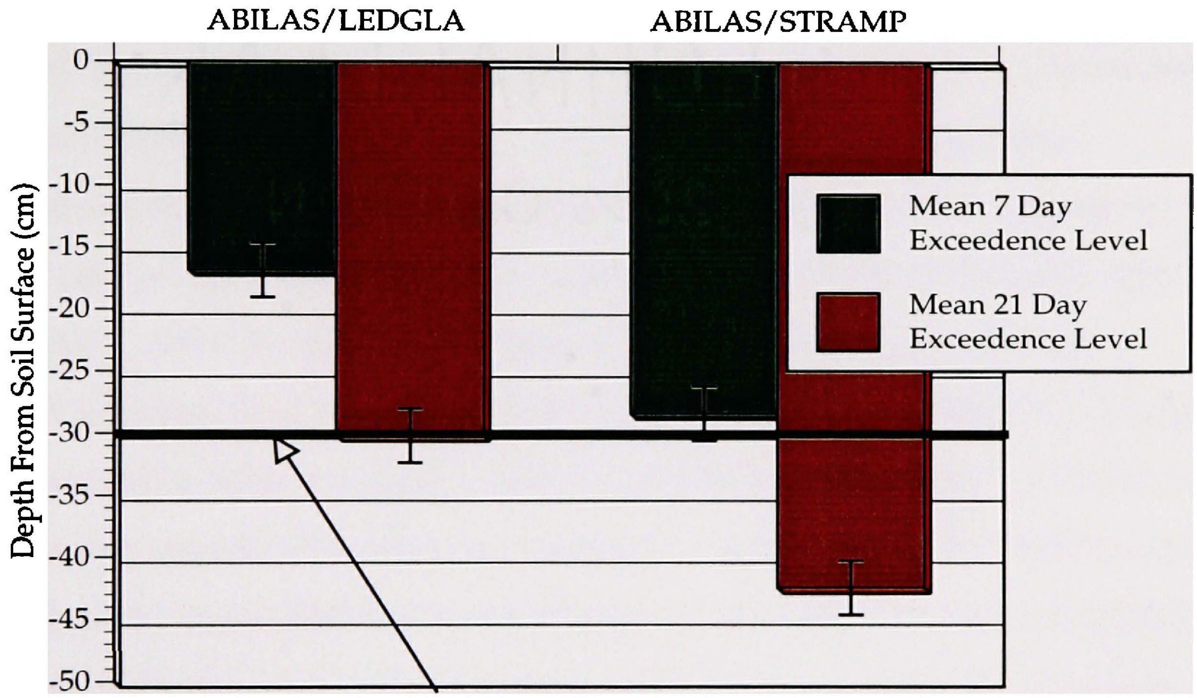
(Tiner 1991). This agrees with the 1987 Corps Manual (Section 49.2) which states that for soil saturation to impact vegetation it must "occur within a major portion of the root zone" which is usually 30 cm (12 in). However, the only significant relationship between the water table and the weighted average scoring method was found when the seasonally high water table was within 15 cm (6 in) of the soil surface. It would be a stretch of this data to conclude that for these subalpine areas only seasonally high water tables within 15 cm (6 in) of the soil surface have a significant influence upon the vegetation community. Further research would be necessary to determine if the critical depth to the determination of wetland hydrology should be reduced to 15 cm (6 in).

Table 20. Spearman Rank Order Correlation analysis between 14 day exceedence level and weighted average vegetation plot scores for all plots

Range of Depth to 14 Day Exceedence Level (N)	Mean Depth (Standard Error)	WA Vegetation Scores v. Plot Hydrology (rho)
Less than 15 cm (23)	5.58 cm (1.16 cm)	0.511*
From 15 cm to 30 cm (29)	22.17 cm (0.86 cm)	0.213
From 30 cm to 45 cm (16)	36.12 cm (1.07 cm)	-0.038
From 45 cm to 60 cm (8)	52.62 cm (1.86 cm)	-0.283

* indicates significance at $P < 0.10$
** indicates significance at $P < 0.05$
*** indicates significance at $P < 0.01$

With this relationship in mind I then could explain the discrepancy between the positive relationships found between vegetation scores and site hydrology in the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type and the non-significant correlations (rho) found in the *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type. Figure 11 illustrates the feature that although the *Abies* *lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type does have periods of wetland hydrology (saturation within 30 cm [29 in] of the soil surface), it does not on average hold water tables within 30 cm (29 in) of the soil surface for durations longer than 14 days. More importantly, the highest average seasonally high water table as represented by the mean 7 day exceedence level, does not rise to within 15 cm (6 in) of the soil surface.



ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk)

Figure 11. Comparison of the mean 7 day and 21 day exceedence levels for the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) and *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat types. Error bars represent the standard error of the mean.

While exploring further vegetation and hydrology relationships I also tested each vegetation strata independently to determine if a single layer can be used to better predict the seasonally high water table. Interestingly, of the five vegetation strata sampled the herbaceous layer correlated best with site hydrology. This indicated that some of the larger shrubs and trees may have a wider ecological amplitude which allows them to survive in both wet and dry sites. It has been previously shown that the presence or absence of some annual herbaceous species may better reflect recent hydrological conditions (Segilquist and others 1990).

Vegetation and Soil Feature Relationships—As with the other analysis within this study, only the correlation coefficients (rho) I calculated within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type were within the modest range. Here I found that the vegetation weighted average scores related similarly to the thickness of the organic A horizon (rho = -.499) as to the depth to which redoxomorphic features were found (rho = .439). In areas with shallow, mineral soils such as the sites I tested, it is logical that the composition of the vegetation community changes as the amount of surface organic material increases or decreases. A thick (> 20 cm [8 in]) organic A horizon is a commonly used indicator of hydric soils. I subsequently found that the depth of organic A horizon is only moderately associated with the seasonally high water table (rho = -0.520). In conclusion, while I found the relationship between the two hydric soil features and the calculated vegetation scores to be a moderate one, this feature alone does not allow the wetland delineator to make a strong connection between plot vegetation and site hydrology.

Soil Features and Hydrology Relationships—Hydric soil features held the best relationships to the seasonally high water table. The majority of soils which did have wetland hydrology and hydric soils did not have evidence of a reducing state such as gleyed colors or redox depletions. Very common within these hydric soils were redox concentrations of iron and manganese masses oxidized into reddish mottles (USDA 1996). This is a feature common to soils with a fluctuating water table (as near a stream) or soils which do not allow saturation to reach a reducing state due to short saturation duration or cold soil temperatures.

The only Spearman Rank Order Correlation analysis which resulted in a rho > 0.70 was the relationship between plot hydrology and the depth to redoxomorphic soil features within the *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea) habitat type (rho = 0.702). This indicates that where there is wetland hydrology, the depth to the seasonally high water table can be determined fairly accurately by measuring the depth to redoxomorphic soil features. Indirect indicators of hydrology such as drift lines or water stained leaves are not applicable in these seep slope wetlands as inundation rarely occurs. Thus, in undisturbed systems, field delineators can be very confident when using redoxomorphic soil features to determine and justify decisions concerning site hydrology.

New Determinations of Ecological Indicator Status

When calculating the individual species' wetland indicator status it should be made clear that the new values reflect only the ecology of the sites in which a species was found within this study (Table 19). This type of averaging has also been found to compress the range of values produced thus producing a greater discrepancy between the Reed (1988) values and the recalculated values for species that are classified as either obligate or upland (Walker and others 1989). This could account for the discrepancy between Reed (1988) values and recalculated scores for the 13 species which had a provisional Reed

(1988) value of 5 (upland). However, further analysis reveals that these 13 species had a mean seasonally high water table of 25.3 cm (10.0 in) below the soil surface, which is be considered to be characteristic of wetland hydrology.

I would argue that there is a combination of factors which is working to produce a discrepancy between the current Reed (1988) values and the recalculated index values. First, many of the species with provisional listings of upland are simply species which were not evaluated during the making of the Reed (1988) list. A provisional listing of upland is the result of omission from the list, and may not be based upon the actual ecological characteristics of a species. Looking at Table 19, this would include species with shallow water tables such as *Habernaria hyperborea* (northern bog orchid), and *Pedicularis bracteosa* (bracted lousewort).

Another factor in the discrepancy between the current listing and recalculated index values may be that these species have wide ecological amplitudes. For example, *Xerophyllum tenax* (beargrass) is common to open slopes and in forests of the montane and subalpine zone of western Montana (Lackschewitz 1991). A provisional listing of upland does not well describe the ecology of the plots I found it in, as it had a calculated ecological index value of 3.27 and a mean seasonally high water table of 26.5 cm (10.4 in), which is within the minimum range considered to be wetland hydrology (Environmental Laboratory 1987). If this particular species had the full range of wet and dry sites sampled in which it is commonly found, it may indeed only occur in jurisdictional wetland sites one percent of the time as is indicated by its upland status. This reasoning can also work the other direction, as I found the listed index value (2.00) of the shrub *Ledum glandulosum* (Labrador tea) indicative of a wetter ecology than the calculated index value (3.05). This seems to indicate that this shrub may survive on sites with lower water tables as well as on sites more typically thought of characteristic of its ecology. Thus, to get an accurate estimate of an individual species' ecological index, the full range of sites upon which a species occurs needs to be surveyed.

CONSIDERATIONS FOR WETLAND DELINEATION WITHIN THE SUBALPINE ZONE AND FUTURE RESEARCH OPPORTUNITIES

In this section I synthesize my findings and recommend the best methods for the determination of jurisdictional wetland status and the delineation of wetland boundaries based upon ecologically sound principles. Following these recommendations I then address ideas for further research in wetlands science, in particular I point to needs within the state of Montana.

Subalpine Areas As Jurisdictional Wetlands

Vernal pools, playas, potholes, and alpine wet meadows are considered isolated waters and are defined as nontidal waters of the United States under the Clean Water Act (33 CFR 330.2). Isolated wetlands fall under Nationwide Permit 26 which allows for alterations to areas less than 4 ha (10 acres) in size with minimal review from the U.S. Army Corps of Engineers division manager (National Research Council 1995). Although isolated and headwater wetlands have less significance within the regulatory realm, these types still play a distinct and critical functional role in the waters that flow downstream from these sites (National Research Council 1995). Furthermore, the National Research Council (NRC 1995) concludes that the "scientific basis for policies that attribute less importance to headwater areas and isolated wetlands than to other wetlands is weak."

Although subalpine wetland systems are not regulated as strictly as lowland systems, it is still important for wetlands managers and researchers to accurately delineate the boundary between wetland and upland. When delineating wetland boundaries within these systems, the first feature to investigate is slope position. Slope position is essential to the determination of jurisdictional wetland status while using the 1987 Corps Manual methods within the wetland to upland ecotone. Although in the majority of cases seep slopes can be considered functional wetlands, I found that most seep slopes in this study do not qualify as jurisdictional wetlands. The toe slopes and low gradient wet meadows receiving water from the seep slopes have a much higher likelihood of being jurisdictional wetlands.

Small 1 m (3.28 ft) to 5 m (16 ft) diameter springs located on these slopes often have hydrophytic vegetation communities immediately adjacent to the spring areas. Small 30 cm (16 in) to 90 cm (36 in) wide rills running downslope from these springs also may support hydrophytic vegetation. Around these features, however, I did not observe flooding or inundation regimes that indicate positive wetland hydrology, and the soils were rarely hydric. These small seeps tend to send flows which accumulate at the toe slope where wetland hydrology is present, as well as hydric soils and hydrophytic vegetation communities, thus making the toe slopes the most likely areas to support jurisdictional wetlands. Again, while these areas may be overlooked as non-jurisdictional wetlands, their functional importance should not be minimized by the wetland manager.

Reliability of the Wetland Field Indicators

Vegetation Community—In a review using the hydrophyte for wetland identification, Tiner (1991) stated: "If a sole criterion was developed for wetland identification, it would certainly be one based on the hydrologic conditions associated with wetlands rather than on the vegetation occupying such sites." Although vegetation communities may well reflect the hydrology of a site, I found that in subalpine systems of Western Montana correlations between vegetation scores and recorded hydrology were not strong. Within these subalpine habitat types, vegetation communities did not accurately reflect the site hydrology accept in cases where the seasonally high water table is within 15 cm (8 in) of the soil surface. However, even in these cases where sites were inundated, correlations calculated between vegetation and hydrology indicators were not strong.

This low correlation may be due to several factors. First, the scoring system used by the 1987 Corps Manual may not accurately reflect the response of the vegetation community to different hydrological regimes. This factor seems likely as I found that the three common methods used by the U.S. Army Corps of Engineers to quantify the vegetation community each resulted in different relationships to the measured site hydrology (Table 8). Furthermore, the use of the dominance ratio method, which is the most commonly used descriptor of the vegetation community in wetland field delineation, correlated most weakly to the seasonally high water table of the three techniques I tested. Of the three vegetation scoring methods I recommend the use of the weighted average indicator method as the most accurate technique for vegetation community description. This method is usually more time consuming and requires the identification of more plant species than just the dominant types (as required by the dominance ratio method), but my data suggests that the use of dominance ratio is ineffective within the subalpine vegetation types I tested.

Second, although I attempted to shape the vegetation polygon to encompass hydrologically similar terrain, the patchy nature of the subalpine seep zone created a mosaic of wet and dry areas within the 10 m (30 ft) radius vegetation plots. It is the patchy hydrologic nature of these sites which make them extremely difficult to delineate. This factor also complicates the attempt to compare the vegetation community to a single well point within a 10 m (30 ft) plot.

Finally, the Reed (1988) plant indicator list which is used throughout the nation to characterize plant species based upon their occurrence within a wetland, may not be entirely accurate. The list of plant species and their characterization was compiled based upon the opinions of regional experts. Only their expertise was used to create plant classifications which greatly affect the determination of jurisdictional wetland status. Table 19 shows that many species found within this study had calculated ecological indices that differed considerably from their listed Reed (1988) values. Although several studies similar to mine have tested the indicators regionally (Segilquist and others 1990), these tests have not been conducted for the entire range of wetland sites within the United States. Plant species which are not listed correctly could greatly affect the accuracy of scores calculated by any of the methods outlined in the 1987 Corps Manual.

I also determined that the herbaceous layer and the short shrub layer consistently better reflected the seasonally high water table and the presence or absence of hydric soils, than the tree, sapling, tall shrub. This finding is consistent with the findings by Segilquist and others (1990), who found that the herbaceous layer was more sensitive to moisture gradients. Segilquist and others (1990) also noted that while some layers may be more responsive to moisture gradients, all layers are used in the 1987 Corps Manual methods. Segilquist and others (1990) concluded that these methods, which use a total calculated from all strata, are more appropriate but not necessarily more accurate when attempting to determine plot hydrology. Indeed, I found that while the Spearman Rank Order correlations for the herbaceous layer and short shrub layer were higher than those calculated for the other strata, they were still only moderate. This indicates that vegetation features or the methods used to measure the vegetation community may be misleading as to indicating the jurisdictional wetland status in these wetlands.

When working along the mid-to-upper wetland to upland ecotone in Western Montana, I found that all three methods for the characterization of the vegetation community to be fairly ineffective. This was especially apparent as I frequently found hydrophytic vegetation communities upslope of areas which had ceased to have hydric soil indicators and wetland hydrology. It was the hydric soil indicators which best reflected the seasonally high water table.

Hydric Soils Indicators—In problem area wetlands, the 1987 Corps Manual allows the field ecologist to use all available information including personal ecological knowledge of a wetland type to determine whether wetland indicators are normally present during part of the growing season. Indicators of wetland hydrology are commonly lacking in these seep wetlands. As the data of my sites shows, measures of the vegetation community do not correlate strongly to site hydrology (Tables 13 through 16). However, I did find that evidence of hydric soil features correlates strongly to the seasonally high water table within sites with wetland hydrology (Table 17). Thus, within the Cryic mineral soils of Western Montana, wetland scientists should pay special attention to the presence of redoxomorphic soil features in the nature of Fe and Mn concentrations in order to determine the depth of the seasonally high water table. Common mottling soil colors included redox concentrations of 10YR 5/6 and depletions of 7.5 YR 5/1. These indicators can be confidently used to make consistent and defendable wetland determinations.

Conclusions—

1) More accurate methods for the characterization of the vegetation community need to be explored;

2) The seasonally high water table is best approximated by the depth to which redoxomorphic soil features are found; and,

3) The upper portion of the wetland to upland ecotone fails to produce consistent and strong relationships between the three wetland field indicators.

Recommendations For Further Research

Quantifying the Water Table—In 1995 the National Research Council reported that the while the importance of hydrology in the formation and maintenance of wetlands is well accepted, "the threshold conditions that satisfy the hydrologic criterion and the methods to be used for determining the presence or absence of wetland hydrology are still in need of study." I believe that the greatest opportunity for the enhancement of the science of wetland delineation will be through the direct quantification of the water table and the study of responses of the vegetation and soils features to different hydrologic regimes. By identifying the most accurate indicators of site hydrology, be it a better vegetation scoring system or regional hydric soils indicators, the field work of the wetland delineator will be much more consistent and defensible. To do this the wetland scientific community needs to address the simple question: What is the depth and duration of saturation required for wetland maintenance in different regions or wetland systems within the United States? Due to the difficulty in directly quantifying the the water table very few studies have been completed that tackle this issue as it relates to wetland delineation (National Research Council 1995).

The key to the quantification of wetland hydrology is the direct observation of surface flooding or seasonal water tables (Carter and others 1994). Many techniques for the direct measurement of wetland hydrology have been documented. Soil augering, soil pits, stream gage stations, piezometer well units, perforated observation well units, and the rusty re-bar method have all been used in attempts to quantify water tables (Zobeck and Ritchie 1984; Schmalzer and Hinkle 1992; Golet and others 1993; Light and others 1993; Skaggs and others 1994; Carter and others 1994).

Project time and money constraints figure heavily into which method is used. In Montana, piezometer well units have been used frequently for the observation of shallow water tables in wetland areas. However, piezometer wells are not designed to observe water table levels (Faulkner and others 1989;

Wetland Research Program 1993). Non-perforated piezometers are "cased wells" open only at the bottom and therefore the level of water within the unit reflects the pressure or hydrologic head only at the bottom of the pipe (Wetlands Research Program 1993). This property makes a piezometer useful for the measurement of groundwater flow direction, but not for the measurement of the surface of free water. It is important to note that to effectively use the piezometer for the measurement of hydraulic head, a nested set of variable length units is required (Wetlands Research Program 1993).

I recommend the use of perforated well units as they provide a more precise measure of the depth to free water. These types of well units should be used following the guidelines for installation found in *Installing and Monitoring Wells/Piezometers in Wetlands* (Wetlands Research Program 1993). While perforated water table wells worked well, lowland studies should attempt to locate study sites near stream gauge stations, or preexisting wells to obtain a long-term record of site hydrology. This method would reduce labor time and expenses considerably.

Using Habitat Types—Habitat types from *The Classification and Management of Montana's Riparian and Wetland Sites* (Hansen and others 1995) worked well in this study. Using habitat types that are known to be commonly found within the wetland-to-upland ecotone allowed me to find sites that, while having similar characteristics,also had a wide range of variation. In similar studies concerning the study of wetland field indicators, soil maps were used to select sites with similar soil properties (Segilquist and others 1990). In many areas of Montana the soils are not mapped which makes the use of this technique very difficult. Although habitat types are intended as tools for management, I would recommend their use as practically feasible, efficient, and a well understood method for site selection.

Regionalization of Wetland Field Indicators—As the population of Montana continues to grow, and demands on our riparian and wetland areas increase, accurate and consistent wetland delineation is essential. This study was a first step toward more consistent delineation within the state of Montana. Montana, however, has many more areas that are considered problem wetland areas which makes consistent delineation very difficult. Those problem areas listed which are of importance in this state are: 1) wetlands on glacial till; 2) prairie potholes; 3) river bars; 4) wetlands on Entisols; and, 5) evergreen-forested wetlands (Federal Interagency Committee for Wetland Delineation 1989).

Obviously, further research that can identify and justify appropriate wetland field indicators for the unique ecological areas of Montana is needed. In 1995 the National Research Council suggested three steps for the regionalization of wetland delineation field methods. First, we need to identify regional areas with unifying properties. Second, the "occurrence and fidelity of wetland field indicators within that region must be determined" (National Research Council 1995). Finally, these indicators must be adopted for application to jurisdictional wetland determinations.

If followed, this series of steps may help standardize research methods within wetland delineation science and allow for the comparison of results from region to region. Most importantly, however, is the dispersal of study results to the personnel who are most involved within this science and can most effectively apply the recommendations of researchers to the field. This includes the U. S. Army Corps of Engineers regional division manager, United States Fish and Wildlife researchers, the Montana Department of Environmental Quality, the Wetlands Council, and independent wetland delineation contractors.

Since this is the first study in the state of Montana which attempts to find regionally specific wetland indicators, I hope that future research can learn from my efforts. Recently the Conservation Strategy Working Group of the Montana Wetlands Council as a part of the Department of Environmental Quality adopted the national wetland goal as the proposed goal for the state of Montana. It states:

> The proposed wetland conservation goal for Montana is to build a wetlands conservation program to achieve no overall net loss of Montana's remaining wetland base, in terms of quantity and quality, to conserve, restore, enhance and create wetlands where feasible, and to increase Montana's wetlands resource base.

The first aim of this goal is the inventory of this state's wetlands and tracking of losses and gains. To do this, it is essential to be able to identify the extent of both functional wetland areas and jurisdictional wetland areas. This would be the first step towards the effective management of wetlands and is important for ensuring that the "quality and quantity of wetlands are sustained and improved" (Montana Wetlands Council 1997). Wetlands are vital components of the Montana landscape (Montana Wetlands Council 1997).

Continued funding and enthusiasm for wetlands research projects such as my study will enhance our information base and ultimately allow us to make wise decisions which will shape the future of Montana's wetlands.

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APPENDIX A. Return Interval Tables

Within each study region, flood-frequency analysis was conducted to determine the probability of occurrence of a specific annual peak flow event. The probability of occurrence is the probability that the peak flow discharge will be equaled or exceeded in any one year. The peak flow discharges for the water years during which this study was conducted are highlighted in bold.

Table A-1. Stream Station# 12344000– Bitterroot River, Darby, Montana.

Probability of Occurrence	Peak Flow Discharge (cfs)	Year
0.02	11500	1947
0.03	11300	1948
0.05	11100	1974
0.06	10500	1972
0.08	10500	1956
0.10	***10100***	***1997***
0.11	9450	1964
0.13	9320	1996
0.15	9080	1976
0.16	9000	1982
0.18	8750	1967
0.19	8670	1971
0.21	8470	1970
0.23	8200	1953
0.24	7870	1958
0.26	7810	1975
0.27	7560	1986
0.29	7560	1984
0.31	7440	1949
0.32	7420	1954
0.34	7160	1978
0.35	7080	1951
0.37	7070	1965
0.39	6930	1950
0.4	6850	1959
0.42	6820	1943
0.44	6780	1969
0.45	6780	1960
0.47	6770	1955
0.48	6240	1960
0.5	6190	1983
0.52	6030	1957

Table A-1. (cont.)

0.53	5990	1979
0.55	5930	1942
0.56	5820	1968
0.58	5590	1963
0.6	5520	1952
0.61	5200	1981
0.63	5160	1995
0.65	4920	1939
0.66	4870	1991
0.68	4590	1993
0.69	4370	1989
0.71	4370	1962
0.73	4060	1946
0.74	3960	1945
0.76	3750	1988
0.77	***3650***	***1998***
0.79	3540	1990
0.81	3470	1985
0.82	3430	1980
0.84	3360	1940
0.85	3060	1944
0.87	2960	1966
0.89	2950	1973
0.9	2820	1977
0.94	2760	1987
0.95	2630	1994
0.97	2420	1941
0.98	2180	1992

Table A-2. Stream Gauge Station# 12365000– Stillwater River, Whitefish, Montana.

Probability of Occurrence	Peak Flow Discharge (cfs)	Date
0.02	5050	1993
0.04	4940	1989
0.05	4670	1990
0.07	***4600***	***1997***
0.09	4570	1991
0.11	4330	1948
0.13	3680	1996
0.15	3680	1996
0.16	3200	1947
0.18	3140	1992
0.2	2950	1991
0.22	2700	1950
0.24	2650	1974
0.25	2650	1949
0.27	2640	1934

Table A-2 (cont.)

0.29	2610	1943
0.31	2560	1990
0.33	2330	1976
0.35	2170	1935
0.36	1950	1933
0.38	1940	1982
0.4	1940	1979
0.42	1940	1975
0.44	1930	1932
0.45	1870	1989
0.47	1750	1936
0.49	1710	1946
0.51	1690	1995
0.53	1690	1995
0.55	1680	1978
0.56	1660	1981
0.58	1480	1964
0.6	***1470***	***1998***
0.62	1470	1942
0.64	1450	1983
0.65	1320	1987
0.67	1300	1986
0.69	1300	1980
0.71	1300	1939
0.73	1280	1993
0.75	1280	1985
0.76	1280	1938
0.78	1260	1994
0.8	1240	1937
0.82	948	1945
0.84	901	1984
0.85	892	1988
0.87	882	1973
0.89	825	1931
0.91	688	1940
0.93	598	1992
0.95	450	1977
0.96	408	1941
0.98	345	1944

Table A-3. Stream Gauge Station# 12370000–Swan River, Bigfork, Montana.

Probability of Occurrence	Peak Flow Discharge (cfs)	Date
0.01	8890	1974
0.03	***8520***	***1997***
0.04	8400	1948
0.05	8280	1933

Table A-3 (cont.)

0.06	8100	1964
0.08	7820	1928
0.09	7520	1959
0.1	7230	1970
0.12	7060	1927
0.13	6810	1961
0.14	6790	1956
0.15	6760	1925
0.17	6540	1972
0.18	6340	1986
0.19	6180	1936
0.21	6010	1965
0.22	5960	1947
0.23	5920	1958
0.24	5900	1950
0.26	5840	1979
0.27	5810	1980
0.28	5810	1996
0.29	5710	1932
0.31	5710	1982
0.32	5630	1954
0.33	5610	1953
0.35	5570	1943
0.36	5540	1967
0.37	5520	1981
0.38	5500	1922
0.4	5500	1960
0.41	5440	1971
0.42	5410	1975
0.44	5380	1924
0.45	5320	1978
0.46	5300	1929
0.47	5160	1985
0.49	5140	1931
0.5	5130	1949
0.51	5060	1955
0.53	5050	1993
0.54	4960	1957
0.55	4940	1989
0.56	4860	1976
0.58	4820	1984
0.59	4790	1983
0.6	4780	1923
0.62	4750	1933
0.63	4750	1951
0.64	4670	1990
0.65	4650	1935
0.67	4610	1946
0.68	4590	1952
0.69	4570	1991

Table A-3 (cont.)

0.71	4530	1962
0.72	4520	1966
0.73	4480	1968
0.74	4380	1969
0.76	4350	1938
0.77	4350	1939
0.78	4220	1987
0.79	3980	1942
0.81	3940	1945
0.82	3910	1995
0.83	***3890***	***1998***
0.85	3860	1926
0.86	3770	1973
0.87	3760	1994
0.88	3740	1963
0.9	3650	1940
0.91	3430	1977
0.92	3380	1937
0.94	3170	1988
0.95	3140	1992
0.96	3120	1944
0.97	2920	1930
0.99	2120	1941

APPENDIX B. Transect Cross-Sections

Transect cross-sections were recorded using a David White Autolaser 350. The graph axes are in feet, however in several cases to make the graphs more manageable the axes are scaled differently. Each graph represents a specific site and a transect at that site. The legend shows habitat type and phase occurring on the transect. The well units are numbered according to the sequence determined in the study The Second Approximation of Jurisdictional Wetland Status for the Habitat Types in The Classification and Management of Montana's Riparian and Wetland Sites (Hansen and others 1995). Hydrographs, as well as vegetation and soils data for each of the well units can be found on-line at the Riparian and Wetland Research Program web site located at: http://www.rwpr.umt.edu

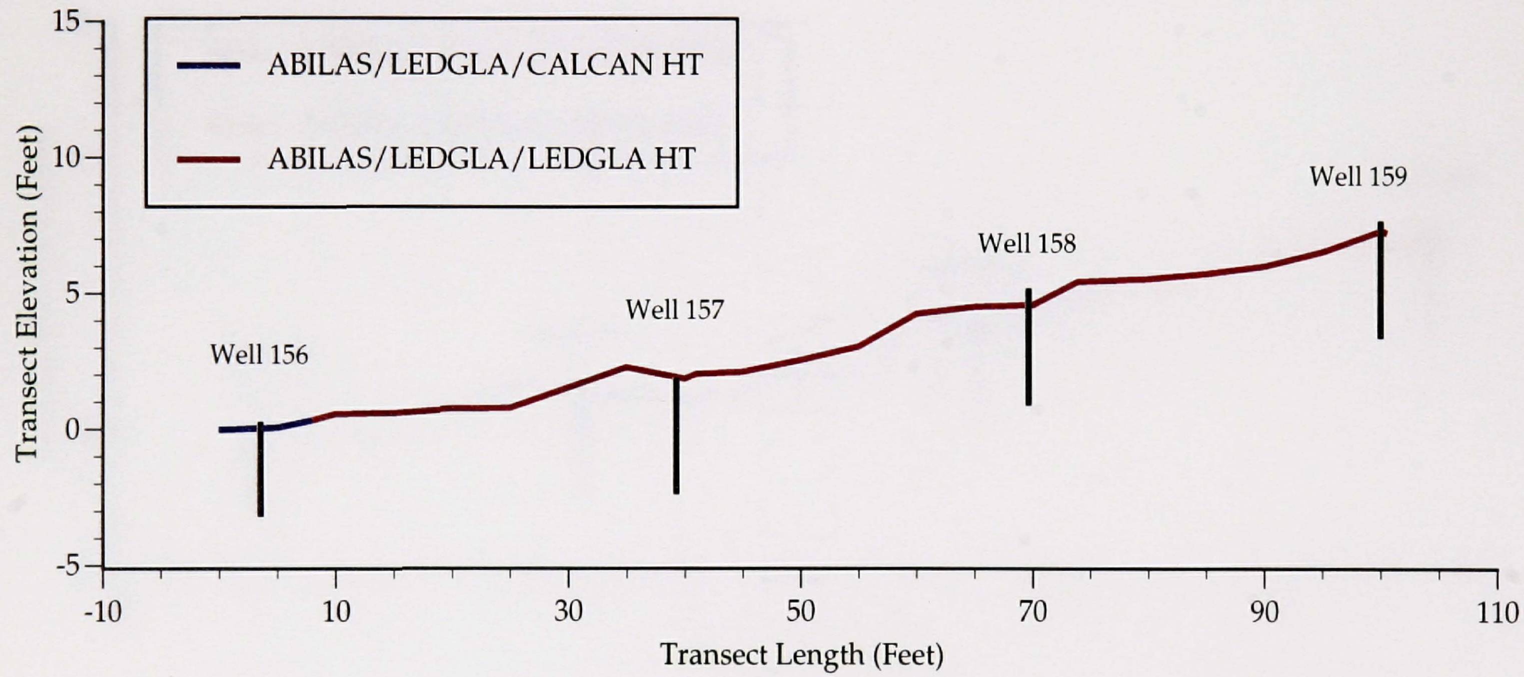

Figure B-1. Site 1, Transect 1: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

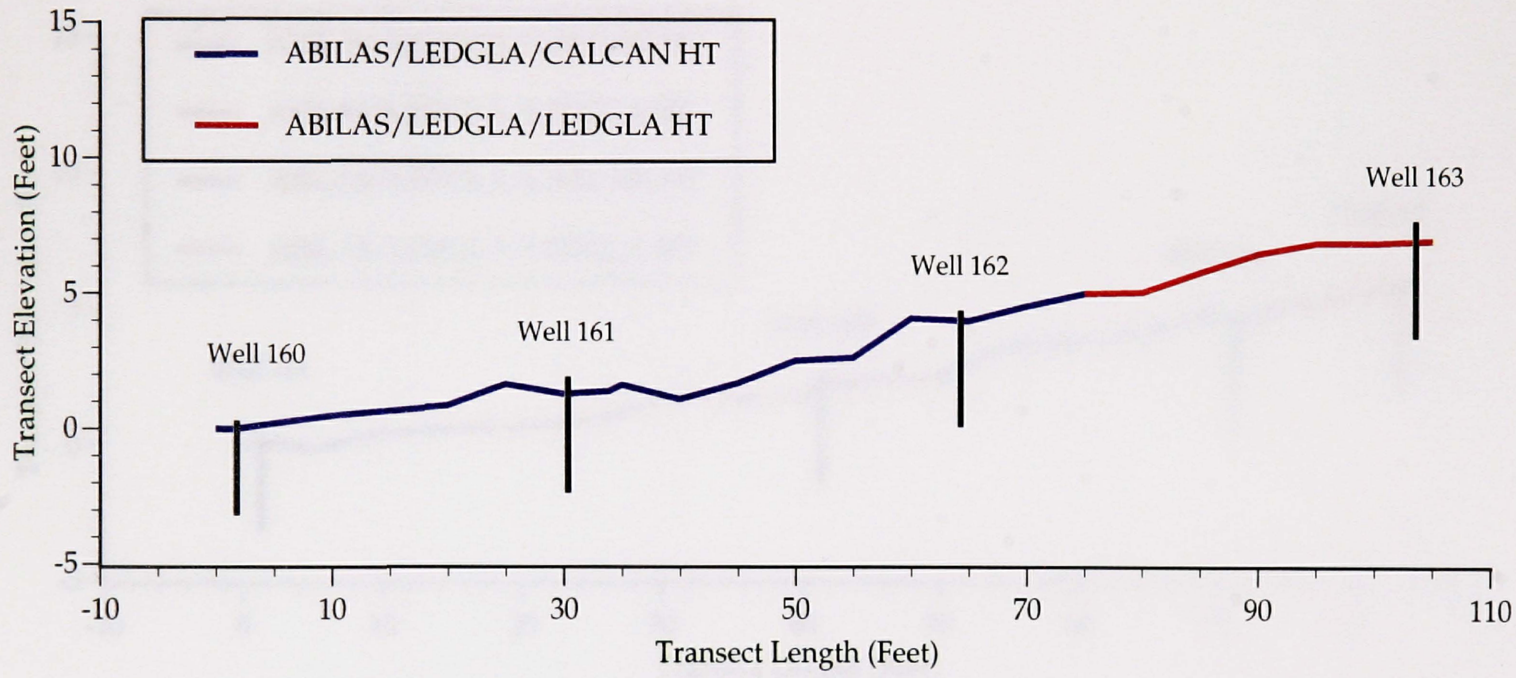

Figure B-2. Site 1, Transect 2: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

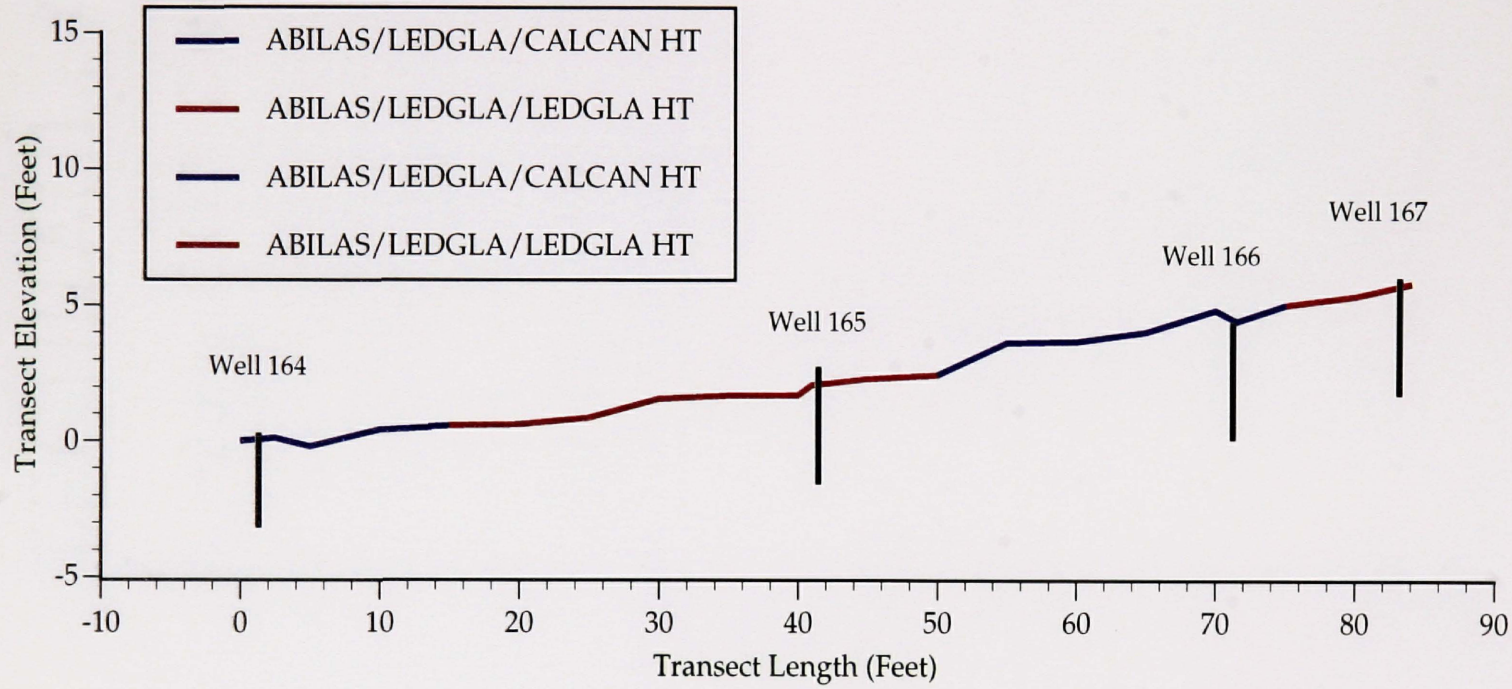

Figure B-3. Site 1, Transect 3: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

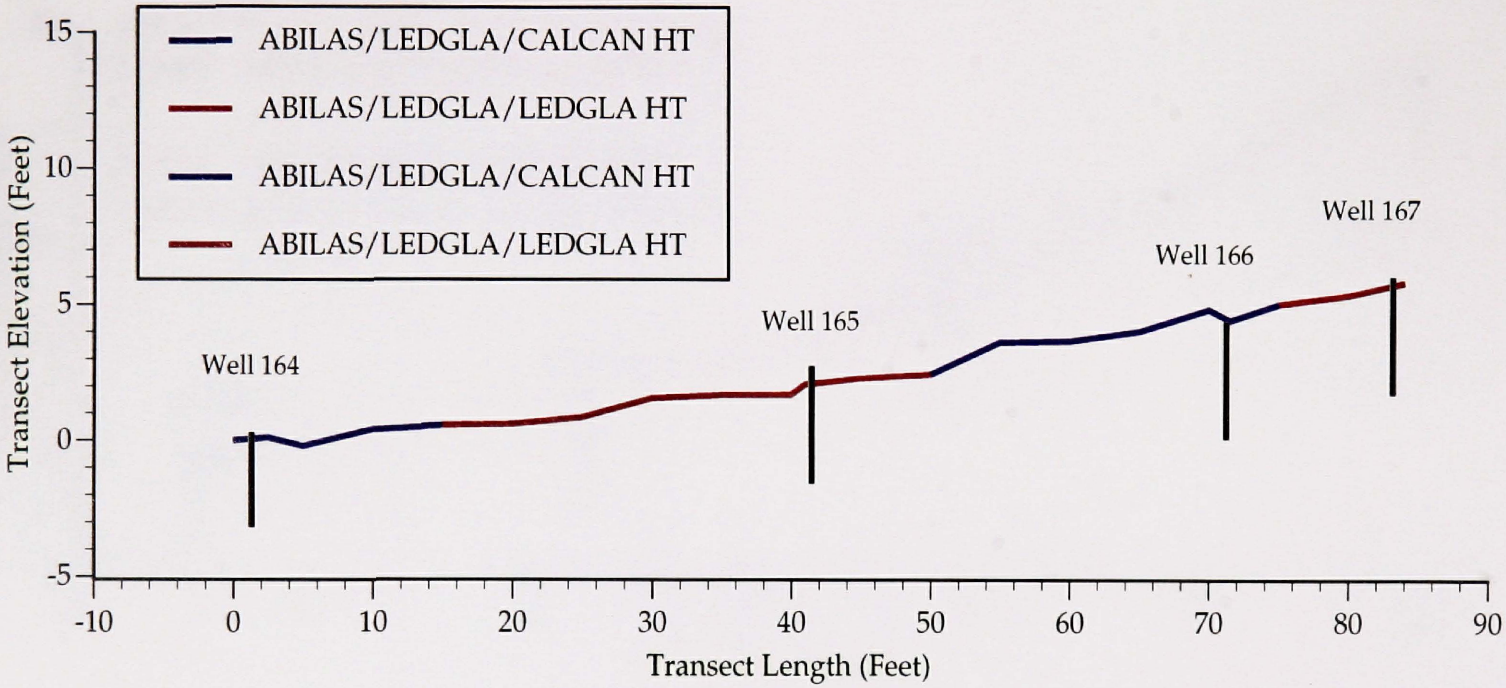

Figure B-3. Site 1, Transect 3: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

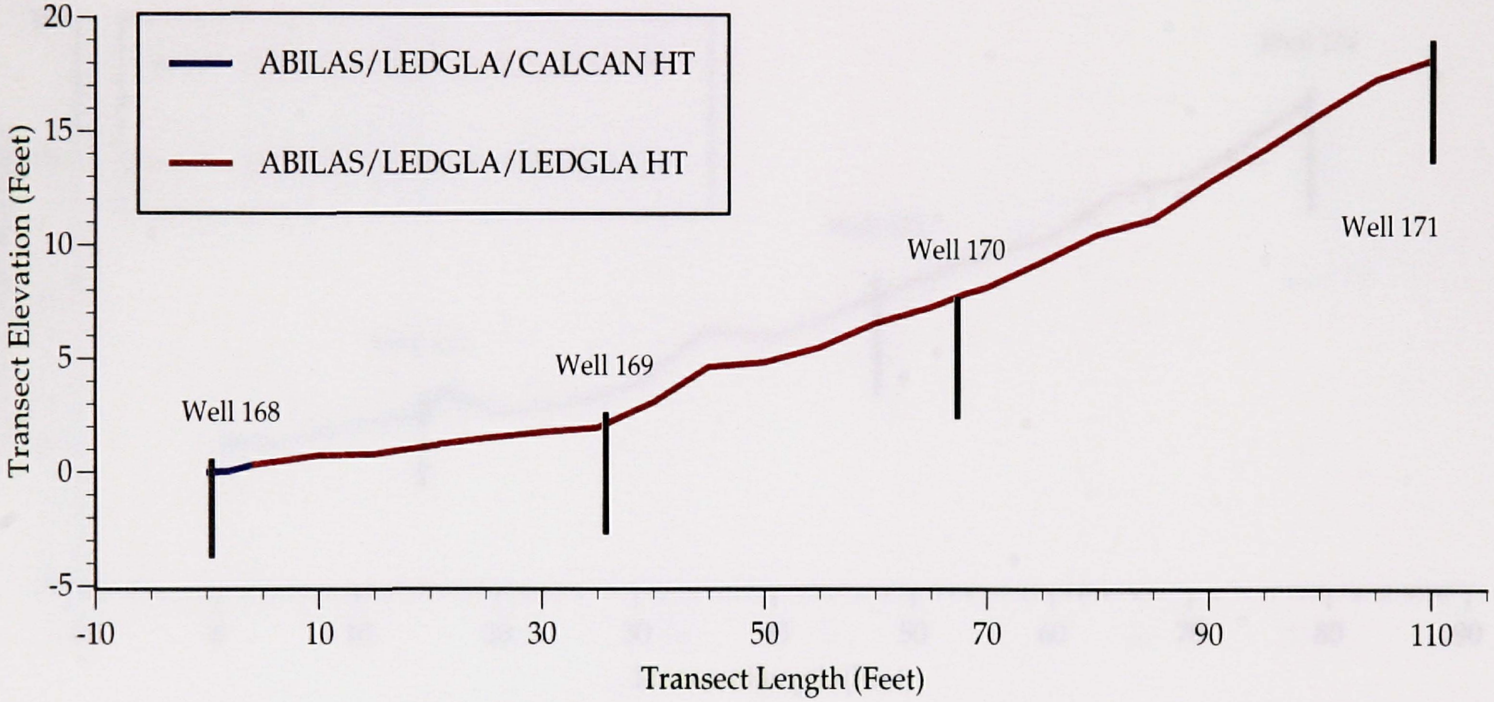

Figure B-4. Site 2, Transect 4: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

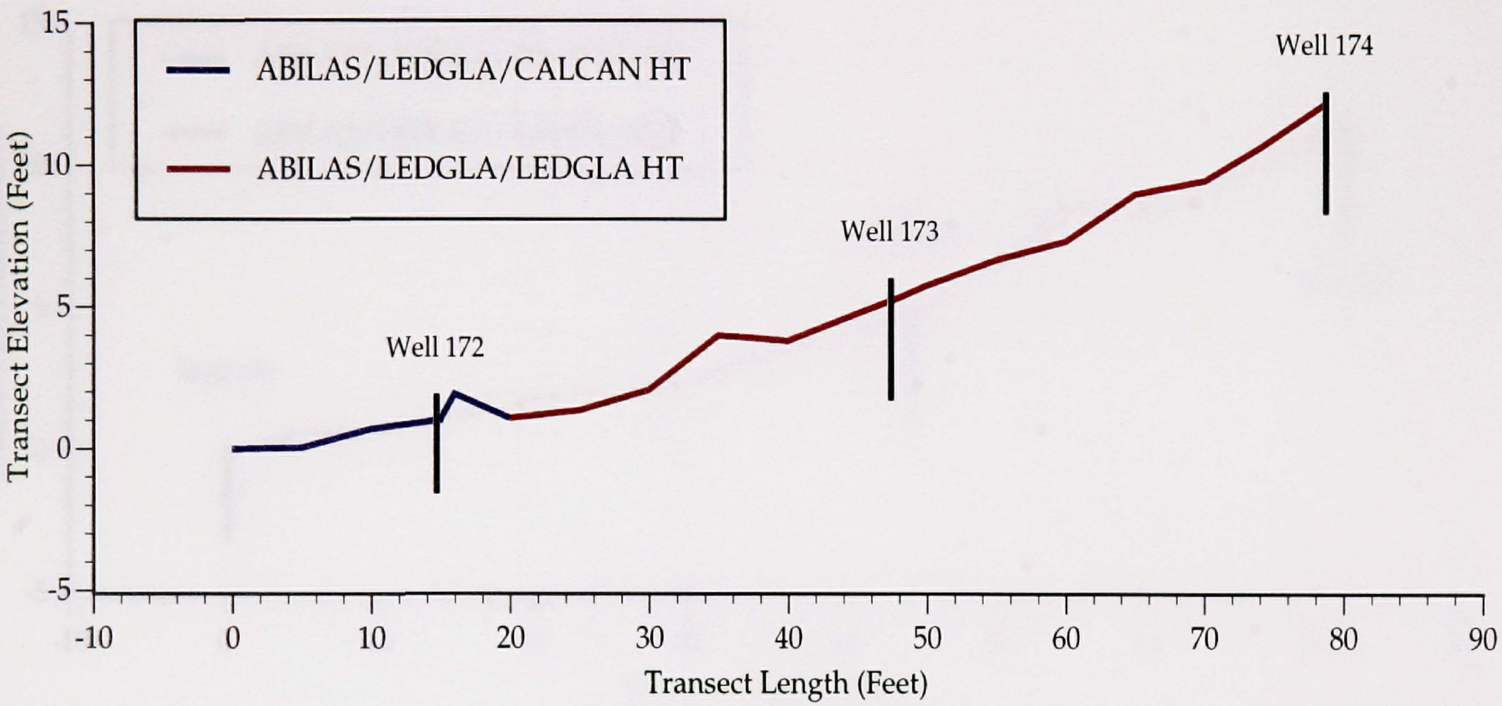

Figure B-5. Site 2, Transect 5: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

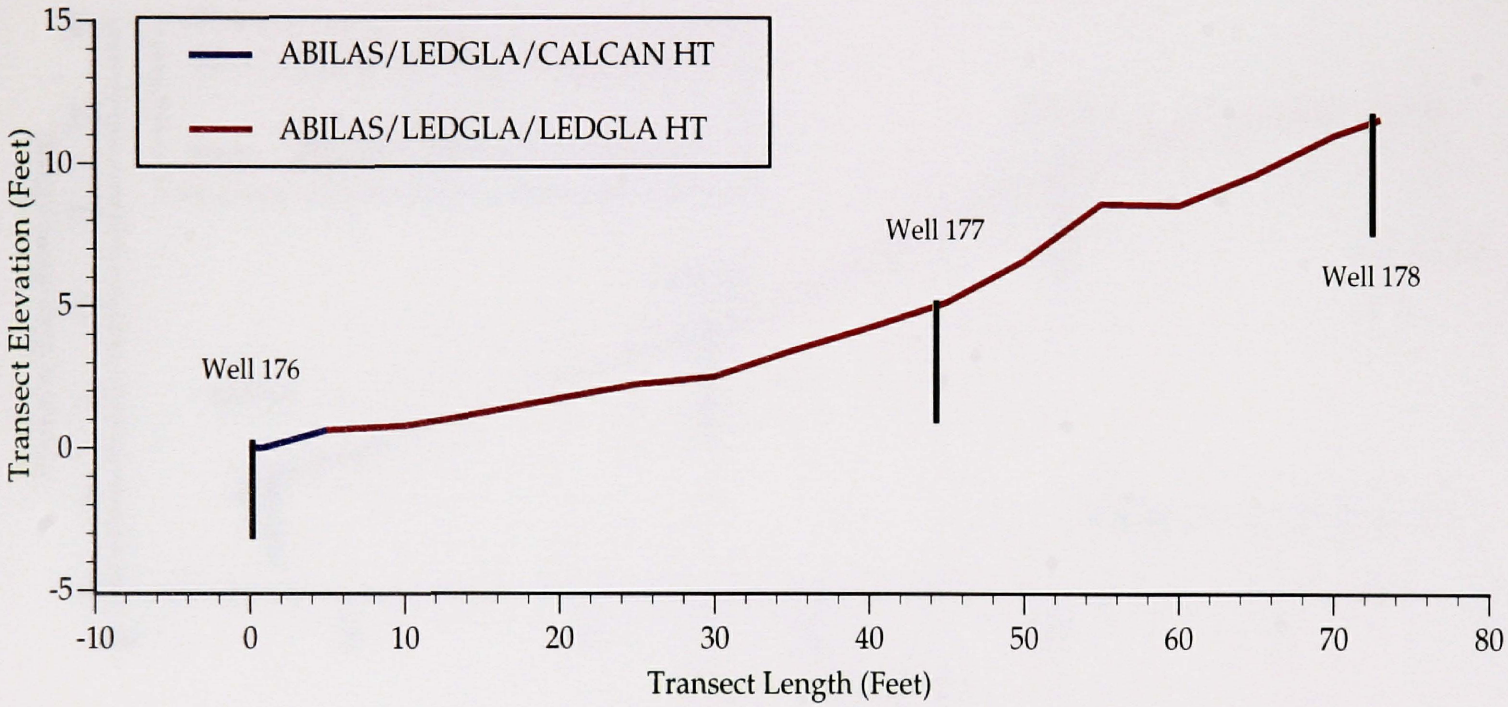

Figure B-6. Site 2, Transect 6: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

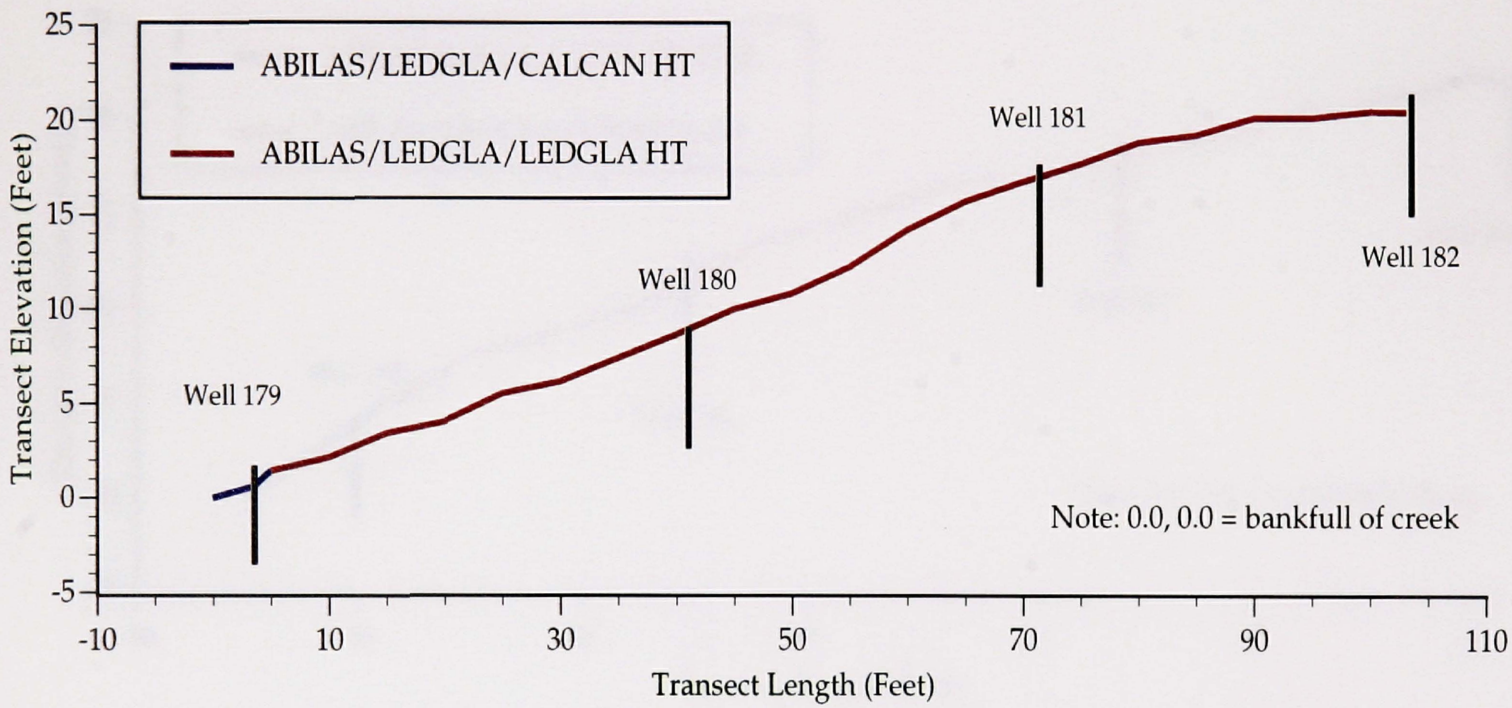

Figure B-7. Site 3, Transect 7: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

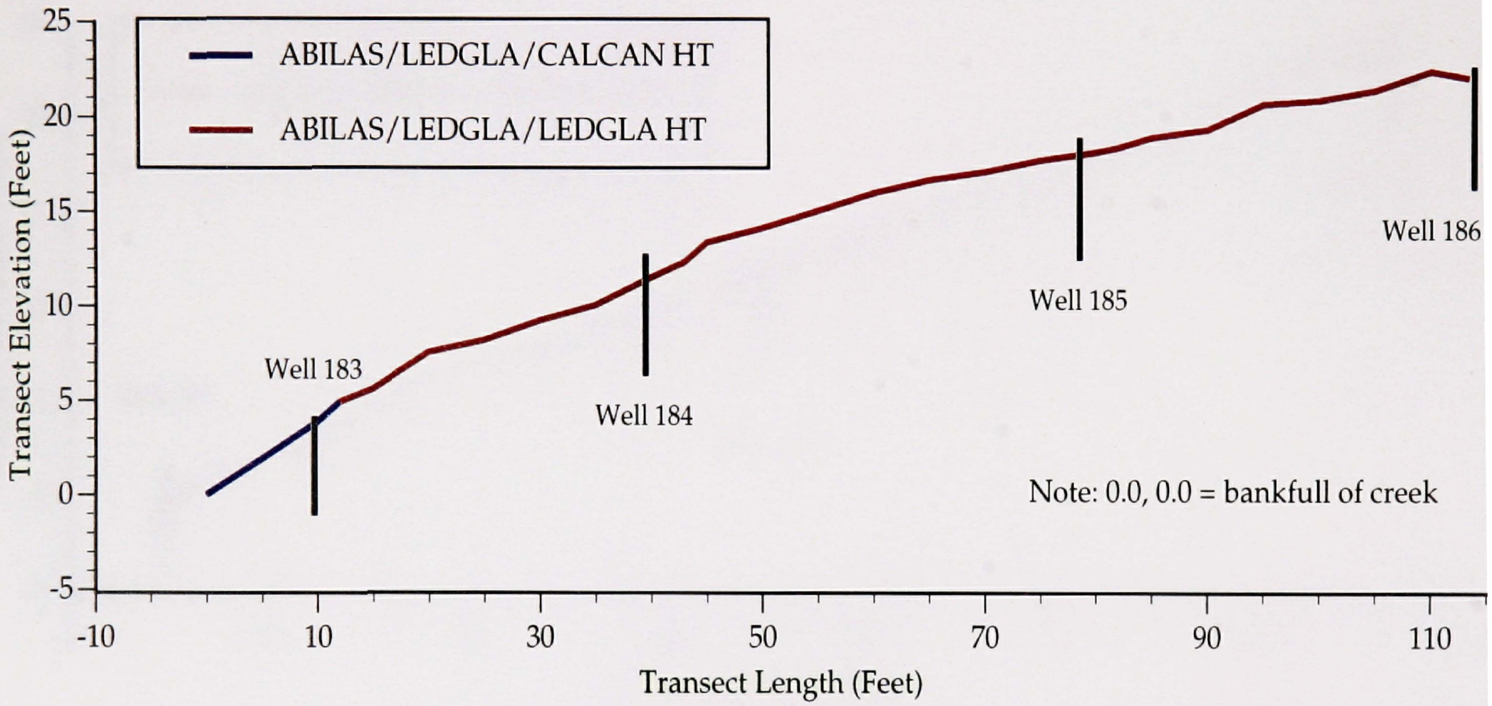

Figure B-8. Site 3, Transect 8: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

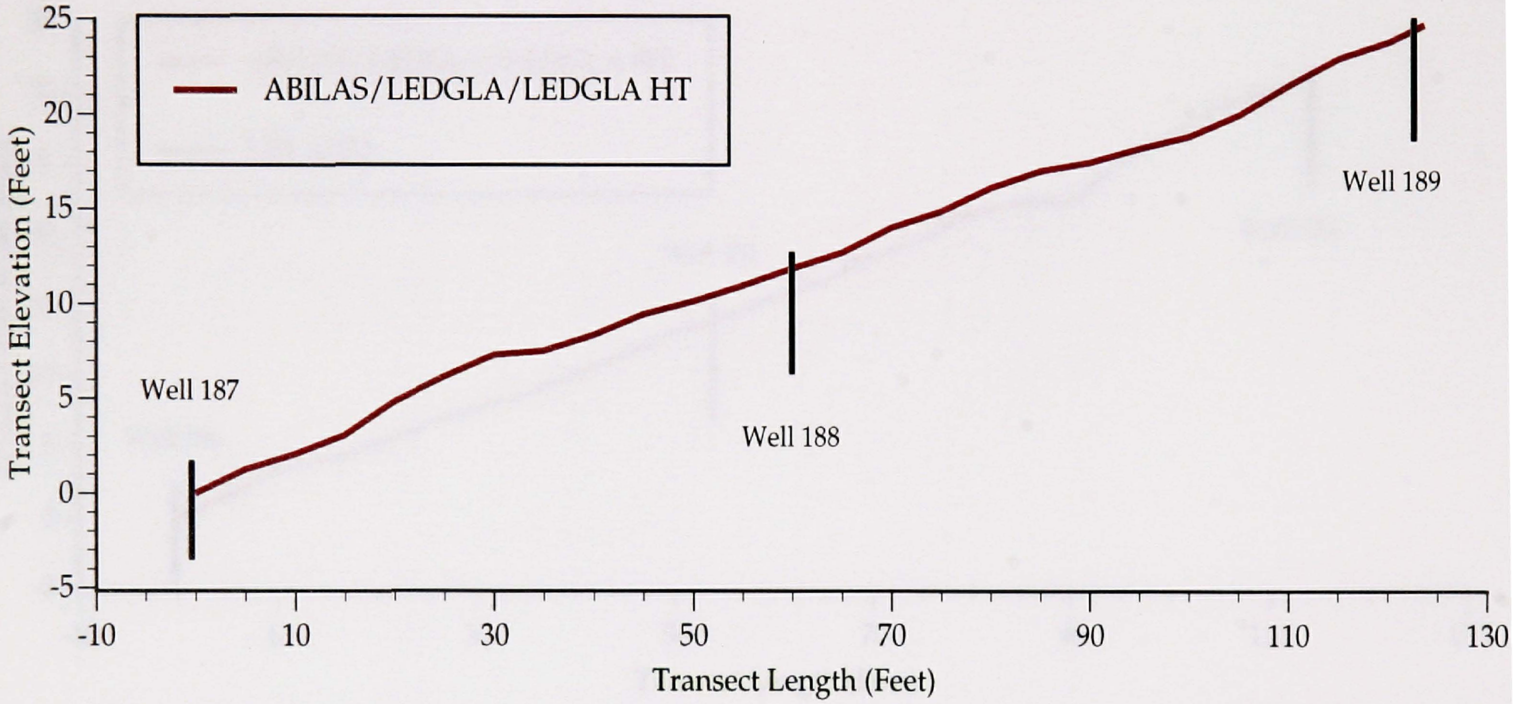

Figure B-9. Site 4, Transect 9: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

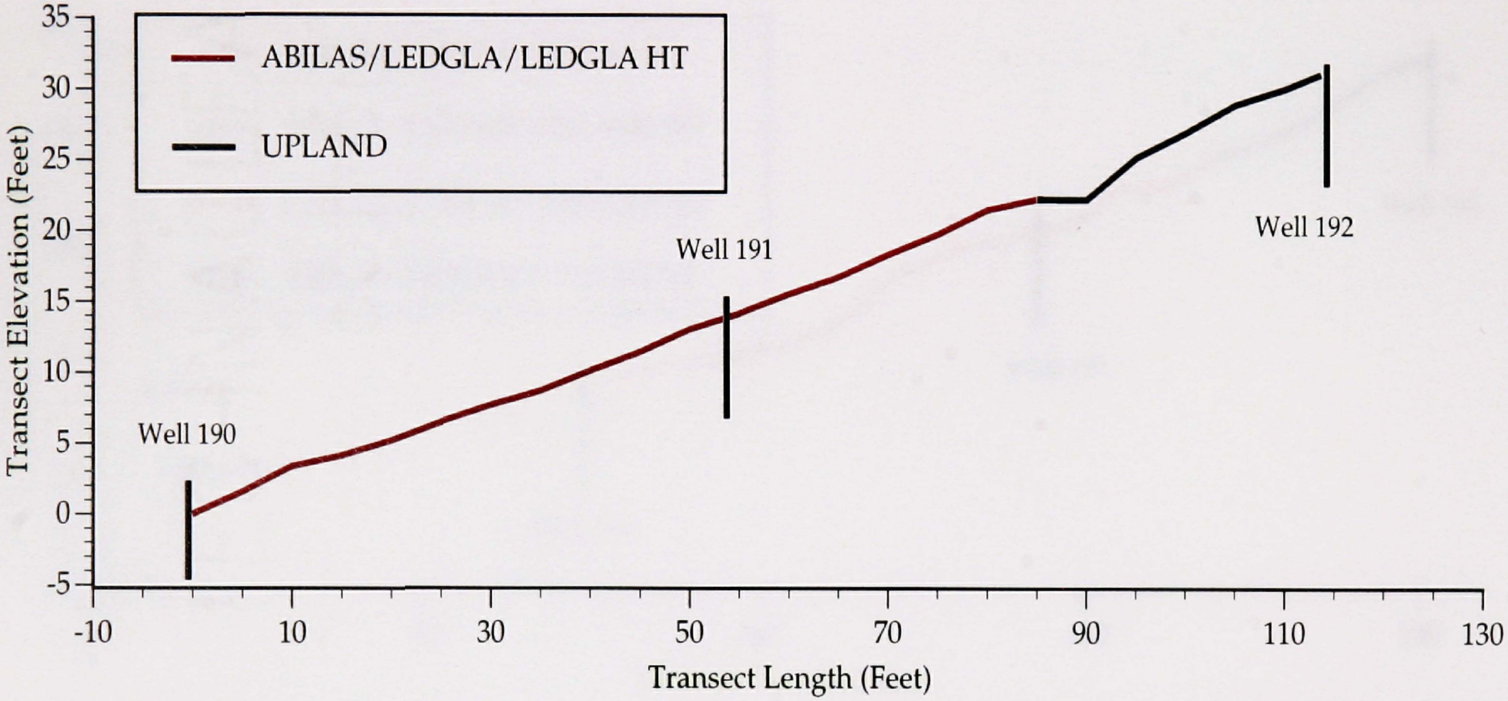

Figure B-10. Site 4, Transect 10: Griffen Creek, Tally Lake Ranger District, Flathead National Forest, Montana

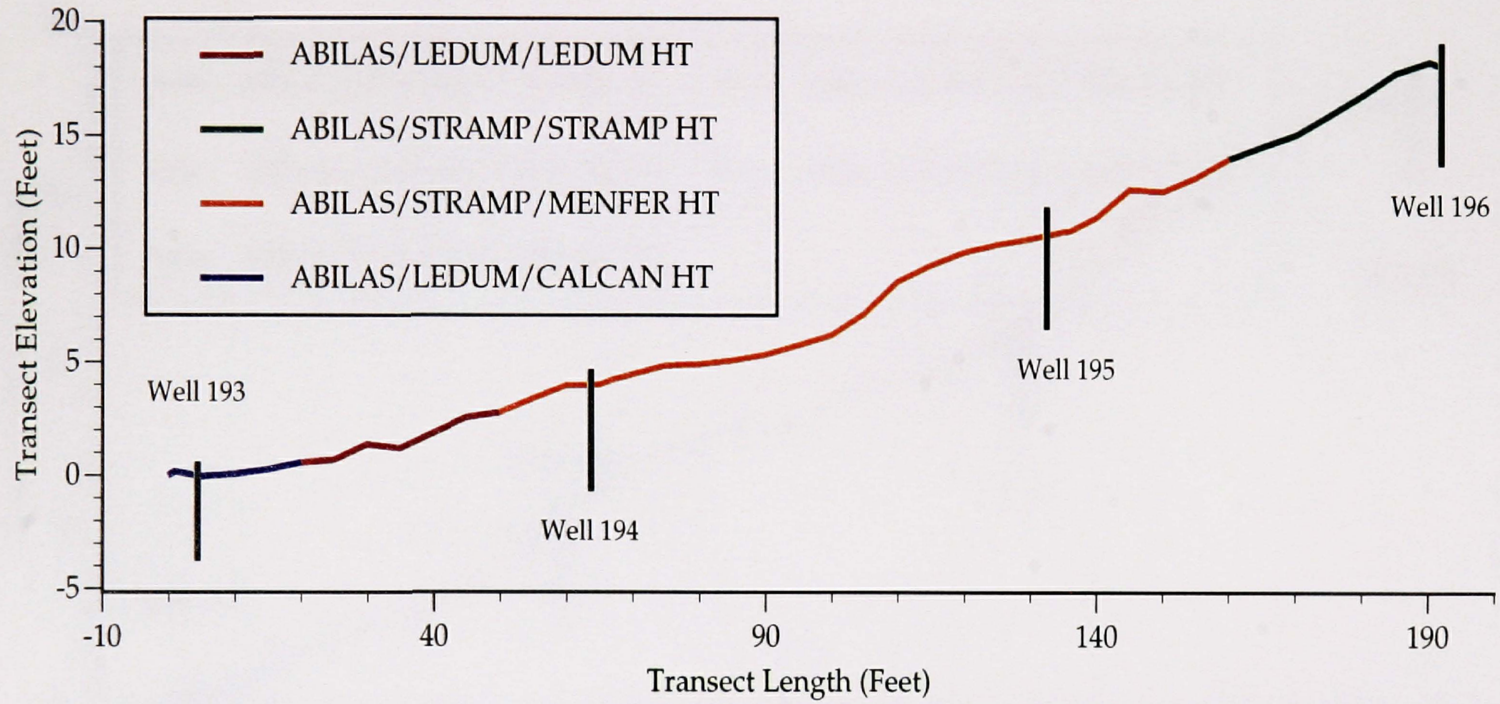

Figure B-11. Site 5, Transect 11: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

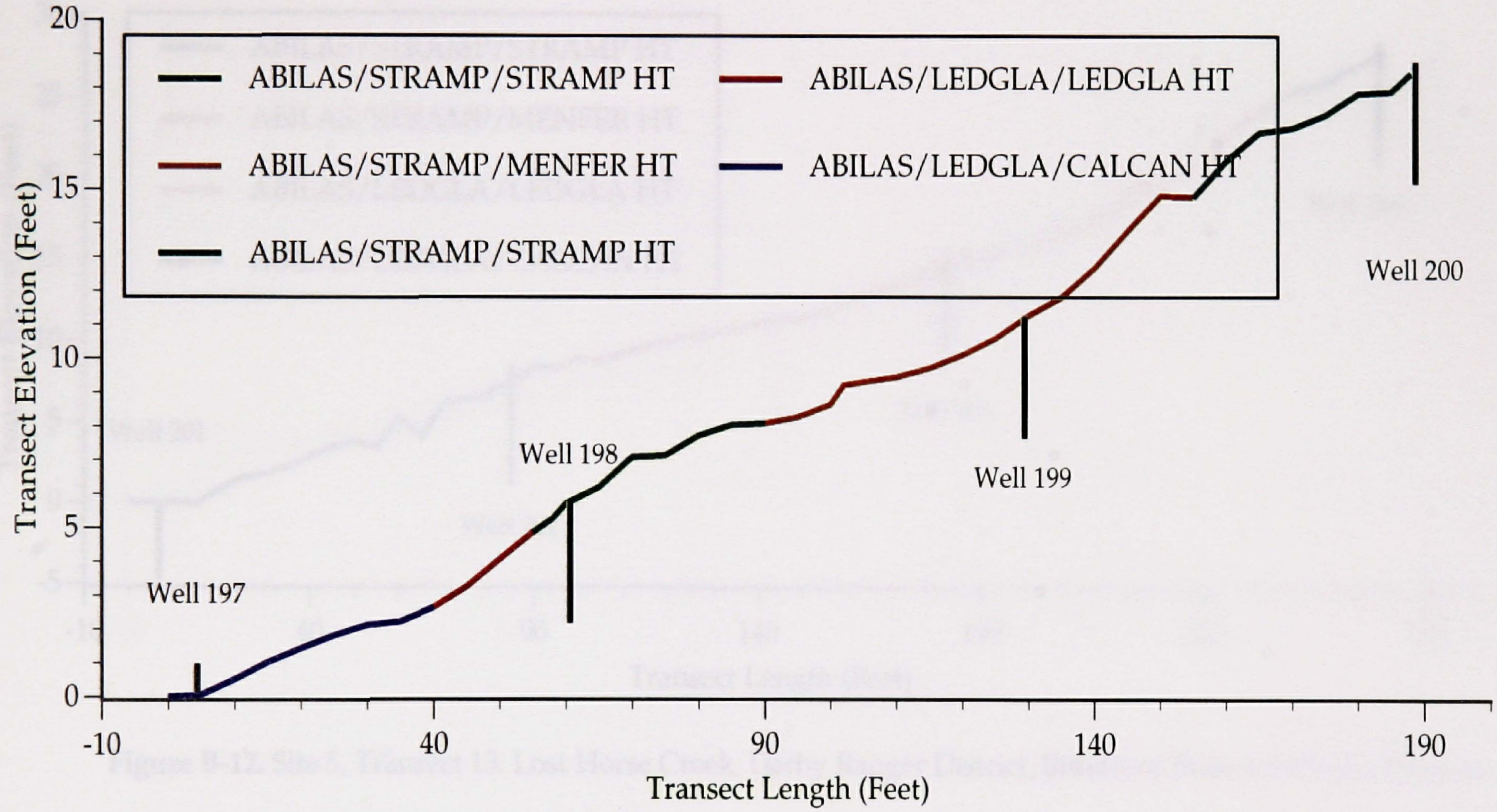

Figure B-12. Site 5, Transect 12: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

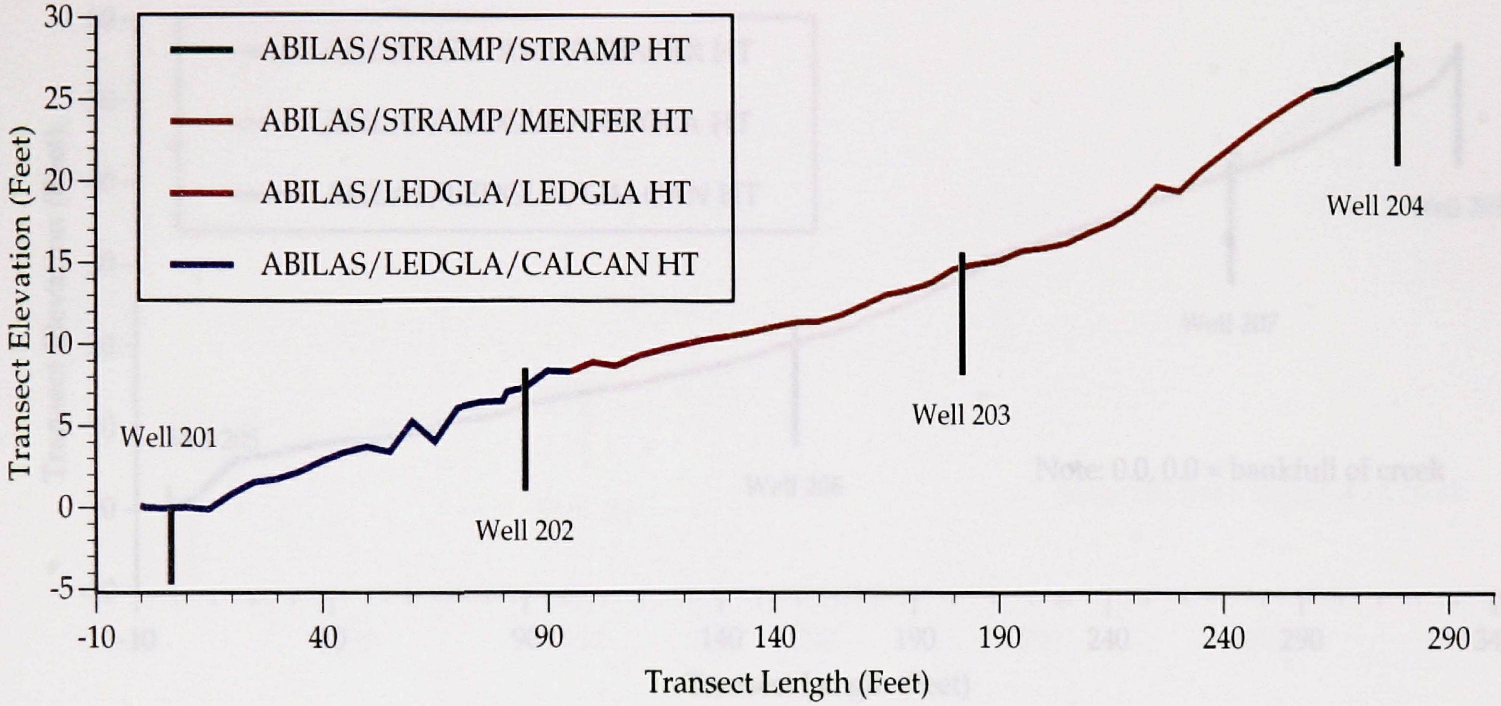

Figure B-12. Site 5, Transect 13: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

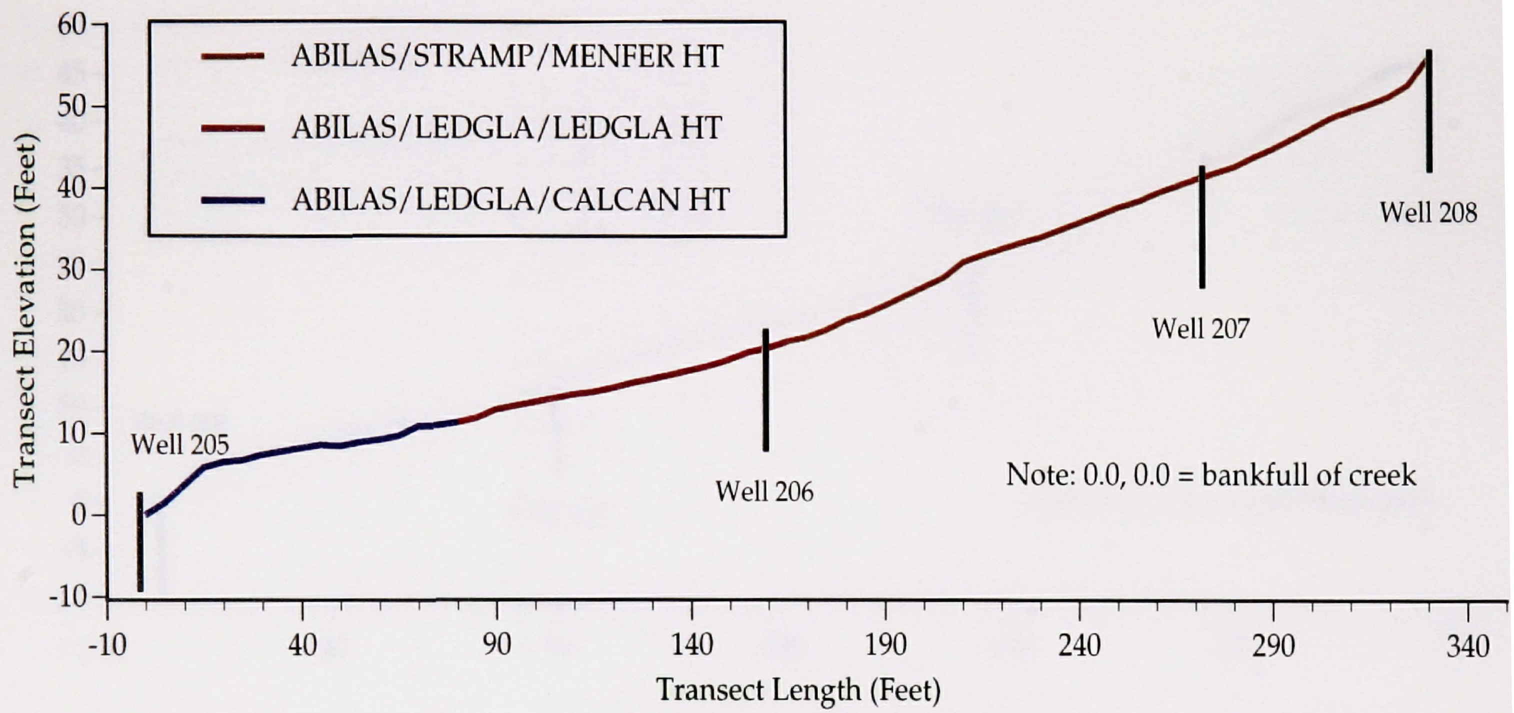

Figure B-14. Site 6, Transect 14: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

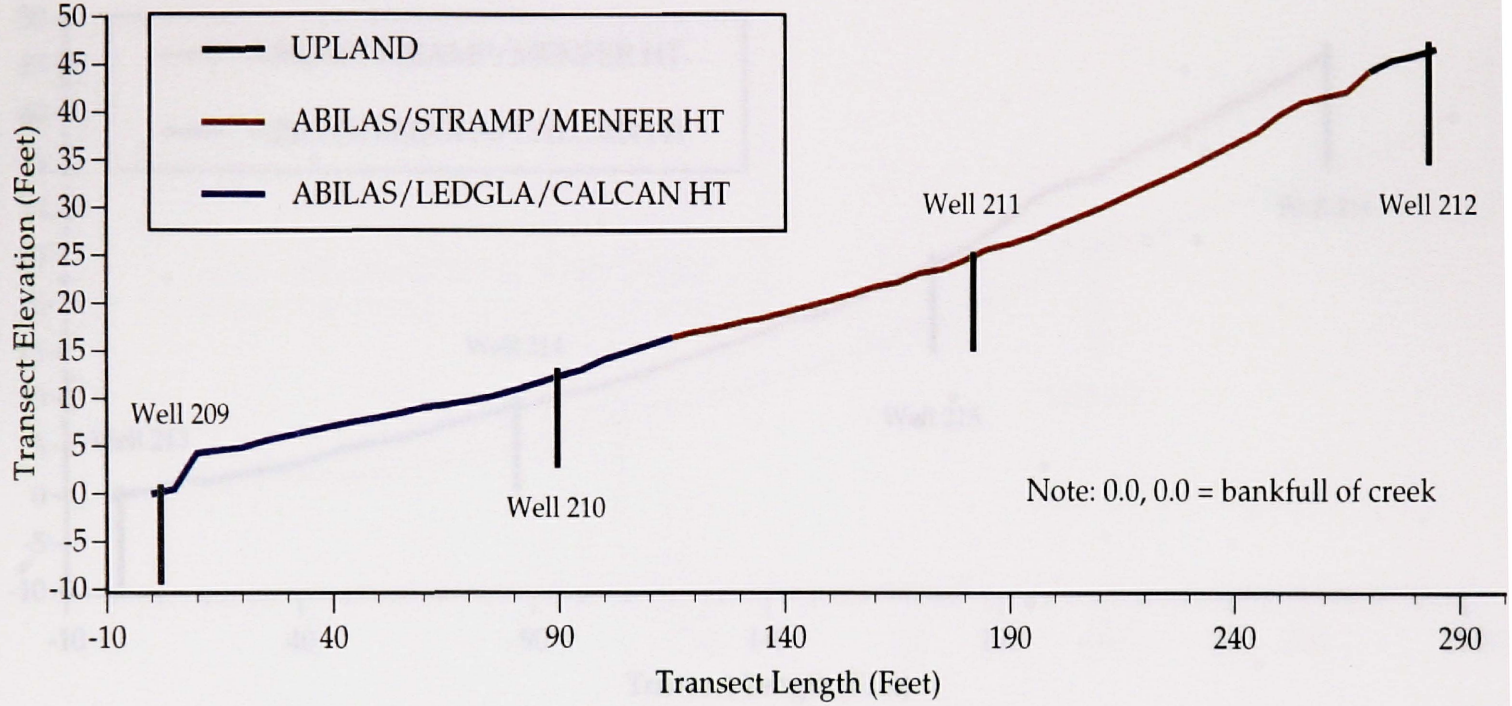

Figure B-15. Site 6, Transect 15: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

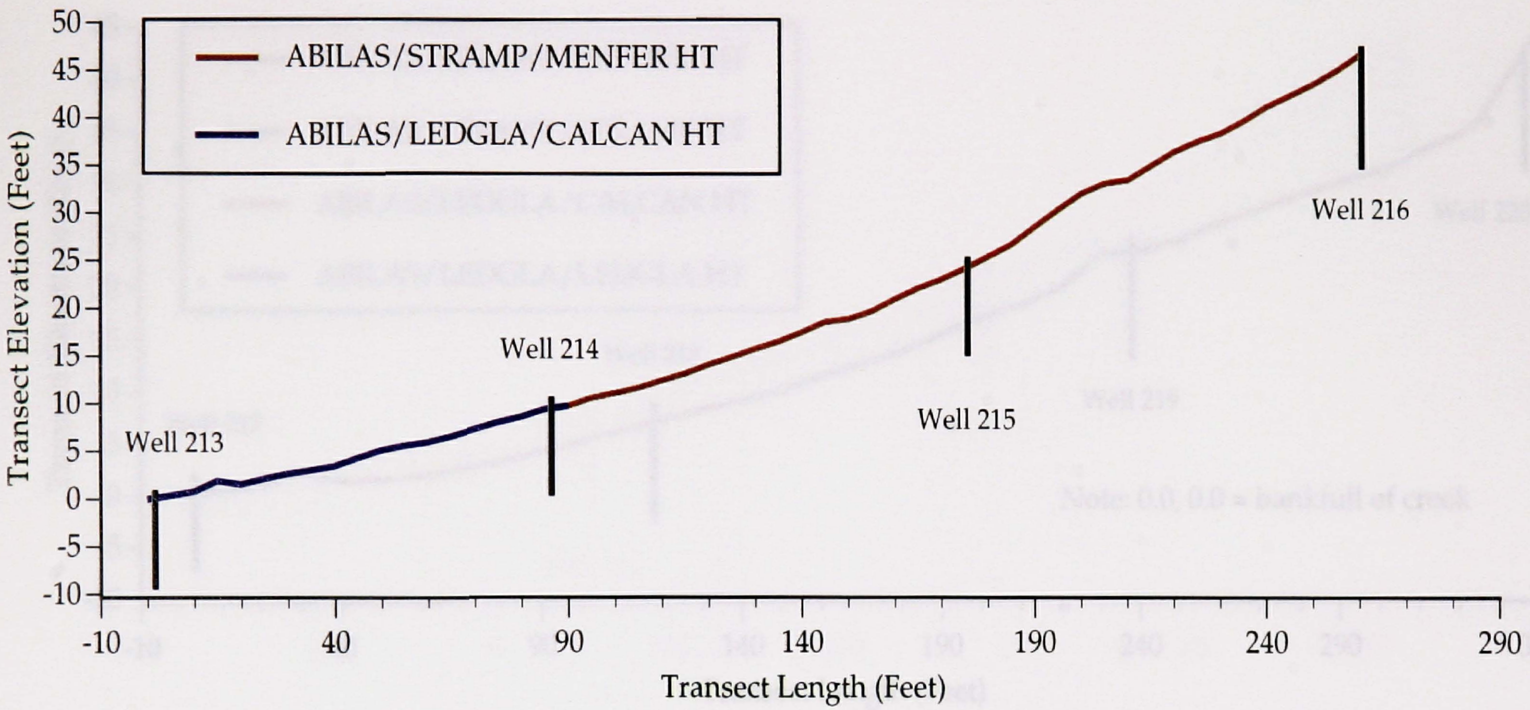

Figure B-16. Site 6, Transect 16: Lost Horse Creek, Darby Ranger District, Bitterroot National Foest, Montana

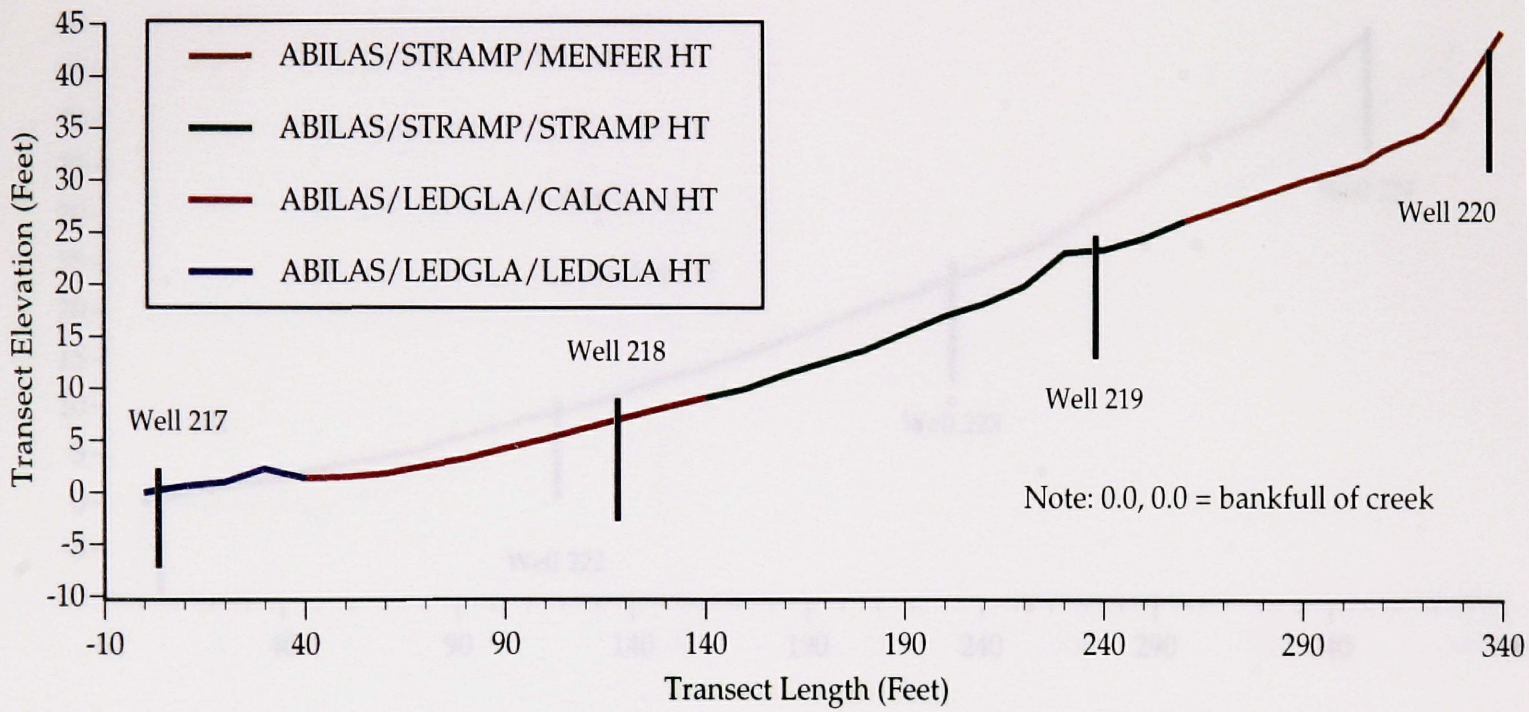

Figure B-17. Site 7, Transect 17: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

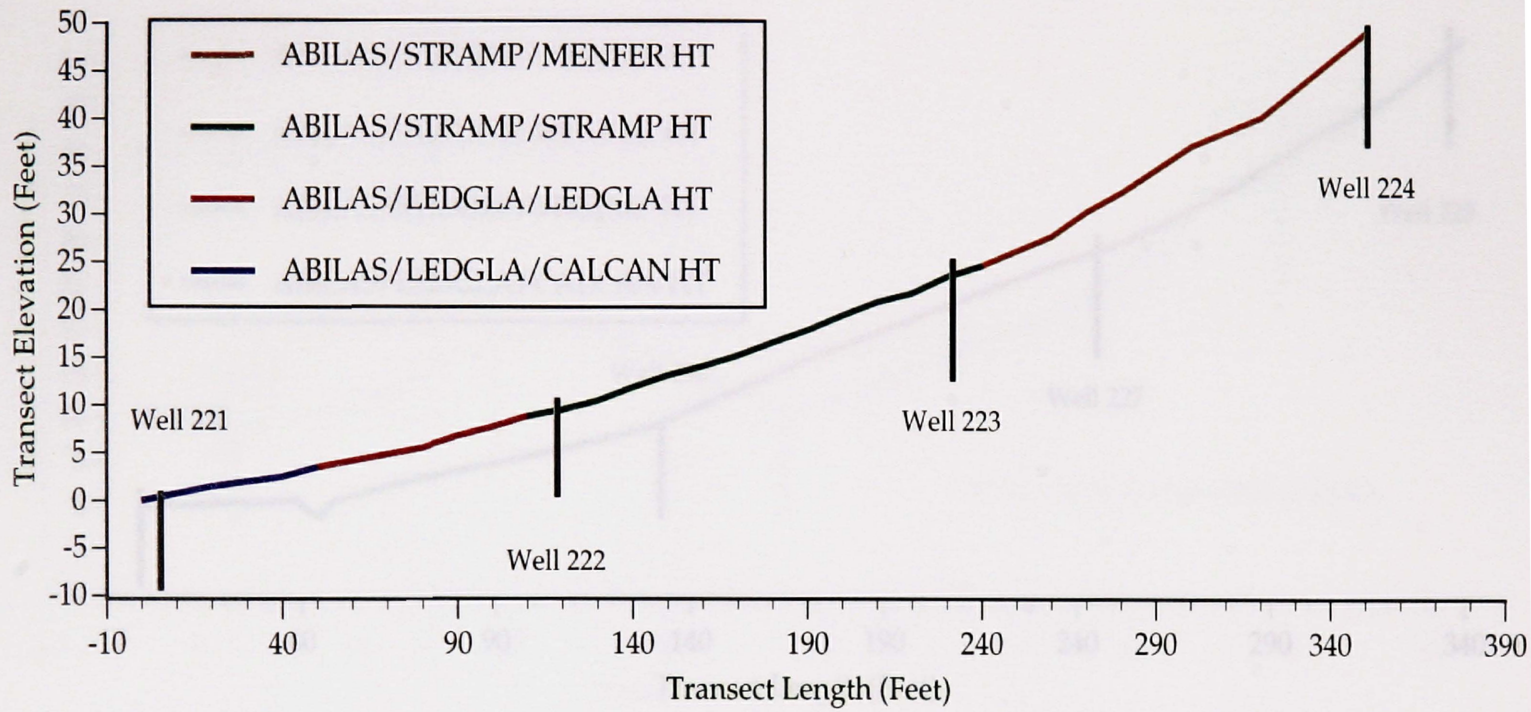

Figure B-18. Site 7, Transect 18: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

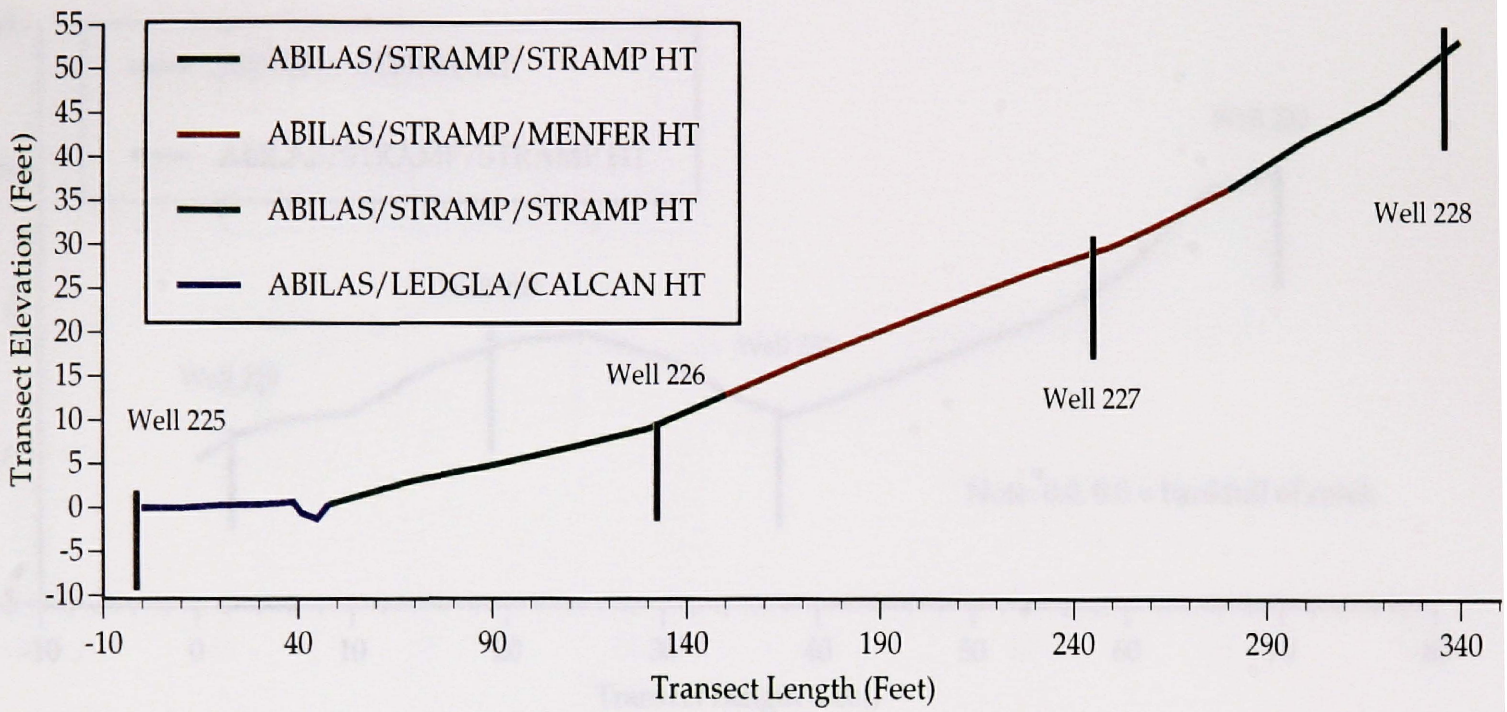

Figure B-19. Site 7, Transect 19: Lost Horse Creek, Darby Ranger District, Bitterroot National Forest, Montana

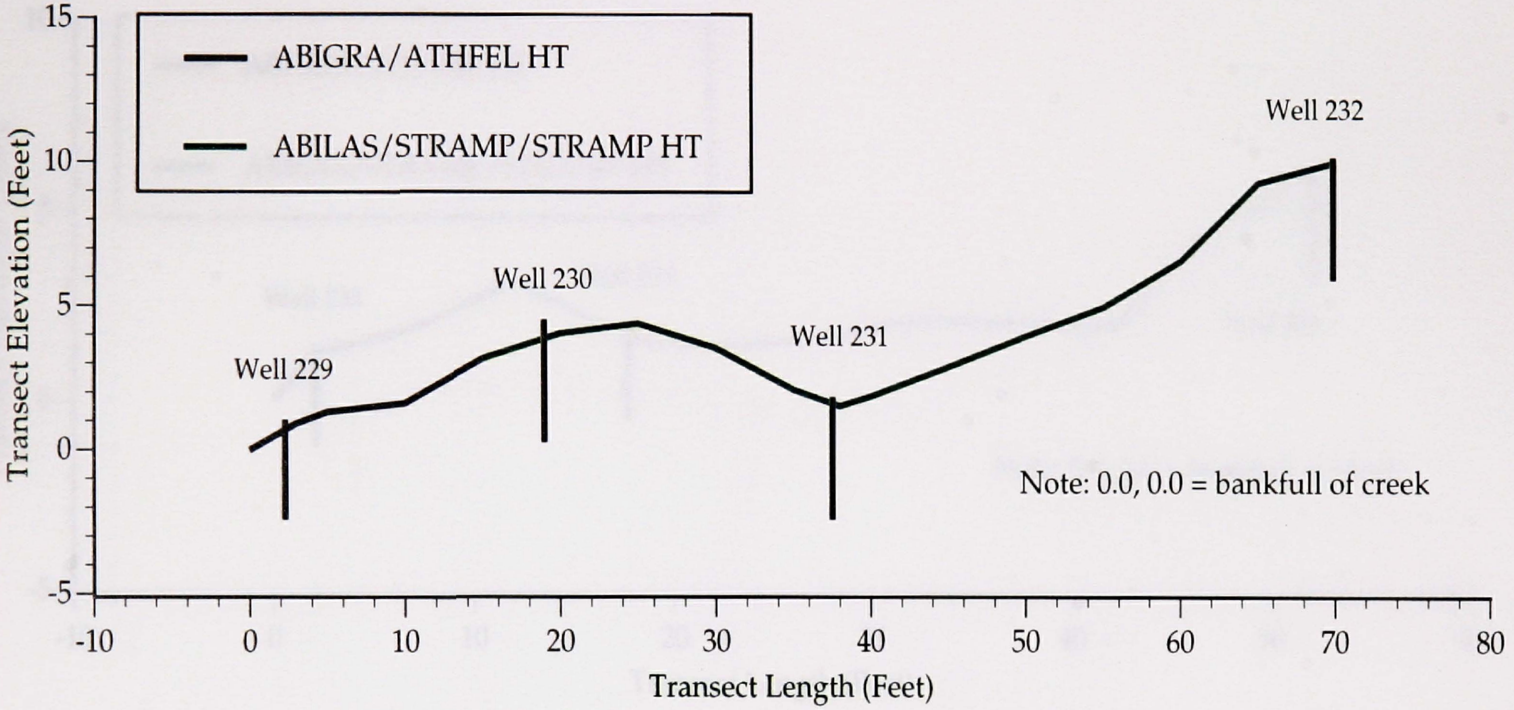

Figure B-20. Site 8, Transect 20: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

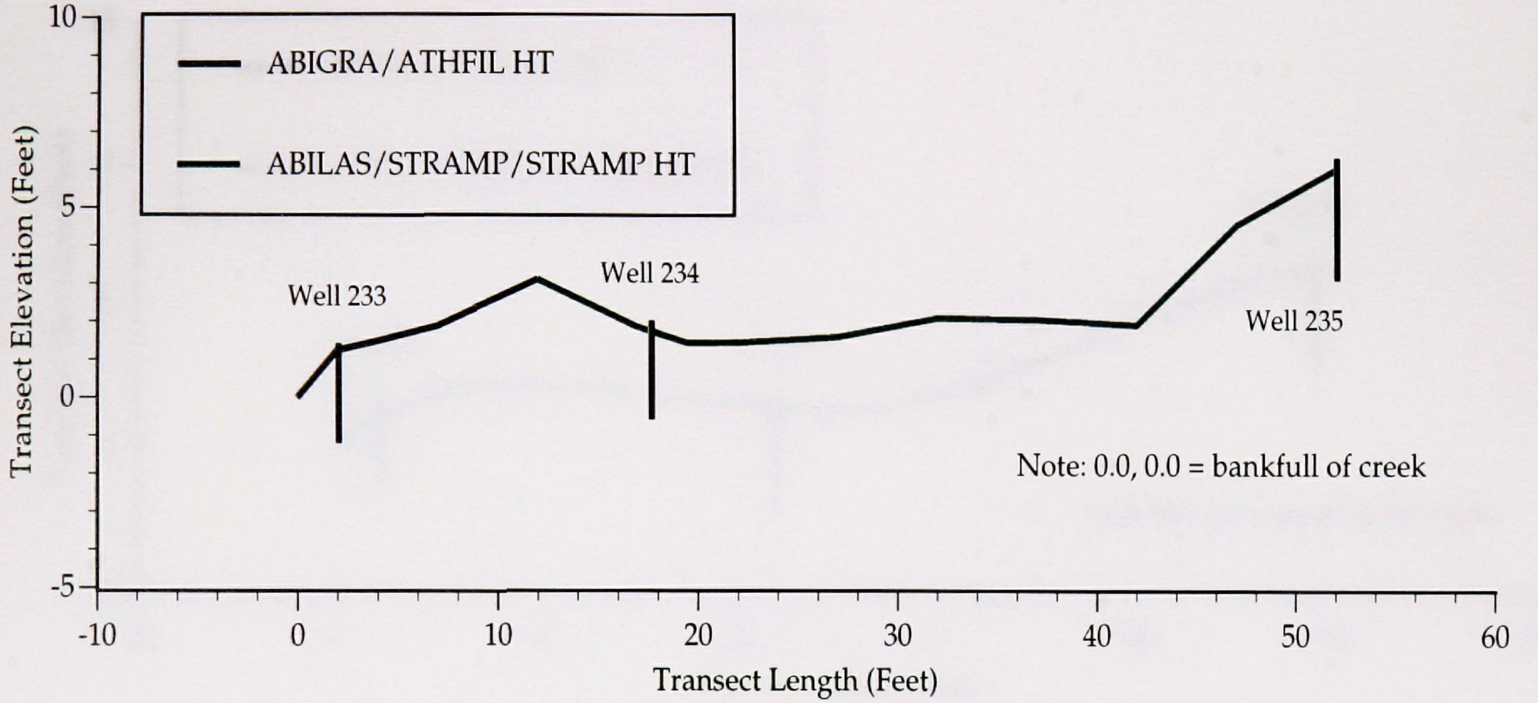

Figure B-21. Site 8, Transect 21: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

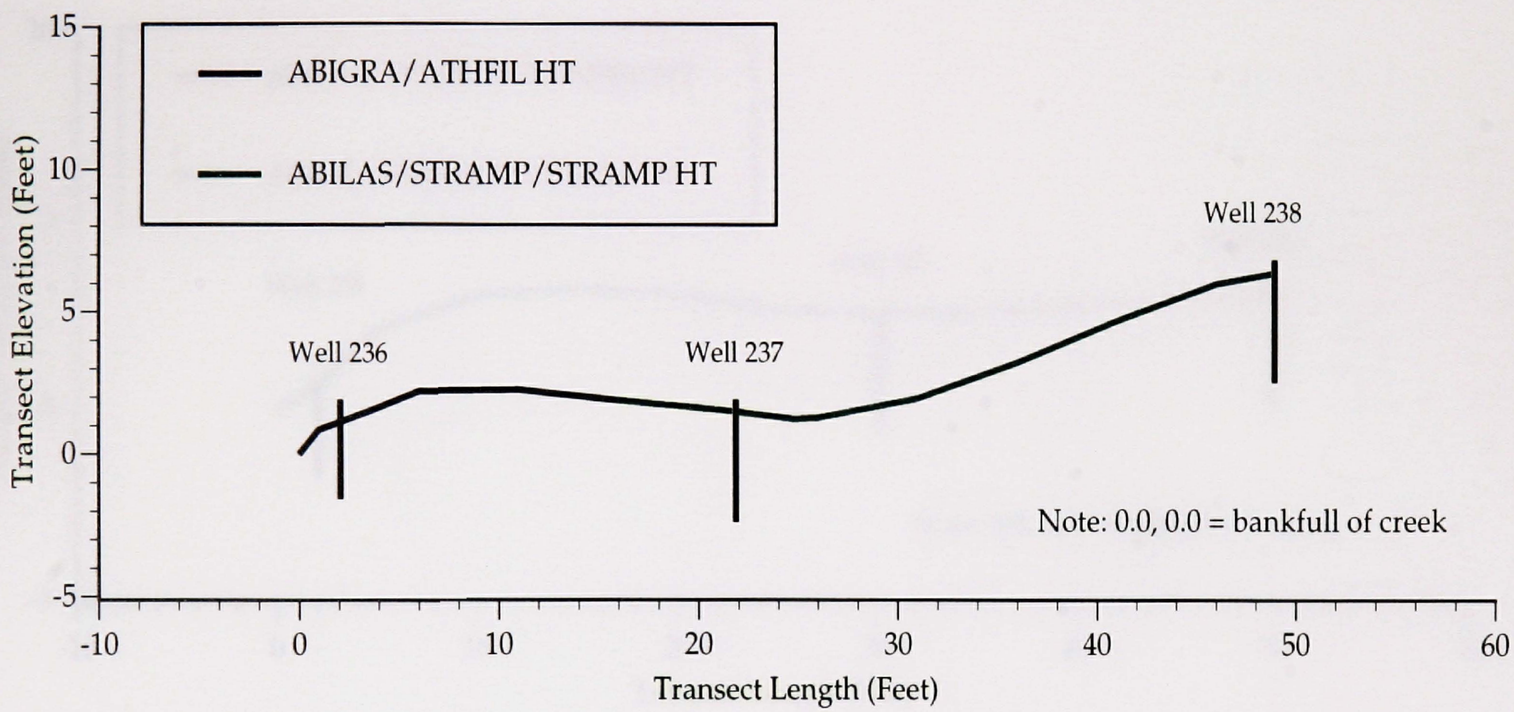

Figure B-22. Site 8, Transect 22: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

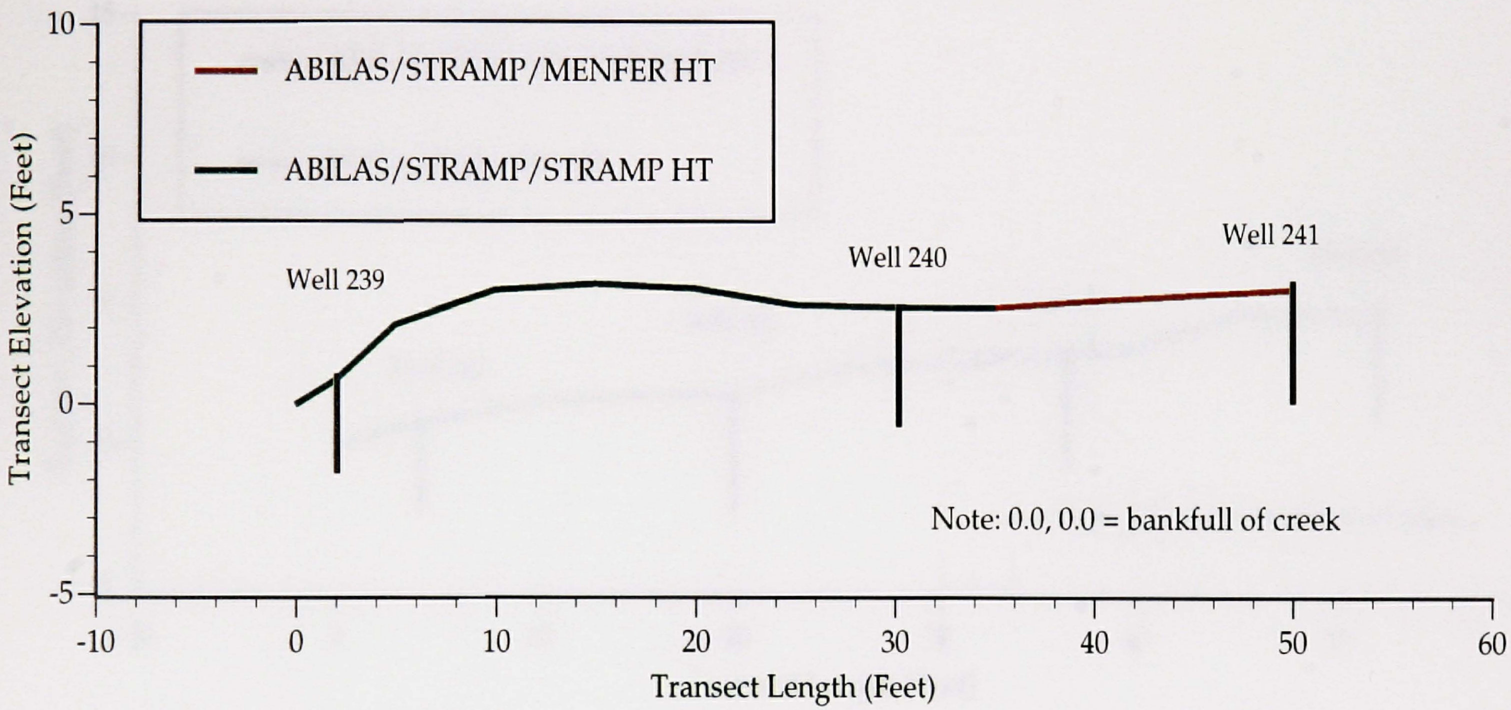

Figure B-23. Site 9, Transect 23: Porquipine Creek, Swan Lake Ranger District, Flathead National Forest, Montana

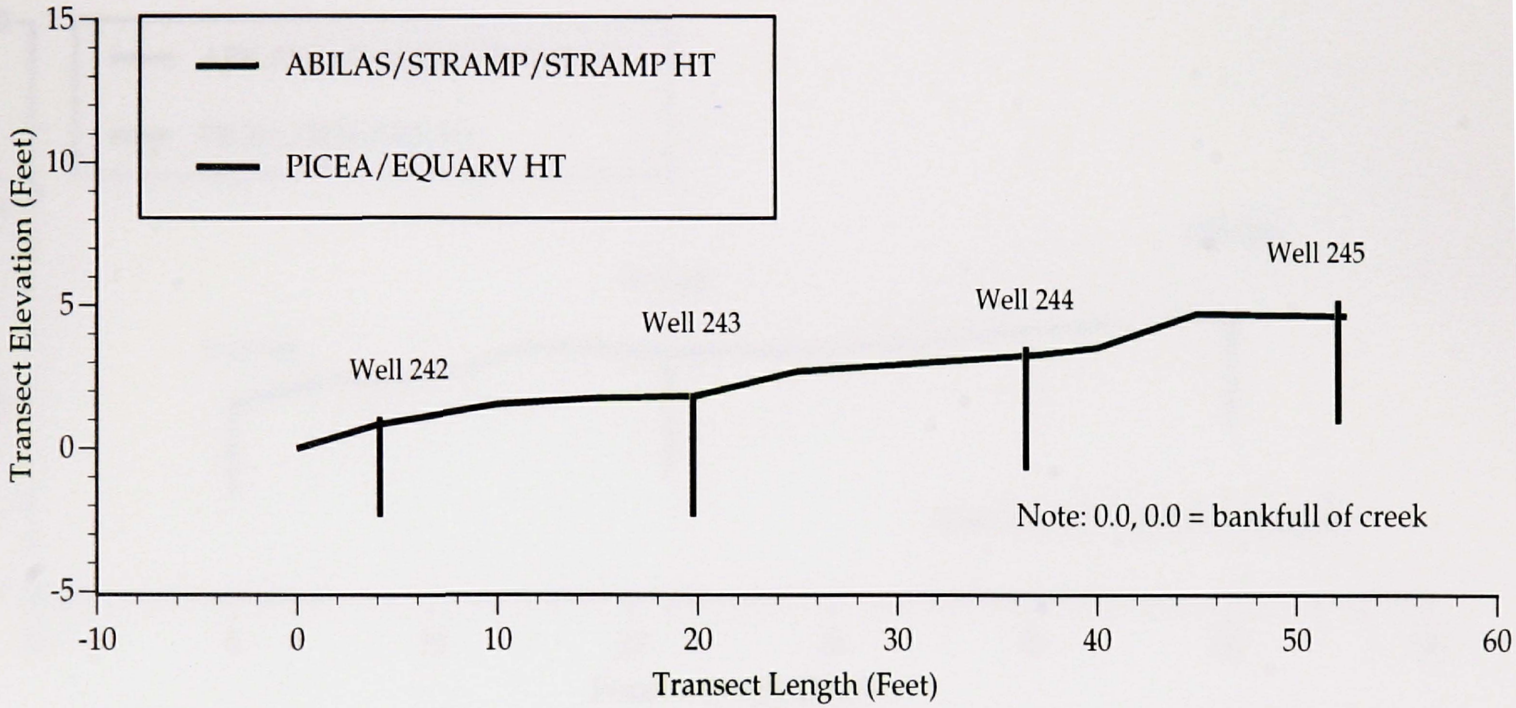

Figure B-24. Site 9, Transect 24: Porquipine Creek, Swan Lake Ranger District, Flathead National Forest, Montana

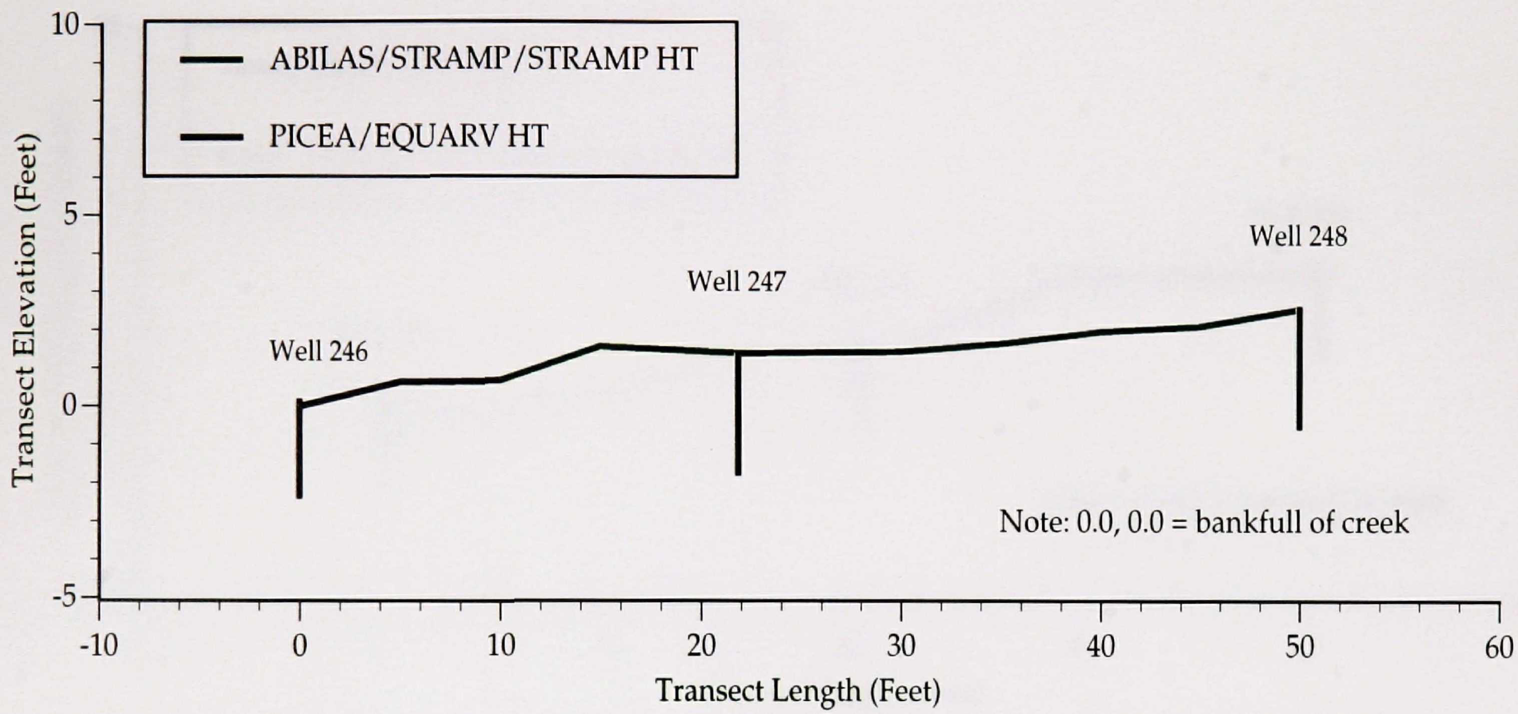

Figure B-25. Site 9, Transect 25: Porquipine Creek, Swan Lake Ranger District, Flathead National Forest, Montana

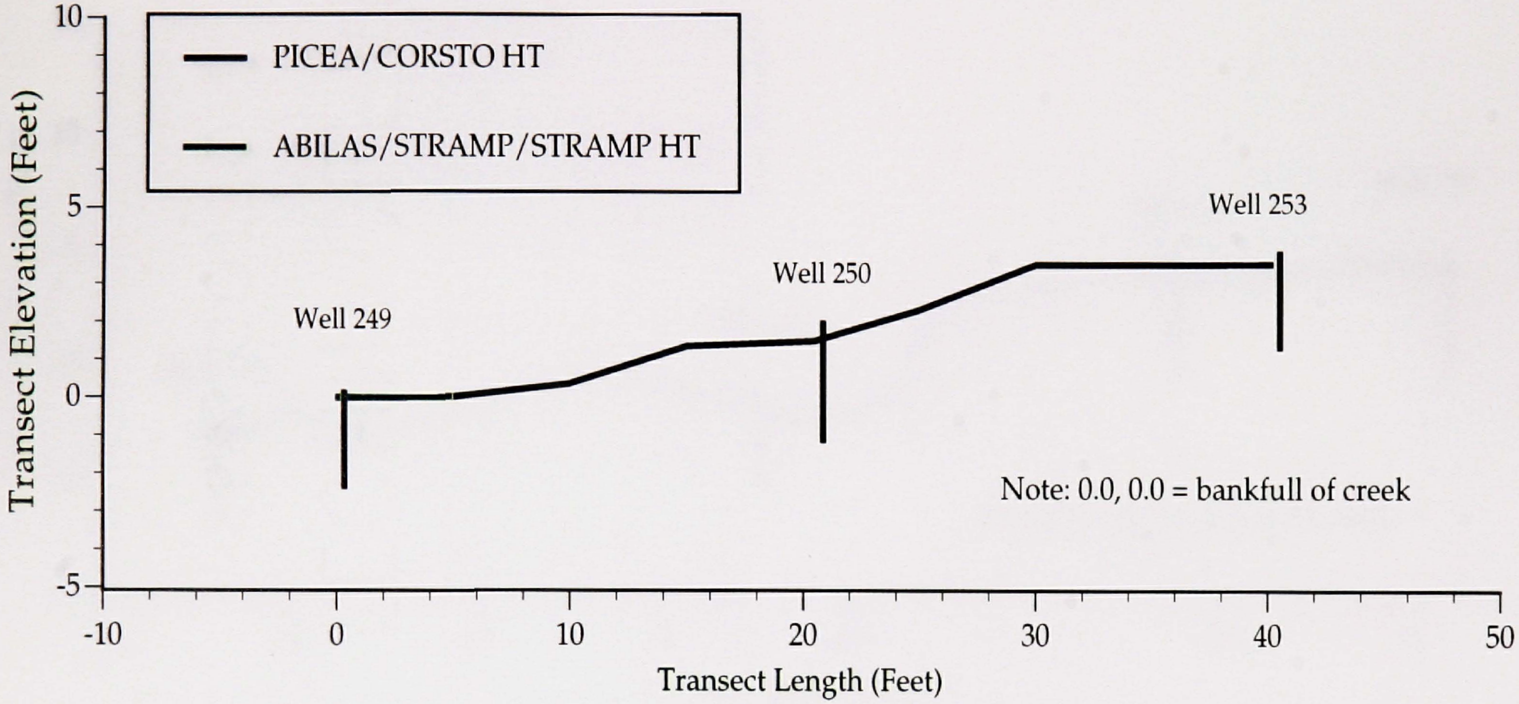

Figure B-27. Site 10, Transect 26: Porquipine Creek, Swan Lake Ranger District, Flathead National Forest, Montana

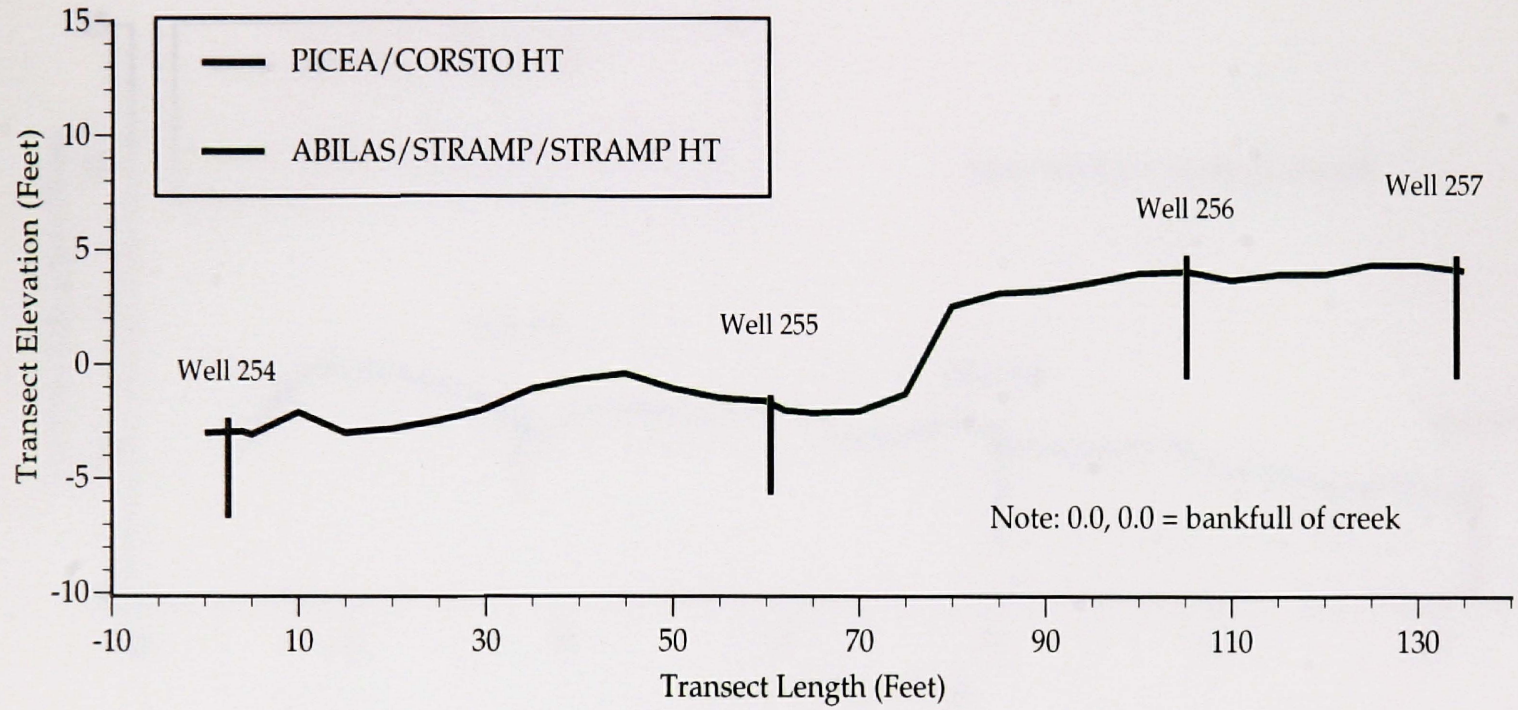

Figure B-28. Site 11, Transect 28: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

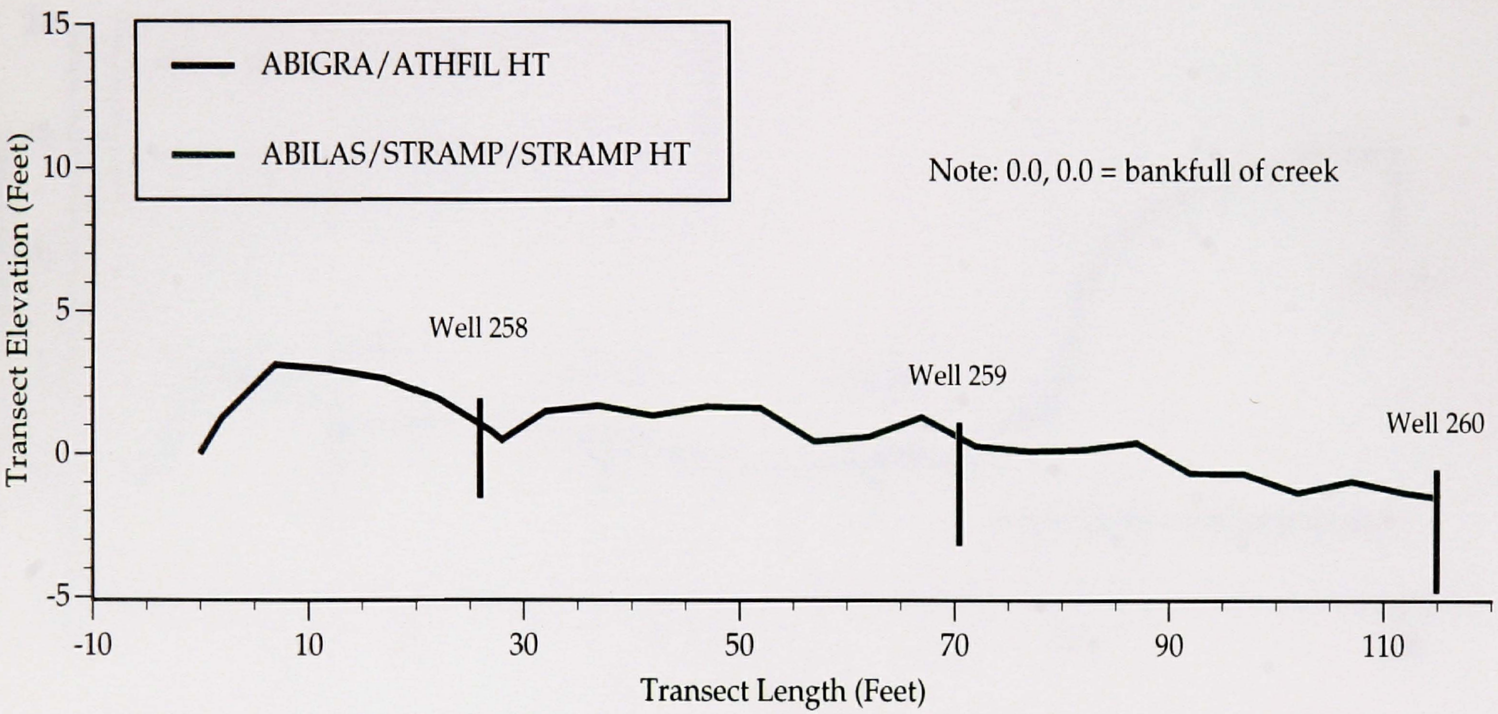

Figure B-29. Site 11, Transect 29: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

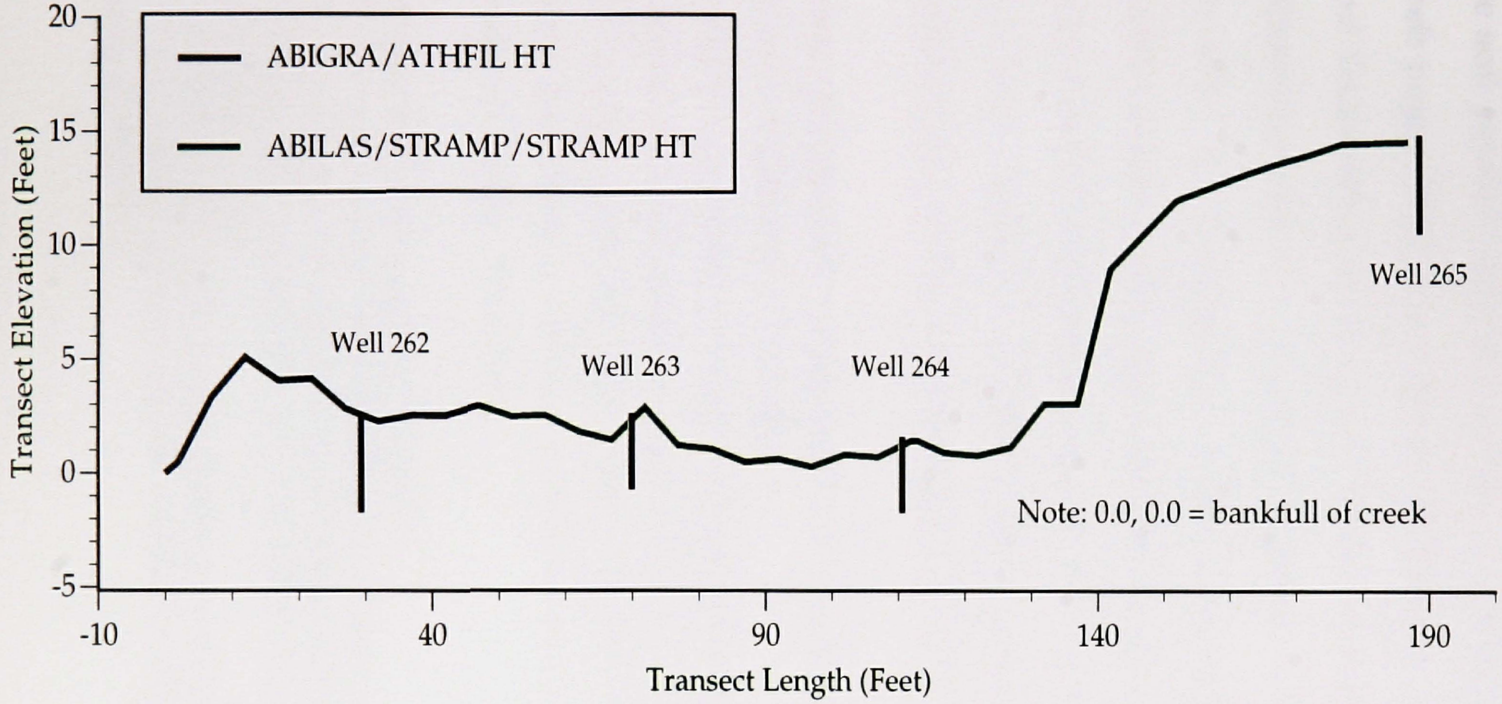

Figure B-30. Site 11, Transect 30: North Fork Lost Creek, Swan Lake Ranger District, Flathead National Forest, Montana

APPENDIX C. Summary of Soil Parameters Measured Within Each Habitat Type and Phase

The following four soil profiles were recorded along with 106 others within this study. All of the soil profiles may be viewed at the Riparian and Wetland Research Program web page. This information is currently located under the Jurisdictional Wetland Delineation Database as a sub-section of the voluminous RWRP Database which is currently located on the internet at: http//www.rwrp.umt.edu. These select few profiles represent what I consider to be typical of the habitat types which I encountered in the field. For information concerning parent materials and other soil forming factors please refer to the main text. Table C-1 is presented to further charcterize the hydric soil features within each of the habitat type and their phases.

Abies lasiocarpa/Ledum glandulosum **(subalpine fir/Labrador tea) Habitat Type** ***Ledum glandulosum*** **(Labrador tea)Phase—**
This habitat type generally consisted of shallow soils which formed in sandy to coarse grained material, with shallow organic horizons. These soils were associated with hillside seeps; generally non-hydric (Table 11). A typical pedon from the Griffin Creek area at 1,824 m (6,000 ft), Tally Lake Ranger District, Flathead National Forest, Montana.

5 to 0 cm	Slightly decomposed organic material
0 to 3 cm	5YR 2.5/1 black humic; very friable; no structure
3 to 5 cm	7.5YR 5/1 depleted silt loam, very weak,; platy structure
5 to 16 cm	7.5YR 5/6 fine silty loam; many roots; platy structure; gradual boundary; many roots
16 to 35 cm	7.5YR 6/3 blocky silt with many pebbles; many roots;
35+ cm	10YR 6/2 silt; many distinct redox concentrations of 5YR 5/8 and reductions of 5YR 6/1

Abies lasiocarpa/Ledum glandulosum (subalpine fir/Labrador tea) Habitat Type *Calamagrostis canadensis* (bluejoint reedgrass) Phase—

This habitat type generally consisted of poorly drained hydric soils; glacial silty with thick organic surface horizons (Table 11). Redox concentrations and depletions are easily identifiable immediately below the A horizon. These soils were associated with wet meadows and slow water areas. A typical pedon from the Lost Horse Creek area at 2,128 m (7,000 ft), Darby Ranger District, Bitterroot National Forest, Montana.

10 to 0 cm	slightly decomposed O horizon
0 to 17 cm	2.5YR 2.5/1 loam; high organic content; many roots
17 to 37 cm	5GY 2.5/- clay loam; many roots; with 20% redox concentrations of 10YR 5/6 and depletions of 7.5 YR 5/1
37+ cm	2.5Y 5/6 red silt sand; many small pebbles; few roots; no structure

Abies lasiocarpa/Streptopus amplexifolius (subalpine fir/twisted stalk) Habitat Type *Streptopus amplexifolius* (twisted stalk) Phase—

This habitat type generally consisted of shallow soils which formed in sandy to coarse grained material, with shallow organic horizons. Redox concentrations were faint and deep within the srofile (30+ cm [12+ in]); generally non-hydric (Table 12). These soils were associated with hillside seeps and alluvial materials near stream washes. A typical pedon from the Porcupine Creek area at 1,672 m (5,500 ft), Swan Lake Ranger District, Flathead National Forest, Montana.

6 to 0 cm	slightly decomposed organic material
0 to 2 cm	7.5YR 3/1 loam; dark humic
2 to 5 cm	7.5YR 7/1 depleted light grey; silt loam; platy
5 to 15 cm	7.5YR 4/6 red silty loam; blocky; many roots
15 to 36 cm	10YR 5/4 yellow brown silt clay; blocky; many pebbles; many roots
36+ cm	10 YR 5/5 yellow brown silt; blocky; many pebbles; few roots; with redox concentrations of 5YR 5/8 and depletions of 7.5YR 5/1

***Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) Habitat Type *Menziesii ferruginea* (false azalea) Phase—**
This habitat type generally consisted of shallow soils which formed in sandy to coarse grained material, with shallow organic horizons; Redox features were faint in the lower horizons; none of the 13 soil profile within this habitat type were hydric (Table 12). These soils were associated with hillside seeps. A typical pedon from Lost Horse Creek area at 2,128 m (7,000 ft), in the Darby Ranger District, Bitterroot National Forest, Montana.

6 to 0 cm	Slightly decomposed organic material
0 to 2 cm	7.5YR 3/1 humic
2 to 3 cm	7.5YR 5/1 depleted; silt loam
3 to 20 cm	10YR 5/2 yellow brown; sandy silt; blocky, many roots
20 to 45 cm	5YR 5/8 yellow; sandy silt; few roots; many faint mottles redox concentrations of 2.5YR 4/6
45+ cm	7.5YR 5/8 sandy silt; many small pebbles; many faint redox concentrations of 2.5YR 5/8

Table C-1. A summary of mean measured soil features found within each habitat type and phase.

Habitat type (n) Phase (n)	Mean Depth (cm) to Redox Feature (SE)	Mean Depth (cm) of O Horizon (SE)	Mean Depth (cm) of A Horizon (SE)
ABILAS/LEDGLA (50)	23.0 (1.8)	6.1 (0.6)	6.8 (1.3)
CALCAN (23)	18.3 (2.2)	8.2 (1.1)	12.4 (2.2)
LEDGLA (27)	29.0 (2.3)	4.3 (0.3)	2.0 (1.0)
ABILAS/STRAMP (45)	34.2 (2.2)	5.2 (0.4)	1.9 (0.4)
STRAMP (32)	32.9 (2.6)	5.2 (0.5)	2.3 (0.5)
MENFER (13)	36.9 (4.3)	5.0 (0.6)	1.0 (0.4)

ABILAS/LEDGLA = *Abies lasiocarpa/Ledum glandulosum* (subalpine fir/Labrador tea)
CALCAN = *Calamagrostis canadensis* (bluejoint reedgrass) phase
LEDGLA = *Ledum glandulosum* (Labrador tea) phase
ABILAS/STRAMP = *Abies lasiocarpa/Streptopus amplexifolius* (subalpine fir/twisted stalk) habitat type
STRAMP = *Streptopus amplexifolius* (twisted stalk) phase
MENFER = *Menziesia ferruginea* (false azalea) phase.