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Analysis and inventory of riparian vegetation along Nevada Creek and Monture Creek using ADAR imagery

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Analysis and Inventory of Riparian Vegetation Along Nevada Creek and Monture Creek Using ADAR Imagery

by

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High resolution imagery was used to map and spatially analyze riparian vegetation along Nevada Creek and Monture Creek. The imagery was taken from a low flying airplane using the Airborne Data Acquisition and Registration (ADAR) system. The 1 x 1 meter pixel imagery has 4 spectral reflectance bands; blue (450-480 nμ), green (460-570 nμ), red (610-680 nμ) and near infrared (780-1000 nμ). Spectral reflectance values in the red and near infrared bands of selected riparian species were compared to determine if significant spectral differences existed between riparian shrub species. Green, red and near infrared bands were used to preform computer assisted classification of the imagery. Field verification of the imagery was conducted by mapping riparian plant communities and conducting transects through each riparian stand. During field verification riparian health was assessed using vegetation, soils and streambanks as attributes.

Significant differences between the mean spectral reflectance values in the red and near infrared bands exist between *Salix geyeriana, Salix drummondii,* and *Alnus incana* vegetation types. Mean spectral values in the red band for *Populous trichocarpa, Salix drummondii* and irrigated hay fields were not significantly different but were in the near infrared band. Unsupervised classification of the imagery resulted in separate classes for each riparian vegetation type when the mean spectral differences were significantly different in both the red and near infrared bands but not when the mean spectral differences were not significantly different in the red band. Preliminary tests with supervised classification indicated a more accurately classified image than unsupervised classification. Vegetation types with similar spectral reflectance values could be easily differentiated on the imagery by their spatial and textural differences. ADAR imagery can be used as an effective tool to map riparian vegetation if the user is familiar with the field. Because spectral reflectance values record the variability on a landscape, the ability of the user to use ADAR imagery to differentiate between vegetation with similar spectral values will depend on the heterogeneity of the rest of the vegetation spectral values.

ACKNOWLEDGMENTS

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INTRODUCTION

Vegetation along a riparian zone influences water quality, quantity, and trout habitat. Woody vegetation near streams affect stream habitat complexity and stream production through the contribution of litter and large woody debris (Nakamura and Swanson 1994, Waring and Schlesinger 1986). The deep binding root masses of willow, dogwood and other riparian shrubs and the rhizomatous roots of sedges provide bank stability and provide cover for trout (Medina and others 1995.) Healthy riparian areas also provide temperature control through shading, reduce peak floods and filter sediments (DeBano and others 1995.) To allow biologists and landowners to communicate about riparian vegetation health, desired vegetative conditions, plan restoration projects, and to monitor vegetative changes, the vegetation along the riparian zone must be identified and described (Hansen and others 1995). High-resolution, remotely sensed imagery can be an important tool to classify, map and evaluate vegetation along riparian zones on a regional scale.

Managers with the Montana Department of Fish, Wildlife and Parks (MDFWP), the Natural Resource Conservation Service (NRCS), local Conservation Districts and landowners are working together to improve trout habitat and water quality along the Blackfoot River and its tributaries. To prioritize riparian improvement projects, managers have decided to take a regional approach to determine problem areas in the Blackfoot River watershed in west-central Montana.

The Blackfoot River runs 132 miles from Roger's Pass to Bonner with 10 principle tributaries, including Nevada and Monture Creeks. Above the town of Lincoln, the river becomes intermittent almost annually during the driest part of the summer. Conifer habitat types dominate the riparian vegetation along the upper portion of the watershed, which is mostly on National Forests. Willow, sedges and grassland vegetation types dominate the middle section of the Blackfoot River as it meanders through the privately-owned Ovando valley. The lower part of the Blackfoot River flows into a coniferous canyon which is owned largely by the Plum Creek Timber Company and is managed by the Montana Department of Fish, Wildlife and Parks (MDFWP). The confluence of Monture Creek and Nevada Creek are in the middle section of the Blackfoot River (Fig 1).

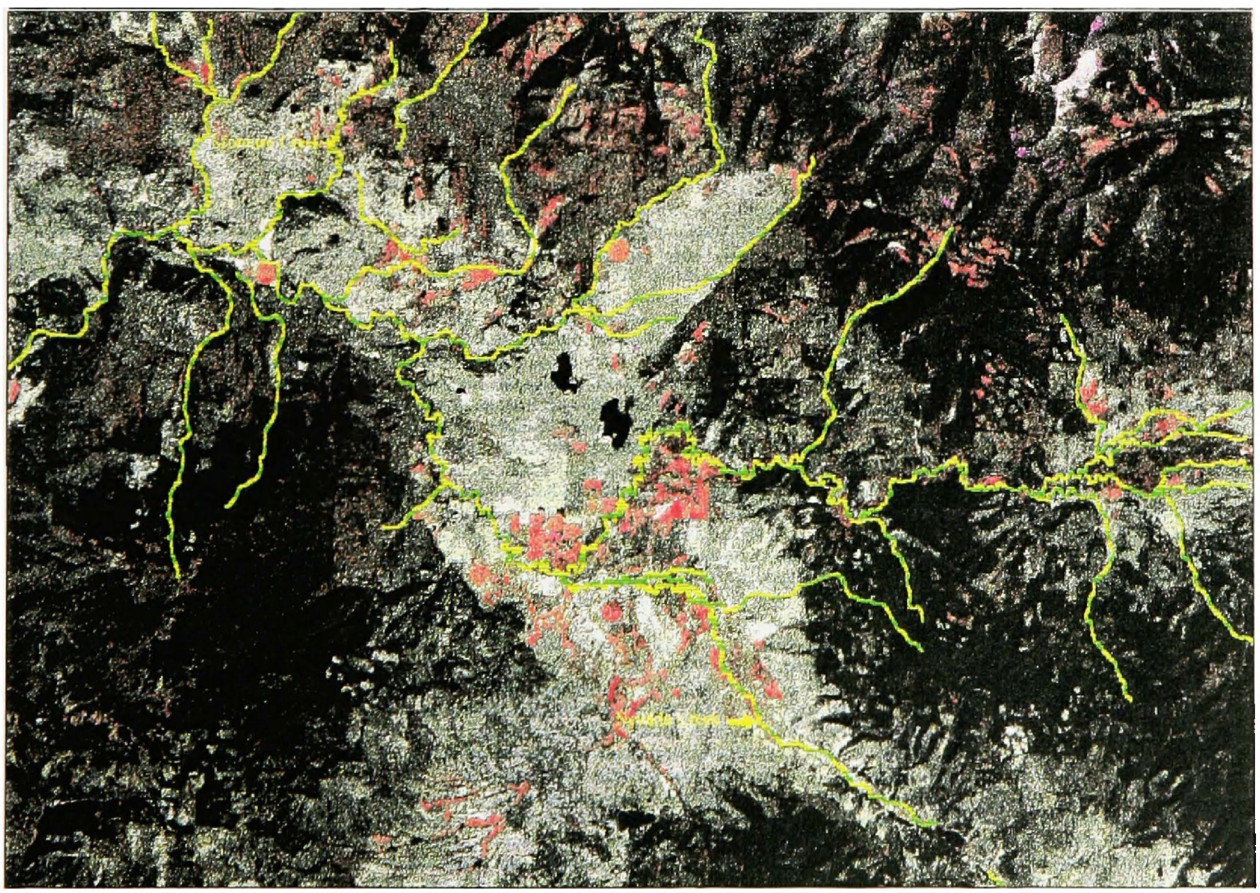

Figure 1 LANDSAT image of the Blackfoot River showing Monture and Nevada Creek

Three native salmonids live in the Blackfoot River and its tributaries. They are the *Oncorhynchus clarki lewisi*, (westslope cutthroat trout), *Salvelinus confluentus* (bull trout) and *Prosopium williamsoni* (mountain whitefish). The westslope cutthroat and bull trout are declining due to habitat alteration and competition and hybridization with exotic trout. Most populations of native trout are now restricted to headwaters and tributaries in the Blackfoot River (Peters 1990, Leary and Allendorf 1989).

In 1989, biologists from MDFWP inventoried seventeen tributaries of the Blackfoot River to assess habitat quality for spawning fish. Factors limiting spawning ranged from barriers to migration, livestock trampling of the banks, dewatering, timber harvest and poor road/stream-side management practices. In most cases, tributaries that did not originate in wilderness areas had intensive timber harvest in the upper portion and unstable banks in the lower portion. Monture Creek, a spring fed creek, supports viable populations of bull and westslope cutthroat trout, while Nevada Creek is one of the major contributors of excessive turbidity, of elevated stream temperatures and elevated levels of nitrates and phosphates in the Blackfoot drainage. The lower portion of Nevada Creek, below the Nevada Creek Dam, has a very low trout population with no native salmonids (Peters 1990).

The species composition and structure of vegetation along a riparian area can directly and indirectly affect fish habitat and water quality. Baseline information about the aquatic and riparian habitat must be obtained to determine where and what the limiting factors are for trout and other riparian dependent species. To communicate effectively about resources and transfer knowledge, land managers use vegetation and habitat classification. Vegetation along riparian areas which has been classified and mapped can be analyzed spatially and temporally and managers may be able to relate aquatic habitat quality to vegetation conditions.

Conventional methods of mapping riparian vegetation involves using aerial photo interpretation, topographical maps and comprehensive field data collection. This method produces data at varying scales which must be compiled and analyzed manually. For spatial analysis, the information may be interpreted using mylar overlays or loaded into a geographical information system (GIS). While comprehensive field data provides the most accurate information about the resource, the high costs and large amount of time required for data collection often precludes its availability. Another alternative to collecting vegetation attributes and aquatic habitat information might be the use of satellite imagery. Satellite imagery has the advantage that it is in digital format which can easily be imported into a GIS package. The seven different spectral reflectance bands recorded on LANDSAT Thematic mapper satellite imagery enable land managers to highlight different attributes on the landscape which may not be visible on aerial photographs (Kalliola and Syrjanen 1991). Satellite imagery has a disadvantage in that the highest resolution is only 30 m^2 pixels, which precludes the delineation of many riparian habitats (Congalton 1991, Pierce 1995). High-resolution, multi-spectral imagery using airborne data acquisition and registration (ADAR) systems taken from an airplane may be a viable tool that can be used to efficiently and accurately classify vegetation along riparian areas.

I evaluated the utility of using this imagery for the classification of riparian vegetation and determining the health of the vegetation along Monture and Nevada Creeks. The results of this pilot study may be applied to the entire Blackfoot River drainage to enable land managers to prioritize management actions and evaluate trout habitat potential.

Objectives and Hypothesis

1) Classify and map riparian vegetation using ADAR imagery and test the accuracy of the imagery with field verification.

2) Develop an efficient methodology for using ADAR imagery to classify, map and spatially analyze vegetation in riparian zones.

3) Assess the riparian health and classify it as functioning, functioning-at-risk or nonfunctioning along Monture and Nevada Creeks during field reconnaissance.

4) Recommend management actions to restore and maintain the natural dynamics of Monture and Nevada Creeks, their water quality, and their fish and wildlife habitat.

The hypothesis being tested relate to the first objective:

H0: Mean spectral reflectance values of selected plant communities along a riparian zone are the same.

H1: Mean spectral reflectance values of selected plant communities along a riparian zone are the different.

LITERATURE REVIEW

Riparian Classification

Ecological classification of vegetation increases land manager's understanding of the role of the vegetation within the ecosystem. One definition of ecological classification describes the process in four steps: 1) observation, 2) description, 3) classification and 4) abstraction. In this case, abstraction is necessary to separate the classified resource and consider it separately (Pfister 1989). Hall (1989) suggests that ecological classification is used by land managers to serve as a framework for storage and retrieval of ecological information which can be used to 1) characterize plant communities, 2) refine prediction of how a plant community will react to management activities and 3) aid in the development of projects to attain a desired functioning resource.

Classification of vegetation in riparian areas by land managers has been largely ignored until recently. In past classifications, riparian vegetation was either lumped with uplands or broadly classed as wet or dry (Winward and Padgett 1989). With the recent awareness of the importance of riparian ecosystems, efforts have been made to begin to classify and map riparian areas to gain a better understanding of these complex communities (Platts and others 1987).

Several classification systems have been developed for riparian areas. Each classification system emphasizes different attributes about the riparian zone. Cowardin and others (1979) developed a comprehensive classification system for wetlands and deepwater habitats across the entire United States. This includes a class for riverine systems. Physical properties are used to initially classify the river system including type of stream, flow duration, substrate type and shoreline type. Shoreline vegetation is classified based on lifeform and only at the finest scale of classification is the dominant species named. This type of classification is useful for a coarse landscape classification of watershed and river basins. However a finer scale classification based on plant communities gives the land manager more information about the biological interactions occurring in the system.

Riparian areas are complex systems which contain a large diversity of plant communities across a small area. The potential of this vegetation is highly variable depending on hydrologic changes and landforms. For these reasons managers have struggled to develop a consistent classification method which incorporates the variability within the riparian vegetation but is not so detailed that it is difficult to use (Platts and others 1987).

Researchers with the USDA Intermountain Research Station have developed a guide based on three different levels of riparian inventory and classification. Each level focuses on different objectives of the land manager (Winward and others 1992). The finest scale classification is a complete description of vegetation species by canopy cover and distribution. This type of classification gives detailed information about the current conditions at a specific site but would be extremely time consuming to apply to a broad area.

Riparian sites in western Montana have been classified into nine coniferous habitat types, eighteen deciduous habitat or community types, sixteen willow habitat or community types, sixteen shrub habitat or community types, seven sedge habitat types, and twenty grass-like habitat or community types (Hansen and others 1995). Most of these habitat and community types occur in tributaries along the Blackfoot River Basin. The Hansen and others (1995) classification system is a field oriented classification system developed for use by resource managers.

Vegetation Mapping Using Remotely Sensed Imagery

Remotely sensed imagery in the form of aerial photographs is commonly used by land managers to map vegetation. Several types of remotely sensed data such as near infrared aerial photographs and aerial video have proven to provide information about riparian vegetation which can be mapped (Valencia 1993, Clemmer 1994). Color infrared aerial photographs are used by the Bureau of Land Management and the Bureau of Reclamation to map riparian vegetation because color infrared film captures a greater range of spectral reflectance variation between vegetation types than does natural color film (Clemmer 1994).

Near infrared aerial photography

Mckee and others (1995) inventoried and mapped riparian vegetation along the Animas River in LaPlata County Colorado with 1:1200 scale color infrared aerial photography.

Seven riparian vegetation classes were developed from field observations and sampling. These classes were based on vegetation overstory or dominance types which could be differentiated using the color infrared photography. Attributes to classify the vegetation included spectral signature differences, texture, size of the class, topographic location on the landscape and the relationship of colors to each other such as mottling or uniform variation. Mckee and others (1995) ground truthed the classes with stratified random sampling and developed an error matrix to asses the accuracy of the classification. They were able to correctly classify the vegetation with 75 - 83% accuracy.

Airborne video imagery

Airborne video imagery is a new technology that is generating an increasing amount of interest among land managers (Bobbe and others 1993). Multi-spectral and real color imagery can be obtained from video cameras mounted on a low flying airplane. The spatial resolution of video imagery is not as good as an aerial photograph but it can highlight subtle spectral differences between vegetation types. Bobbe and others (1993) evaluated the use of real color and multi-spectral color video imagery to interpret riparian features, stream morphology and vegetation. They were able to differentiate between *Alnus rubra* (red alder) and *Populus trichocarpa* (black cottonwood). Everitt and others (1992a and 1992b) used multi spectral video imagery to distinguish between selected weed and brush species in Texas rangelands. In one study, they found that *Isocoma coronopifolia* (common goldenweed) and *I. drummondii* (drummond goldenweed) could be distinguished from surrounding vegetation. In another study they were able to distinguish *Gutierrezia sarothrae* (false broomweed), *Lygodesmia juncea* (Pursh) (spiny aster) *and Tamarix ramosisima* (Chinese tamarisk) from the associated vegetation. The Arizona Game and Fish Department is using video imagery in combination with satellite imagery and field data to generate a statewide map of riparian vegetation communities (Valencia 1993).

Vegetation mapping using satellite imagery

Satellites provide imagery of the earth's surface in digital form. The most common imagery used to map vegetation comes from Landsat Thematic Mapper (TM) because it has higher precision of radiometric data, higher cartographic accuracy and higher spectral dimensionality (Scott 1993). This imagery has seven different spectral wavelength bands and the pixels are $30m^2$.

Stenback and Congalton (1990) used LANDSAT imagery and an unsupervised classification to determine the presence or absence of understory vegetation under different levels of overstory canopy closure. Unsupervised color classification is a process by which the computer groups pixels with similar spectral reflectance values into computer generated classes. They found that classification using the mid range infrared band gave the highest accuracy in predicting the presence or absence of understory. The reflectance in mid-infrared bands is due to plant water content (Lillesand and Kiefer 1979).

The utility of satellite imagery to classify vegetation depends on the level of vegetation classification desired and the topographical and vegetational variation in the region to be classified. Factors such as soil background color, atmospheric conditions, and the optical properties of the vegetation can cause light scatter which affects the accuracy of the spectral imagery (Ford and others 1994). Spectral signatures become more varied and less accurate for vegetation classification in areas with high topographical variation, clumped canopies and in arid environments (Baker and others 1991, Kremer and Running 1993).

LANDSAT data has been used to map general vegetation types or ecosystem types such as alpine tundra, krummholz, vegetated talus, bare rock and mixed conifer forest in a study by John Craighead and others (1982) to quantify grizzly bear habitat. They used supervised training to initially classify the images and ground verified the classes using aerial photographs, vegetative sampling and on-site inspection. Supervised classification is similar to unsupervised classification except that the user trains the computer to recognize certain groups of pixels or spectral reflectance values as a class. The computer then groups all the pixels in the image into one of those classes. They conclude that vegetation mapping using digital remotely-sensed imagery is "essentially the conversion of an ecological to an ecospectral classification" and that:

"Ecospectral classification is valuable in that, within prescribed ecological limits, it can be computer-extrapolated for relatively large biogeographic areas to minimize mapping time and costs and to maximize resource information."

Craighead and others (1988) extended this mapping method to map the artic vegetation in Northwest Alaska. They used modified cluster training of pixels to classify three different alpine vegetation complexes, four riparian vegetation complexes, three forest complexes and six ocean shoreline/bare rock classes. Modified cluster classification involves a combination of supervised and unsupervised classification. It requires prior knowledge of the field by the operator. The distance between values is determined by the operator based on what level of classification or how many classes the operator desires. Several sub-classes are created using supervised training and then the sub-classes are collapsed using unsupervised classification. These classes are then coded for the original target classes.

The National Biological Service (NBS) has been using satellite imagery from the Landsat Thematic Mapper to map vegetation across the U.S. for the GAP analysis project (Jennings 1996). The GAP analysis project uses GIS capabilities of digital map overlay to identify species, species-rich areas and vegetation types that are inadequately protected by existing preserves across the U. S. (Scott and others, 1990). The vegetation has been classified using a combination of supervised, unsupervised and guided clustering. Jennings (1996) reports that the guided clustering approach developed by NBS provided consistently better results than supervised or unsupervised training.

In a few studies, researchers have had some success in differentiating between species and communities using LANDSAT imagery (Everitt and others 1993, Kremer and Running, 1993). Everitt and others (1993) successfully mapped three different types of weeds in a large agricultural area. Walsh (1980) used LANDSAT imagery to classify different coniferous tree species in Crater Lake National Park using controlled clustering and achieved a 88.8% accuracy.

Different scales of vegetation classification have been used, depending on the scale of the analysis and the objectives of the user. On a regional and global scale, vegetation indices such as the normalized difference vegetation index (NDVI) (Fig. 2) or a simple band ratioing (VI) computed from red and near infrared color bands are used.

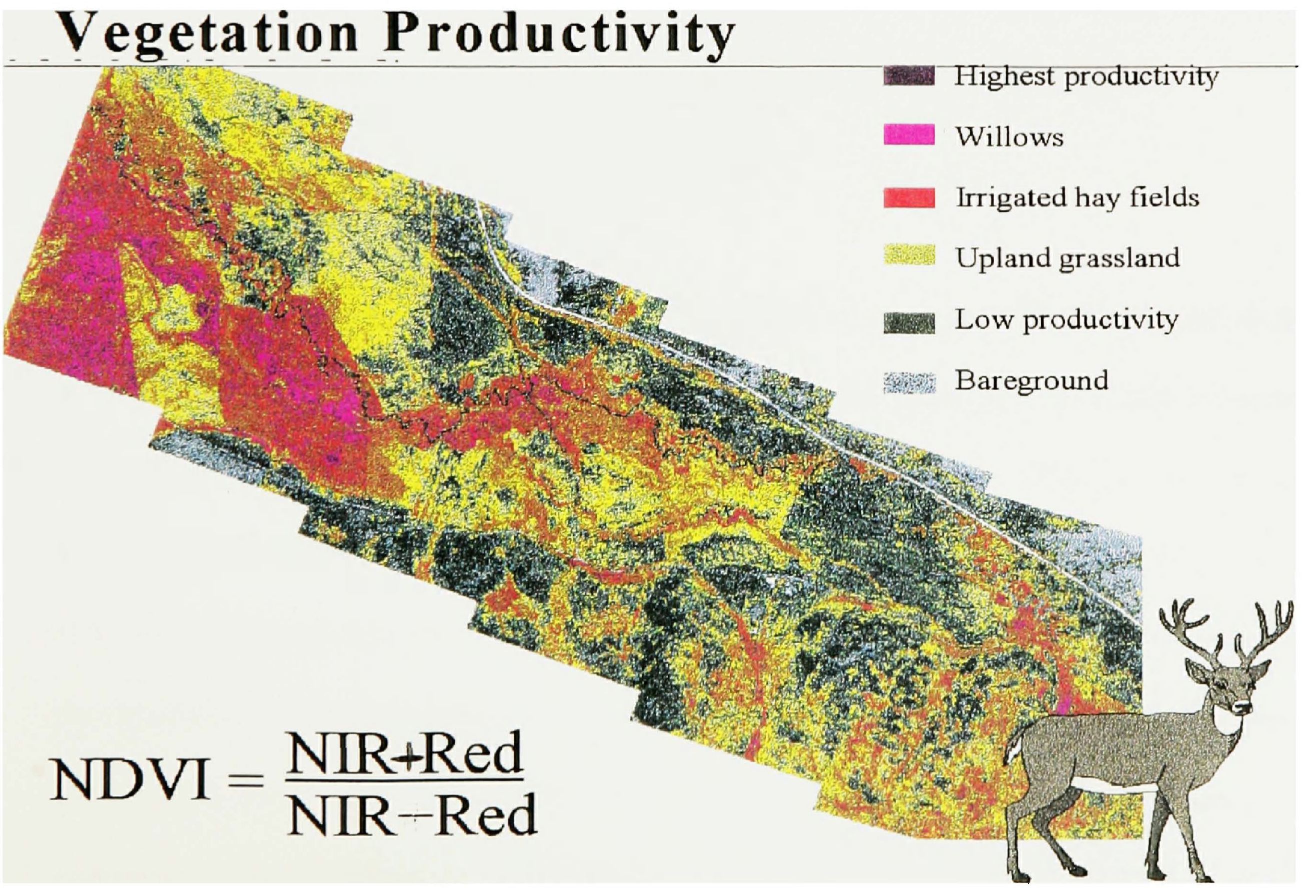

Figure 2 Vegetation Productivity map image of Nevada Creek based on NDVI

NDVI is calculated from the reflectance of the visible red (R) and near infrared (NIR) radiation. The equations for the indices are NDVI=[NIR+R]/[NIR-R] and VI=NIR/R. The associations between NDVI chlorophyll and leaf area index (LAI) have been tested (Yoder and Waring 1994, Begue 1993). In general, as chlorophyll concentration in the leaf increases, the reflectance value of the red color band decreases and when LAI increases the near infrared band increases. Band ratioing is effective when an inverse relationship exists between the two bands. The histogram of the imagery is stretched to augment differences between the two bands (Campbell 1987). NDVI is primarily used to evaluate and determine leaf area index, vegetation productivity, canopy structure and chemistry (Gamon and others 1993), model hydrologic systems and evaluate photosynthesis rates (Manasai 1990, Lloyd 1990).

LANDSAT Satellite imagery contains seven bands which can provide information about soil texture, moisture and roughness, chlorophyll and plant moisture, suspended materials in water such as tannin and suspended sediments on a coarse scale. This data can be used by managers to conduct landscape level studies of hydrologic regimes in wetlands and other environmental features. The use of LANDSAT imagery has not been successful in the classification of vegetation in many studies (Kalliola and Syrjanen 1991, Baker and others 1991, Pinter and others 1990, Johnston and Barson 1993) because the scale of the vegetation being mapped requires a smaller pixel size and the background scatters the light to prevent meaningful classification.

Many species have different spectral signatures in the near infrared, red and green color bands which can be detected using a low flying airplane or field spectrometer (Price 1994). In areas where the inherent geological and biological variability is greater than the coarse spatial resolution of the satellite data being gathered, accurate information cannot be obtained. The result is that spectral reflectance values of too many variables are being averaged across each 30 m^2 for each pixel and therefore not enough detail is retained. This problem is exasperated in narrow riparian corridors which often are less than 30 m wide (Fig. 3). Information about total leaf areas, and photosynthetic activity can be

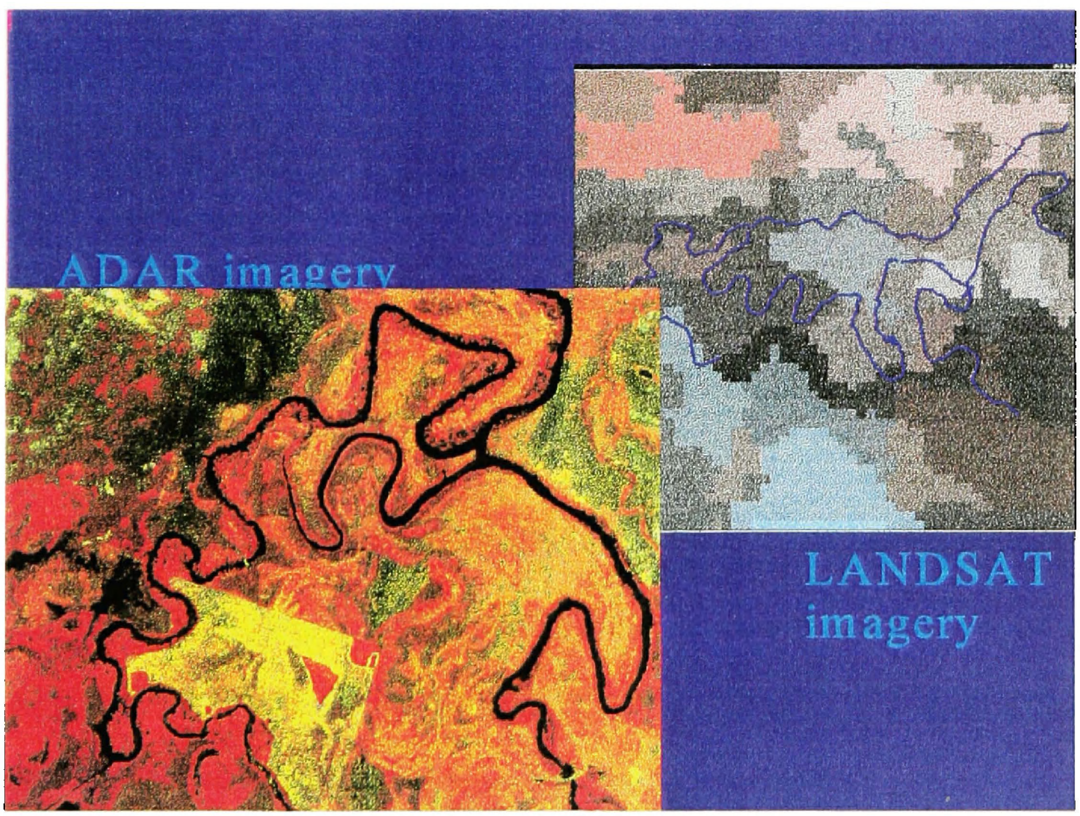

Figure 3 ADAR and LANDSAT imagery of the confluence of Nevada Spring Creek and Nevada Creek in Powell County, Montana

identified with LANDSAT imagery which is useful for an analysis of total water budgets in a watershed and global production predictions. Resource managers conducting a finer scale analysis may want information about vegetation species, structure and wildlife habitat which requires the use of higher resolution data collected from a low flying airplane (Price 1994).

Airborne Digital Acquisition and Registration System (ADAR)

Treitz and others (1992) used airborne digital acquisition imagery of a 5 x 5 meter pixel resolution to determine to what attributes of vegetation can be mapped using remotely sensed imagery. They collected vegetation plot information and developed two types of classification systems. They used a supervised classification system to process the imagery. The accuracy of the classification varied. The more unique and the less variable the spectral signature of the vegetation, the better the accuracy.

The Confederation of Salish and Kootenai tribes in west central Montana, have initiated a classification of wetlands on the Flathead Reservation using high-resolution, multi-spectral, remotely sensed imagery. This Airborne Data Acquisition and Registration (ADAR) System 5000 imagery, from Positive Systems of Kalispell, Montana has a 2 x 2 meter pixel resolution and four spectral reflectance bands. Because the technology was new and specific software had not been developed, the image processing required hundreds of person hours. Unsupervised classification was used on vernal pools and potholes in the bottom of ancient Lake Missoula. Limited ground verification showed that classifying the potholes using Cowardin and others (1979) classification system would probably be successful, but the project was never completed (Beebe 1994, Ball 1996).

Benkelman and others (1992) have used ADAR data in Oregon, Washington, New Mexico and California. In Oregon and Washington they were able to characterize forest canopy components such as shaded areas, sunlit areas and tree canopy gaps to determine the extent of forest fragmentation and determine riparian condition. In another study they conducted, ADAR imagery was used to map desert scrub vegetation in New Mexico. NDVI was computed and compared to above ground biomass. In a fourth study in southern California Benkelman and others (1992) were able to use ADAR data to calculate a VI for beetle infested pine trees and correlate the degree of infestation with this VI.

Pierce (1995) has used ADAR data to differentiate between pool depths, riffles and runs in the Blackfoot River Drainage. Different riparian vegetative life forms, plant community types and/or species may be identified using the one meter pixel, multi-spectral, high resolution data.

METHODS

I conducted my research along Nevada and Monture Creeks, tributaries to the Blackfoot River. I used two flight lines from two different streams to capture some of the variability in riparian vegetation types in the Blackfoot River Drainage. I chose Monture Creek because of its importance as a bull trout spawning stream and the upper reaches do not receive impact from livestock. Overall, Monture Creek riparian vegetation communities are dominated by conifer tree species and *Alnus incana.* Some areas of Monture Creek has extensive wetlands dominated by several willow species and Betula spp. I chose Nevada Creek because it has poor water quality and contributes elevated levels of sediment and organic material into the Blackfoot River. The entire riparian area is privately owned and impacted by livestock. Nevada Creek riparian vegetation is dominated by riparian shrubs and has very few trees. Flooded areas were dominated by *Carex* spp. and *Juncus* spp. Plant communities in the two drainage were very different from each other and combined represented many of the riparian plant species in the Blackfoot River drainage.

I compared spectral reflectance values of different riparian shrubs and evaluated the health of the riparian areas along both creeks. The spectral reflectance values were recorded on multi-spectral imagery and the riparian health was scored during field verification. Image processing involved rectifying images, mosaicing images, geo-referencing flight-lines, color classifying the flight lines and importing flight lines into a geographical information system (GIS) package. Once the imagery was in a GIS system I created new layers of management units and plant communities. I overlaid these layers on the images to generate reports about spectral values of riparian shrubs, hectares of plant communities and meters of eroding banks.

Study Area

Monture Creek, 26 miles long, is one of the few tributaries of the Blackfoot which still supports a viable population of bull trout. The upper portion of the creek meanders along a narrow V-shaped valley on the Lolo National Forest and is lined with *Picea engelmannii* (Englemann spruce), *Cornus stolonifera* (red-osier dogwood) and *Salix drummondii* (drummond willow) (Fig. 4).

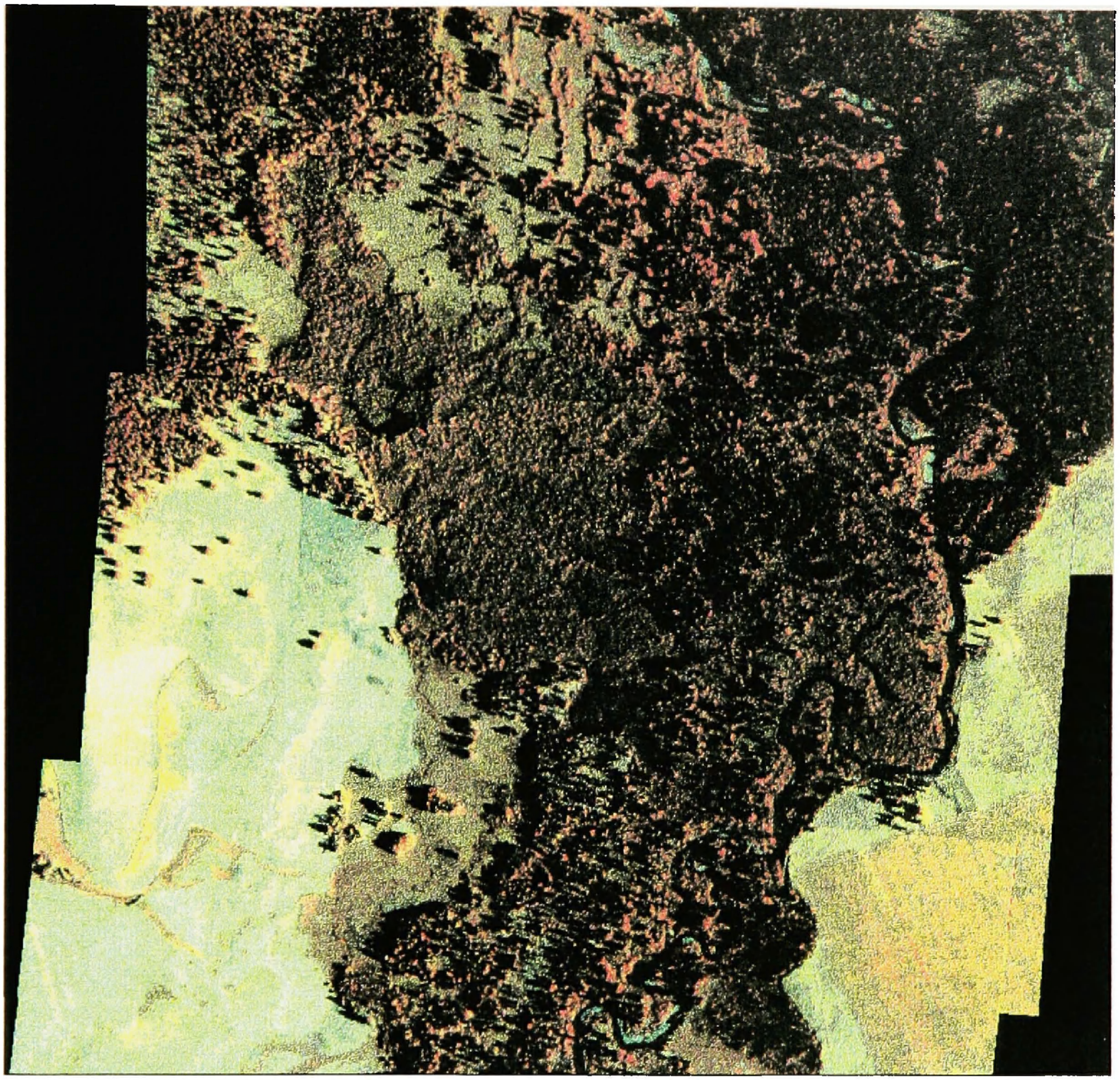

Figure 4 Image of Monture Creek riparian area at stream miles 7-9 from the mouth of the Blackfoot River, looking upstream (north)

This portion of the creek has good pool development and small gravel substrates and is dominated by westslope cutthroat trout. The middle stretch of Monture Creek is in a privately owned, wide glacial valley with knob and kettle topography. A large wetland dominated by *Salix boothii* (Booth willow), *Salix bebbiana* (Bebb willow) and *Salix* *geyeriana* (Geyer willow) with small islands of *Picea englmannia, Alnus incana* (red alder) and *Cornus stolonifera* characterize this portion of the creek. Drier portions of the unique willow wetlands have been cleared and drained for pasture. On this portion of the Creek, *Crataegus succulenta* (black hawthorn), *Prunus virginiana* (common chokecherry) and exotic grasses and forbs are more common than in the upper portions of the Creek. Large woody debris is abundant within the stream channel and streambanks are in fair condition. The riparian area from stream mile 3 through stream mile 7 has been impacted by livestock. In places near Highway 200, almost all the riparian vegetation has been removed, banks are eroding and the stream is wide and shallow. The first three miles of Monture Creek from its confluence with the Blackfoot River, the riparian vegetation has only been moderately impacted by livestock and provides some bank stability and shading.

Nevada Creek, a tributary to the Blackfoot River, contributes about a third of the upper Blackfoot River's discharge. The rate of lateral movement in this wide valley is controlled primarily by vegetation and flow intensity (Rosgen 1985). Seven species of willows (*Salix boothii, S. lasiandra, S. bebbiana, S. exigua, S. drummondii, S. alba, and S. geyeriana*) and eight species of facultative riparian shrubs (*Prunus virginiana, Cornus stolonifera, Betula occidentalis, Alnus incana, Rosa woodsii, Crataegus succulenta, Symphoricarpos occidentalis*, and *Ribes lacustre*) comprise the riparian vegetation along Nevada Creek (Fig. 5). In some places *Populus trichocarpa* and *Populus* *tremuloides* (quaking aspen) grow within the riparian zone. Extensive wetlands of *Carex rostrata* (beaked sedge), *Juncus* spp. (rush), *Scirpus* spp. (bullrush) and *Eleocharis* spp. (spikesedge)

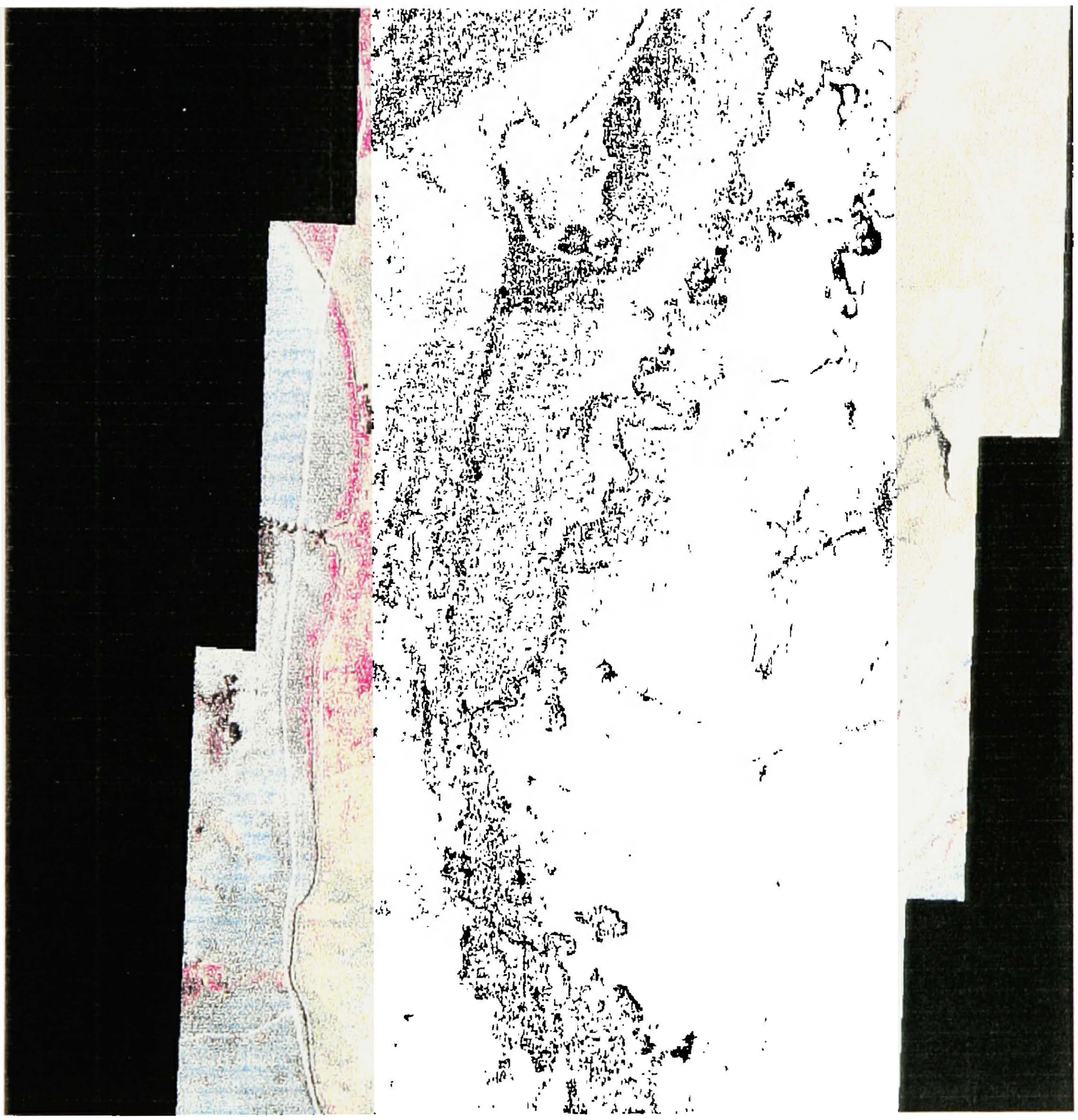

Figure 5 Image of Nevada Creek and surrounding area from Nevada Creek Ranch looking down stream Nevada Creek

occur in old oxbows and meanders of Nevada Creek. Some of the flood plain and drier areas have 100% *Phleum pratense* (timothy) and are mowed for hay.

Nevada Creek Reservoir was built at stream mile 31 in 1938 for irrigation and stock water. The dam is currently managed by the North Powell Irrigation District for irrigating hay fields and pastures below the dam. Nevada Creek is the third most important contributor of sediment into the Blackfoot River (Ingman and others, 1990). In 1989, phosphorous levels were extremely high and failed to meet state standards by a substantial margin and aquatic insects intolerant to low oxygen levels and high nutrient levels were absent (Ingman and others 1990). Water temperatures during the summer were also frequently elevated for extended time periods (Pierce and Peters 1990). Three brown trout and two rainbow trout were found in a 650 foot section in the lower portion of the creek during a 1990 survey by MDFWP's biologists (Peters 1990). Landowners and dam operators are currently pursuing an ongoing effort to improve water quality and trout habitat along Nevada Creek.

Image Processing

Positive Systems of Kalispell, Montana was contracted by the Montana Department of Fish, Wildlife and Parks to collect high-resolution (1 x 1 meter pixel) ADAR imagery of the Blackfoot River and selected tributaries, including Monture and Nevada Creeks (Fig. 6). Positive Systems used a low flying airplane equipped with four frame capture scanning cameras to record

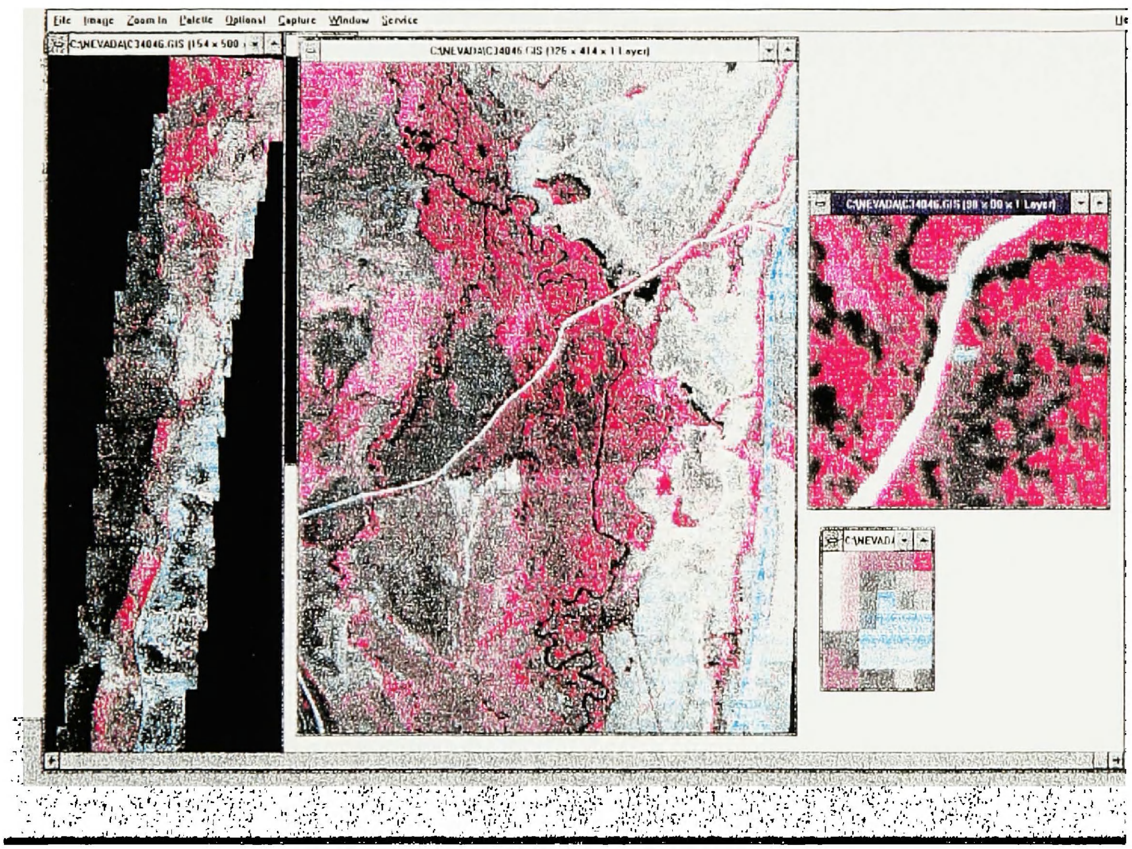

Figure 6 ADAR image of Nevada Creek Ranch-riparian vegetation along Nevada Creek at three different zoom levels

reflected electromagnetic energy. The reflected energy was stored by individual scenes on magnetic disks. Each scene of digital dat consists of 1500 x 1500 one meter pixels with four recorded spectral bands. Each pixel of data contains a value between 1 and 255 for each spectral band. Four levels in the electromagnetic spectrum were used to produce data; blue (.45-.52 um), green (.52-.60 um), red (.76-.90 um) and near infrared (.63-.69 um) (Benkelman and others 1992). The image files have sufficient overlap so that scenes can be combined to form flight lines.

For Monture and Nevada Creeks, five flight lines per creek were taken. I rectified each image to correct for earth curvature distortion but not for topographical distortion. I then matched file coordinates from each image and mosaiced the images together using VIMAP version 2.1 (1995) to produce flight lines 4 to 12 scenes long. Once the files were mosaiced, the flight lines were geographically referenced using Universal Transverse Mercator (UTM) coordinates.

To geographically reference the flight lines, file coordinates had to be associated with a known location on the earth. To collect locations of the file coordinates, I used a global positioning system (GPS) receiver. I collected approximately 14-20 global positioning system (GPS) points per flight line using a Tremble Pathfinder receiver set to collect points in UTM coordinates with a NAD-83 datum. For each location point at least 180 data points were collected using a 3-D mask (4 satellites). I differentially corrected location points using the Missoula County Court House base station and points were averaged to achieve a 2-3 meter accuracy. Ground points were chosen based on my ability to locate the area on field copies of the imagery and to ensure an even spread of locations across the flight lines.

Monture Creek images were geo-referenced by Zhengkui Ma using WinView 2.1.1 software (1995). Nevada Creek images were geo-referenced by Jiri Doskocil using PCI (1995) software. Winview software (1995) creates geo-referenced images with 1 x 1 meter pixels, creating or deleting pixels to fit GPS points. PCI software stretches the existing image and pixels to fit GPS points which results in pixels that may not be exactly 1 x 1 meter. Pixel sizes are dependent on the height of the airplane above ground level. An airplane at 3,225 meters above ground level will record pixels that are approximately 1 x 1 m. During geo-referencing pixel size inaccuracy can be caused by three sources of error. 1) The GPS receiver is only accurate to 2-3 meters after differential correction. 2) The height of the airplane above ground could have varied slightly during the time the images were recorded. 3) The exact location of the ground point recorded on the field copies of the images may not have been precise.

Pixels must be exactly 1 x 1 meter to import digital images into PAMAP 4.1 (1993), a GIS software program. When images did not have exactly 1 x 1 meter pixels, images were transformed using ERDAS 7.5 software (1991) to conduct nearest neighbor pixel resampling which preserves geographic information (ERDAS Staff 1996).

Individual scenes within a flight line had radiometric (recorded spectral value) differences between the top of one scene and the bottom of the next scene. This resulted in different histograms for each image which were not consistent for the entire flight line. Therefore, when I began the analysis, I believed it was necessary to radiometrically correct scenes in the flight line before they were mosaiced, geo-referenced and classified. Without radiometric correction two separate classes were assigned to areas with similar attributes during computer assisted classification.

Jiri Doskocil attempted to radiometrically correct the flight lines. The result was that the scenes got lighter going downstream and darker and darker going upstream because the difference in spectral reflectance was not between scenes but within each scene. Positive Systems engineers thought that this was probably due to a bi-directional reflectance problem. Bi-directional reflectance is a function of the zenith angle of the sun and the angle of the scanning cameras when the images were being recorded (Pinter and others 1990). A macro program could be written to correct the problem if spectral reflectance value changes were consistent within each scene (Doskocil 1996). This would involve determining the degree of light reflectance change between each row of pixels within the scene and reprocessing each scene through a image transformation program.

The flight-lines were color classified using both supervised and unsupervised training without radiometric correction. I used the red, near infrared and green color bands to classify the vegetation. The near infrared wavelengths provide important information about the internal structure of plant leaves, while chlorophyll absorbs the red wavelengths and reflects green radiation (Congalton 1991). The blue wavelengths are the shortest, provide the least information about vegetation and often undergo atmospheric scattering (Campbell 1987, Queen 1996) and therefore were not used to classify the images.

Color classification is the process of combining pixels into a set of classes or categories based on their spectral values. How those classes are defined is based on pattern recognition among the mean of the spectral reflectance values for each pixel. The classification process involves the development of a statistical file by pixel on the three spectral bands being used and a decision rule. The statistical file becomes the criteria that the computer uses to group pixels into classes. The decision rule is the mathematical algorithm that uses the statistics for the spectral reflectance values to sort and group pixels (ERDAS staff 1991). To achieve the best color on the classified images I used ERDAS

7.5 software (1991) to create the statistical files for classification. Then I used VIMAP 2.1 (1995) software to classify the images using Euclidean spectral distance for the decision rule. Three different Euclidean distances of 20, 30, and 40 were used during unsupervised classification to determine what the optimum distance was to highlight riparian species differences. Using three color bands, Euclidean distance (Fig 7) calculates the spectral distance between pixel signatures. The spectral distance is calculated for all possible classes and the pixel is assigned to the class which has the lowest spectral distance to that pixel (ERDAS staff 1991).

Where :

n = number of bands (dimensions)

I = a particular band

c = a particular class

X_{xyi} = spectral reflectance value of pixel x,y in band I

μci = mean of spectral reflectance values in band I for the sample class c

SD_{xyc} = spectral distance from pixel x,y to the mean of class c

$$Sd_{xyc} = \sqrt{\sum_{I=1}^{n} (\mu ci - X_{xyi})^2}$$

Figure 7 Euclidean Distance Equation

One flight line from Monture Creek and one flight line from Nevada Creek were color classified four time using unsupervised classification.

Field Verification

I evaluated the functioning riparian area and the adjacent vegetation within the 100 year flood plain. The definition of a riparian area is a subject still debated (Tellman and others 1993), however most of the data that I recorded was within areas with hydric soils and a high water table. The areas all had potential to grow riparian obligate species. Wetlands above the floodplain of each creek and along smaller tributaries were outside the scope of this analysis. I delineated vegetation communities into polygons on field copies of the ADAR imagery, using a minimum mapping unit (mmu) of 20 m^2. All polygons along Monture Creek and along the first 22 km of Nevada Creek were field verified The vegetation along the remaining 45 km in Nevada Creek was similar to the first 22 km, so I could predict the vegetation based on field copies of the imagery. For the remaining 45 km, I field verified random vegetation polygons and polygons with unique spectral signatures.

I mapped three scales of riparian vegetation during my field work. The finest scale of vegetation mapping was at the species level. I identified individual tree and shrub species, areas of noxious weeds and eroded banks on the field maps of the imagery. These small groups of pixels were used 1) to train pixels during the supervised classification for Nevada Creek, 2) to identify classes in unsupervised training in both creeks, 3) to assess the classification accuracy of each type of classification and 4) to test spectral signature differences between species.

The second mapping scale was at the riparian vegetation community level. Polygons were delineated on field copies of the imagery and field verified. I collected the following data along a series of transects for each polygon: habitat or community type according to Hansen and others (1995), canopy cover by species with 5% or more canopy, approximate average height of shrub layers, approximate average diameter at breast height of large shrubs and trees by species, relative distribution of the species and an ocular estimate of percent ground cover (Appendix B).

The largest mapping scale was in management units. Management units were identified based on land ownership, and management changes within individual ranches along fence lines (Appendix A). On the management unit level a three part riparian health assessment was conducted using a form developed by the Montana Riparian and Wetland Association (Appendix C). Vegetation health was based on riparian shrub and tree regeneration, canopy cover and total ground cover. Soils/Geology health was determined based on the amount of material available to act as a rooting medium and the amount of human-caused bare soil. Hydrology/Streambank health was determined based on percent of lateral cutting, percent of human-caused disturbance and the percent of the streambank with a deep binding root mass. Scores were given for each riparian component and an overall score was given for the health of the riparian management unit.

Land managers can use the riparian health score as a tool to determine whether a riparian area is Healthy (Functioning), At Risk or not Healthy (Non-Functioning). A healthy riparian area is considered to be functioning based on vegetation shading of the stream, deep root masses binding the streambank, ground cover filtering runoff and reducing sediment input, and a complex vegetation structure providing wildlife habitat. A riparian area scored to be At Risk is one that will become unhealthy and not function if impacts are not removed and the riparian area is not allowed to recover. An unhealthy riparian area lacks a deep binding root mass, usually has a very simple vegetation structure and the native riparian dependent species have often been replaced by exotics or upland vegetation. Accelerated lateral erosion is usually occurring and shading over the water is minimal (Fig. 8).

Figure 8 Photographs illustrating A) unhealthy and B) healthy riparian areas along Nevada Creek

A

B

An overall health rating and a rating for vegetation, soils and hydrology were assigned to each management area in Nevada Creek and entered into a database to be an attribute to the PAMAP polygons.

Data Analysis

The computer assisted classification was based on the assumption that different species or groups of species had different reflectance values. To test this, I digitized polygons around individual trees and shrubs and different types of plant communities which I had mapped on the ground along both Monture and Nevada Creeks. I used the statistical overlay model to calculate mode, mean and standard deviation of spectral reflectance in the infrared and red bands for each plant communities or species. In Nevada Creek, I had 10 samples of four different woody plant communities and three herbaceous communities. The four woody plant communities were; *Populous trichocarpa*/herbaceous (black cottonwood/herbaceous) community, *Salix geyeriana* (geyer willow) community dominated by *Salix boothii* (booth willow), *Pinus ponderosa*/herbaceous (ponderosa pine/herbaceous) community and *Populous tremuloides/Poa pratensis* (quaking aspen/Kentucky bluegrass) community. The three herbaceous communities were; irrigated *Phleum pratense* (timothy) hay with 100% ground cover (GC), fields with 50% ground cover of *Phleum pratense* and 5 to 10% ground cover of *Symphoricarpos* spp. (snowberry) and areas with 40% ground cover consisting of at least 10% forbs.

In Monture Creek , I analyzed three different species and five different plant communities. The three different species were; *Alnus incana* (mountain alder), *Populous trichocarpa* (black cottonwood), and *Salix drummondii* (drummond willow). The five different plant communities were *Cornus stolonifera* /*Alnus incana* (red-osier dogwood/mountain alder), *Picea* spp./*Cornus stolonifera* (spruce/red-osier dogwood), *Salix geyeriana* (geyer willow) community type, *Salix drummondii* (drummond willow) community type and *Alnus incana*/*Cornus stolonifera* (mountain alder/ red-osier dogwood).

I compared the mean of the spectral reflectance of the red band and of the near infrared band for each plant community or species group in an one-way ANOVA table. Then I preformed a Tukey's multiple comparison test on the same variables. The ANOVA is useful to determine if there is a significant difference between the means of different groups and the Tukey's multiple comparison test determines which means of the spectral reflectance values are different and by what magnitude.

Once I determined that there was a significant difference in spectral reflectance between some of the vegetation types in Nevada Creek, I evaluated the unsupervised classification to determine what classes had been assigned to each vegetation type and what the accuracy of the classification was. During preliminary tests, the classified images which had a Euclidean spectral distance of 40 lumped all riparian vegetation into one class and images which had Euclidean spectral distance of 20 created many classes that had no correlation to ground attributes. Therefore, I overlaid the plant communities and species polygons over a classified surface cover which used Euclidean spectral distance of 30. I then used the Analyzer overlay functions in PAMAP to calculate the four most prevalent values or computer assigned classes assigned to each species or plant community polygon. Polygon sizes varied, depending on the type of vegetation and the uniqueness of the spectral class, resulting in varying numbers of pixels per polygon. For each polygon I calculated what percent of a specific class or value occurred in each polygon and then charted those numbers in a mis-classification matrix to determine how specific computer created classes were to species, plant communities or vegetation types.

Once I knew what the computer assigned classes represented, I could target different vegetation communities and determine the hectares of each community within a management unit. To calculate the hectares of vegetation community types by management unit in Nevada Creek, I determined which classes represented each type of vegetation. Then I used Analyzer overlay functions in PAMAP to combine the management units with the classified imagery and determine the area of specific classes of each vegetation type. I used this information to sum the number of pixels of each class that represented each vegetation type. For example, four classes all represented *Salix boothii* (booth willow) along Nevada Creek. I summed the pixels of all four classes within a management unit polygon to determine the hectares of *Salix boothii* by management unit. To check the accuracy of this method, I digitized around the plant communities in each management unit and created new polygons. I compared the calculated hectares of the new digitized polygons to the summed hectares of each class for that particular vegetation type.

For each management unit along Nevada Creek, I created a data base which included fields for the three different scores for riparian health and overall health, hectares of willows, wetlands, bare ground, areas with <25% ground cover and eroded banks. The health scores were entered manually. I mapped the eroded banks on Nevada Creek based on my field inventory and on the inventory conducted by the North Powell Conservation District in 1992. A vector file of the eroding banks were mapped on the imagery and meters of eroded bank were derived by management unit.

RESULTS AND DISCUSSION

Spectral Reflectance of Riparian Shrubs

Using an one-way ANOVA and Tukey's multi-comparison test I compared the differences between mean red and mean near- infrared spectral reflectance values of *Pinus ponderosa* (PINPON) , *Populous tremuloides*(POPTRE), *Populous trichocarpa* (POPTRI), *Salix geyeriana*/ *Salix boothii* community (SALGEY), two irrigated *Phleum pratense* fields

(PHLPRA and 50% PHLPRA), and a grassland with 40% ground cover (40% GC) in Nevada Creek. Significance tests were conducted at the .05 confidence level. *Pinus ponderosa* and irrigated *Phleum pratense* (timothy) hay fields were significantly different in both the red and the near-infrared mean spectral reflectance values. The spectral reflectance means of *Populous tremuloides, Populous trichocarpa* and *Salix boothii* in the red band were not significantly different at the .05 level, but were significantly different the near infrared band. The two grassland types and *Populous tremuloides* were not significantly different from each other in the red band but were in the near infrared band. (Table 1).

Table 1 ANOVA and multiple comparisons of mean spectral reflectance values in the near infrared and red bands of vegetation types along Nevada Creek

Species and Communities are identified by their six letter Latin code

ONE-WAY ANOVA

Mean NIR	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance
Between Groups	167.974	6	27.996	365.229	.000
Within Groups	4.829	63	7.7E-02		
Total	172.803	69			

Mean Red	Sum of Squares	Degrees of Freedom	Mean Square	F Value	Significance
Between Groups	73997.7	6	12333.0	177.394	.000
Within Groups	4379.953	63	69.523		
Total	78377.7	69			

Multiple Comparisons For the Mean Values of NIR and Red

(I) Veg types	(J) Veg types	Mean Red Difference (I-J)	Mean NIR Difference (I-J)
PINPON	POPTRE	-1.7690*	-69.9060*
	POPTRI	-1.6700*	-26.5800*
	SALGEY	-1.7800*	-87.0100*
	PHLPRA	-2.4730*	-102.8640*
	40% GC	2.2310*	52.5930*
	50% PHLPRA	.4510*	63.0490*
POPTRE	POPTRI	9.900E-02	43.3260*
	SALGEY	-1.10E-02	-17.1040*
	PHLPRA	-.7040*	-32.9580*
	40% GC	4.0000*	17.3130*
	50% PHLPRA	2.2200*	6.8570
POPTRI	SALGEY	-.1100	-60.4300*
	PHLPRA	-.8030*	-76.2840*
	40% GC	4.0110*	-26.0130*
	50% PHLPRA	2.2310*	-36.4690*
SALGEY	PHLPRA	-.6930*	-15.8540*
	40% GC	4.0110*	34.4170*
	50%PHLPRA	2.2310*	23.9610*
PHLPRA	40% GC	4.7040*	50.2710*
	50% PHLPRA	2.9240*	39.8150*
40% GC	50% PHLPRA	-1.7800*	-10.4560

* The mean difference is significant at the .05 level.

In Monture Creek, I evaluated the spectral reflectance values of four plant communities and three species using the one way ANOVA and Tukey's multiple comparison test at the .05 significance level. The four plant communities were *Salix drummondii* (SALDRU) community, *Salix geyeriana* (SALGEY) community, *Picea* spp./*Cornus stolonifera* (PICEA/CORSTO) community and *Alnus incana*/*Cornus stolonifera* (PICEA/CORSTO) community. In the multiple comparison test, only the mean red reflectance value of the *Picea* spp/*Cornus stolonifera* community was significantly different from that of the other communities (Table 2). However, in the near infrared band, all four communities exhibited mean reflectance values that were significantly different from each other at alpha = 0.05.

Table 2 ANOVA and Multiple comparisons of mean spectral reflectance values in the near infrared band and red band of plant communities in Monture Creek

Species and Communities are identified by their six letter Latin code

ANOVA

		Sum of squares	df	Mean Square	F	Sig.
MEAN_RED	Between Groups	4156.244	3	1385.415	22.972	.000
	Within Groups	2171.140	36	60.309		
	Total	6327.384	39			
MEAN_NIR	Between Groups	69414.7	3	23138.2	80.643	.000
	Within Groups	10329.2	36	286.921		
	Total	5.785	39			

Multiple Comparisons For the Mean Values of NIR and red bands

(I) Plant community	(J) Plant community	Mean Red Difference (I-J)	Mean NIR Difference (I-J)
SALDRU	ALNINC/ CORSTO	3.3580	26.2330*
	PICEA/ CORSTO	26.4340*	109.6420*
	SALGEY	8.5420	67.9760*
ALNINC/ CORSTO	PICEA/ CORSTO	23.0760*	83.4090*
	SALGEY	5.1840	41.7430*
PICEA/ CORSTO	SALGEY	-17.8920*	41.7430*

* The mean difference is significant at the .05 level.

I also compared the differences in NDVI and VI values between the four plant communities in Monture Creek. The mean NDVI values between each community were significantly different from one another. While the means between the VI values were significant between most of the communities, the *Salix geyeriana* VI was not significantly different from the *Picea* spp./*Cornus stolonifera* community or the *Alnus incana/Cornus stolonifera* community, but was significantly different between the *Salix drummondii* community at the .05 significance level (Table 3).

Table 3 ANOVA and Multiple comparisons of mean NDVI and VI values between plant communities in Monture Creek

Species and Communities are identified by their six letter Latin code

ANOVA

		Sum of squares	df	Mean Square	F	Sig.
MEAN_NDVI	Between Groups	1.1E+08	3	3.7E+07	77.920	.000
	Within Groups	1.7E+07	36	475028		
	Total	1.3E+08	39			
MEAN_VI	Between Groups	3.467	3	1.156	17..949 .000	.000
	Within Groups	2.318	36	6.4E-02		
	Total	5.785	39			

Tukey's multiple comparison

(I) Plant community	(J)Plant community	Mean NDVI Difference (I-J)	Mean VI Difference (I-J)
SALDRU	ALNINC/ CORSTO	1366.5700*	.3840*
	PICEA/ CORSTO	4463.9880*	.8120*
	SALGEY	2868.2570*	.5480*
ALNINC/ CORSTO	PICEA/ CORSTO	3097.4180*	.4280*
	SALGEY	1501.6870*	.1640*
PICEA/ CORSTO	SALGEY	-1595.731*	-.2640

* The mean difference is significant at the .05 level.

This is in agreement with other research (Qi and others 1993, Gamon and others 1993, Mcgwire and others 1993, Campbell 1987) that shows that NDVI is a better metric for separating classes of vegetation than VI.

The three species in Monture Creek that I tested were *Populous trichocarpa* (POPTRI), *Salix drummondii* (SALDRU) and *Alnus incana* (ALNINC). The variability between the means of the species in the near infra-red band, the red band, the VI and the NDVI was significantly different between alder and the other two species. *Salix drummondii* and *Populous trichocarpa* were not different from each other (Table 4).

Table 4 ANOVA and Multiple comparisons of mean spectral reflectance values in the near infrared band, red band, and NDVI values of riparian species in Monture Creek

Species and Communities are identified by their six letter Latin code

ANOVA

		Sum of squares	df	Mean Square	F	Sig.
MEAN_RED	Between Groups	217.3663	2	108.6832	6.2799	.006
	Within Groups	467.2759	27	17.3065		
	Total	684.6422	29			
MEAN_NIR	Between Groups	6144.477	2	3072.239	12.402	.000
	Within Groups	6688.475	27	247.721		
	Total	12833.0	29			
MEAN_NDVI	Between Groups	1.9E+07	2	9549923	14.510	.000
	Within Groups	1.8E+07	27	658173		
	Total_	3.7E+07	29			

Tukey's Multiple Comparisons

Species (I)	Species (J)	Mean red Difference (I-J)	Mean NIR Difference (I-J)	Mean NDVI Difference (I-J)
POPTRI	SALDRU	68.7820	-2.7790	-102.6650
	ALNINC	69.5950	28.8740*	1638.9550*
SALDRU	ALNINC	74.8550	31.6530*	1741.6200*

* The mean difference is significant at the .05 level.

The results of comparing spectral reflectances between different riparian shrubs appear to be inconsistent between the two creeks. In the near infrared band the means of the spectral reflectances between plant communities were significant for most comparisons at the .05 level.. In the red band however, the means of the spectral reflectance values were not significant for most of the comparisons in Monture Creek and were in most of the comparisons in Nevada Creek.

The differences in the results between Nevada Creek and Monture Creek can be explained due to inherent differences in the imagery and the riparian areas of the two creeks. Before the imagery is taken, the histogram of each spectral band must be calibrated by the sensor operators.. When the coupled devices record the spectral reflectance of the vegetation within each band, the value is recorded in a range between 1 - 256. Many species have been shown to have different reflectance values in one or more bands (Campbell 1987, Price 1994). Ideally, the recorded spectral reflectance values in each band should be normally distributed in the form of a bell shaped curve. This difference in recorded spectral values can be used to classify vegetation on an image when the differences are consistent and significant between species or communities of species (Everitt and others 1993, Everitt and others 1991, Lawrence and others 1994, Klock 1989).

When there is high variability of reflectance values because of vegetation or topographic variability in the scene recorded, the differences between two similar values will be lost. In Monture Creek, there was a wide range of spectral values in the near infrared band so the riparian vegetation values were compressed to a range between 220 and 256. In Nevada Creek, the range of actual spectral reflectance values was much less and the riparian vegetation was a larger feature on the landscape. Therefore the riparian vegetation was recorded spectrally with a wider range and differences between vegetation types were easier to detect on the imagery. This difference manifests itself in the computer assisted classification.

Vegetation Classification

To evaluate the accuracy of an unsupervised classification I overlaid the plant community polygons over a classified image. In Nevada Creek, I compared 11 computer generated classes across 6 different plant communities (Table 5). Each number in Table 5 indicates the percent of the total pixels that were in each derived class by existing plant community. Some derived classes in Table 5 were associated with riparian shrubs over conifer

Table 5 Pixel class identification by vegetation types for Nevada Creek (values in %)
Species and Communities are identified by their six letter Latin code

Class	PINPON	POPTRI	POPTRE	SALGEY CT	100% GC PHLPRA.	50% GC PHLPRA
3	47%	53%	0	0	0	0
4	0	34	32	34	10	0
9	0	0	0	0	0	100
20	29	71	0	0	0	0
10	100	0	0	0	0	0
13	9	0	0	7	34	48
8	0	4	68	28	0	0
32	0	7	35	28	30	0
27	0	44	51	0	5	0
23	3	8	9	43	37	0
12	0	94	6	0	0	0

or grassland, while other classes seemed to indicate trees rather than shrubs and still other classes were very specific to the species or plant community.

In Monture creek, the results were much more variable. All the same classes were represented in different percentages for the species and plant communities that I tested (Table 6). This is probably a result of the higher variability of the vegetation in

Table 6 Pixel class identification by vegetation types for Monture Creek (values in %)

Class	POPTRI	SALDRU	ALNINC	ALNINC/ CORSTO	PICEA/ CORSTO	SALGEY
2	0	10	80	10	0	0
6	22	23	20	12	0	23
8	19	21	22	17	20	21
13	0	57	12	21	10	0
23	24	26	19	18	7	6

Monture Creek and therefore the riparian shrub species were more likely to be combined during unsupervised classification . The range of values in the near infrared band that were reflected by riparian vegetation was very narrow. The spectral reflectance values of other types of vegetation may be masked out to stretch the part of the histogram where riparian vegetation reflectance values were recorded. This would accentuate the riparian vegetation spectral reflectance differences. The lower classification accuracy is probably a

Better results using the current histogram may be achieved by isolating the riparian vegetation in the Monture creek flight line and classifying it with a smaller minimal spectral distance. However, the smaller the minimal spectral distance used during classification, the more likely problems related to light scatter and bi-directional reflectance will be accentuated.

Preliminary tests with supervised classification in Nevada Creek indicated a more accurate classified image than with unsupervised classification (Table 7).

Table 7 Classification accuracy table for supervised classification of vegetation types along Nevada Creek

Actual Class	**POP TRI**	**POP TRE**	**SAL GEY**	**JUN CUS**	**HAYF IELD**	**50% GC**	**<15% GC**	**WATER**	**HIGH WAY**	**DEAD WOOD**	**% COR RECT**
POPTRI	**17**	4	15	0	1	0	0	0	0	0	46
POPTRE	4	**88**	4	5	0	0	0	0	0	5	82
SALGEY	24	5	**82**	0	13	0	0	0	0	0	66
JUNCUS	0	6	0	**115**	0	0	0	0	0	0	95
HAY FIELD	15	0	12	0	**106**	0	0	0	0	0	69
50% GC	0	0	0	0	0	**60**	0	0	0	0	100
<15%GC	0	0	0	0	0	0	**60**	0	0	0	100
WATER	0	0	0	0	0	0	0	**49**	0	0	100
HIGH WAY	0	0	0	0	0	0	0	0	**60**	0	100
DEAD WOOD	0	17	0	0	0	0	0	0	0	**15**	47
% Correct	30	73	75	96	88	100	100	100	100	75	

The improved accuracy using supervised classification is consistent with other vegetation mapping using satellite imagery (Congalton 1991, Walsh 1980, Jennings 1996).

In both the supervised and unsupervised classification of Nevada Creek, pixels in the *Populous tremuloides*and the *Salix geyeriana* vegetation types were grouped into the same class. The *Salix geyeriana* community was dominated by *Salix boothii* and it may be that *Salix boothii* and *Populous tremuloides* have similar spectral reflectance values. In the Tukey's multiple comparison test comparing the mean red spectral reflectance value between these two vegetation types, they were not significantly different (Table 1). Dead wood in the supervised classification was taken from large piles of willows and alder that had been cut and piled. The dead wood and the *Populous tremuloides* were mis-classsified during the supervised classification (Table 7). *Populous tremuloides* has an open canopy and many dead branches. This is may be why dead wood and *Populous tremuloides* are mis-classifed.

Classification accuracy results of ADAR imagery could be improved without the bi-directional reflectance problem. Due to this problem, the spectral reflectance values for a given species is not consistent throughout each scene. Since pixel classification is based on spectral values, two pixels which may have the same real reflectance values but were recorded on the imagery as having different reflectance values could be classified into different classes. The computer would group these two pixels into the same class if the difference between the two recorded spectral reflectance values was less than the difference between the spectral reflectance values of other similar pixels. The computer would also group the two pixels into the same group if the spectral distance decision rule that was used was greater than the bi-drectional reflectance difference between the two pixels. In riparian areas, the riparian shrubs all have similar reflectance values and leaf structures. To differentiate between the spectral reflectance values of the different riparian vegetation types, the user must use a narrow decision rule. On imagery with bi-directional reflectance problems, this could cause a higher rate of vegetation mis-classified.

The relatively high accuracy of supervised and unsupervised classification in Nevada Creek indicates that computer assisted classification may be a useful tool to classify riparian vegetation community types and species. The classified imagery can be used to map a variety of vegetation attributes including weeds, vegetation production and vigor, and differences in ground cover. Riparian vegetation can be classified best using a combination of computer assisted classification based on spectral attributes and spatial and textural attributes of the vegetation on the imagery. In some cases the spectral reflectance values will be almost identical, but spatial and textural differences will be extremely different. An example of this is between an irrigated alfalfa field and a *Salix geyeriana* community on Nevada Creek. The alfalfa field and the *Salix geyeriana* community were grouped into the same classes because of the similarity in spectral values and leaf area. However, the alfalfa field appears extremely uniform on the imagery while the Salix spp. are clumped and variable.

Mapping and Evaluating Plant Communities

For Nevada Creek I determined the hectares of different vegetation types as baseline information for landowners. I used field information and counts of pixels in each derived class by management unit to determine the amount of riparian vegetation present in each unit. This information will be used as baseline information to monitor improvement and restoration of the Nevada Creek riparian area. To monitor change of vegetation over time, the vegetation changes must be quantified. If the Nevada Creek ranchers want to use ADAR imagery as a change detection tool they will have to obtain a new flight of the imagery after a given time period. The hectares of the different vegetation types could then be compared to determine how the riparian vegetation has changed.

Most of the riparian vegetation along Nevada Creek can be classified as *Salix geyeriana* community type dominated by *S. boothii*. Other common willows included *Salix exigua* (sandbar willow), *S. bebbiana* (Bebb willow) *S. lasiandra*, (Pacific willow), *S. geyeriana* (geyer willow) and *S. drummondii* (drummond willow). Riparian shrubs included *Cornus stolonifera* (red-osier dogwood), *Alnus incana* (mountain alder), *Prunus virginiana* (common chokecherry), *Crataegus douglasii* (black hawthorn), *Ribes odoratum* (buffalo currant), *Rosa woodsii* (wood rose) and *Symphoricarpos* spp. (snowberry). Riparian trees included scattered *Populous tremuloides* (quaking aspen) groves, *Populous trichocarpa* (black cottonwood), and many of the willows such as, *Salix bebbiana* and *Salix lasiandra* grew into large tree forms (Fig 9).

Figure 9 Bebb willow along Nevada Creek

Each shrub species has a specific ecological response to grazing pressure. The dominance of *S. boothii* and only an occasional *S. geyeriana* indicates moderate grazing pressure. *S. geyeriana* is eliminated with minor grazing pressure. *S. bebbiana* is the most resilient to grazing and can continue to grow with high grazing pressure (Hansen and others, 1995). The absence of *Cornus stolonifera* in many parts of the Creek also indicated moderate grazing pressure. Under moderate grazing pressure, *Cornus stolonifera* is replaced by

Prunus virginiana and *Crataegus* spp. Under high grazing pressure, many shrubs are eliminated and *Rosa woodsii* and *Symphoricarpos* spp. will dominate.

The understory was predominately *Phleum pratense* (timothy), *Bromus inermis* (smooth brome), and *Poa pratensis* (Kentucky bluegrass). In isolated areas, the understory consisted of various species of *Carex* and *Juncus*. *Carex rostrata* (beaked sedge) and *Scirpus microcarpus* (small-fruited bulrush) were common in wetter areas. Forbs included *Potentilla palustis* (marsh cinquefoil), *Rumex crispus* (curled dock), *Potentilla anserina* (common silverweed), *Mentha arvensis* (field mint), *Iris missouriensis* (Rocky mountain iris), *Hyoscyamus niger* (henbane), *Carum carvi* (wild caraway), *Taraxacum officinale* (common dandelion), and *Hercleum lanatum* (cow parsnip). Densities and distribution of forbs depended on ground cover by grasses and recent disturbances. Noxious weeds were limited in extent. *Centaurea maculosa* (spotted knapweed) was common around Nevada Creek dam and different species of thistle including *Cirsium vulgare* (bull thistle), *Carduus nutans* (musk thistle) and *Cirsium arvense* (Canadian thistle) occurred in pastures. Hayfields and riparian shrub areas had few, if any noxious weeds.

Table 8 shows the hectares of *Salix geyeriana* community type, *Carex/Juncus* wetlands, bare ground and areas of low ground cover by management unit. Management units are based on land ownership and pasture boundaries. The presence of *Salix* spp. or other wetland vegetation are indicators of a proper functioning riparian area, while bare ground and low ground cover indicate areas susceptible to erosion and possible sources of excessive sediment.

Table 8 Vegetation type per management unit (hectares), Nevada Creek

Stream mile	Management unit	*Salix* spp	Bare ground	<25% GC	*Juncus/Carex* Wetland	Total
31	State land	3.24	.5	.75	.2	8.98
30.6	John Stitt	2.52	.28	.3	.01	15.3
30	Jay Stitt	4.07	.57	3.27	.01	20.4
29.3	UpWineglass	5.05	1.91	2.03	0	27.9
28.6	UpHatch	3.38	1.13	4.0	.05	18.3
27.4	Hatch	13.24	.97	2.56	.74	24.8
26.3	MidWineglass	7.8	.01	.01	.21	9.2
24.7	Mannix Hay	2.5	.02	.04	.36	7.1
23.8	Mannix Pasture	1.66	.92	1.35	.02	6.96
23.1	D. Mannix	6.6	.35	.55	2.52	29.4
22.2	Wineglass	11.6	1.25	1.80	7.39	36.53
20.8	Lowfield Wineglass	17.8	.86	.49	4.31	39.96
17.7	Mannix above Helmville	.5	.1	1.33	.01	7.32
16.4	McKee	1.5	.1	.26	.01	7.46
15.6	UpGeary	1.75	.01	.52	.03	7.92
13.6	Mannix below Helmville	7.59	.01	.05	.24	16.12
12.3	Lower Mannix	2.9	.02	.52	.33	5.96

Stream mile	Management unit	*Salix* spp	Bare ground	<25% GC	*Juncus/Carex* Wetland	Total
8.9	UpPotts	8.8	.05	1.06	.24	33.13
4.7	Meyers	1.59	.37	.52	1.45	8.24
4.3	MDFWP	18.69	1.99	.83	11.92	106.4
3.1	Bradshaw	5.93	.03	2.63	9.99	32

Riparian Health

Riparian health is a measure of how well the natural ecological processes, function are occurring and how similar the structure is to potential. The riparain health form I used (Appendix C) scores many of the riparian attributes that determine a riparian zones natural function and process. This method of determining riparian health is quantifiable and repeatable which allows land managers to use this method as a monitoring tool. The evaluation of the riparian health on a given stream could be repeated over time to detect changes in riparian health.

Nevada Creek

Overall, 53 % of the riparian zone along Nevada Creek is categorized as being At Risk, 46 % is categorized as Unhealthy and 1 % is categorized as Healthy (Fig 10). This is mostly due to a lack of riparian shrub regeneration , open canopy cover and high bank erosion.

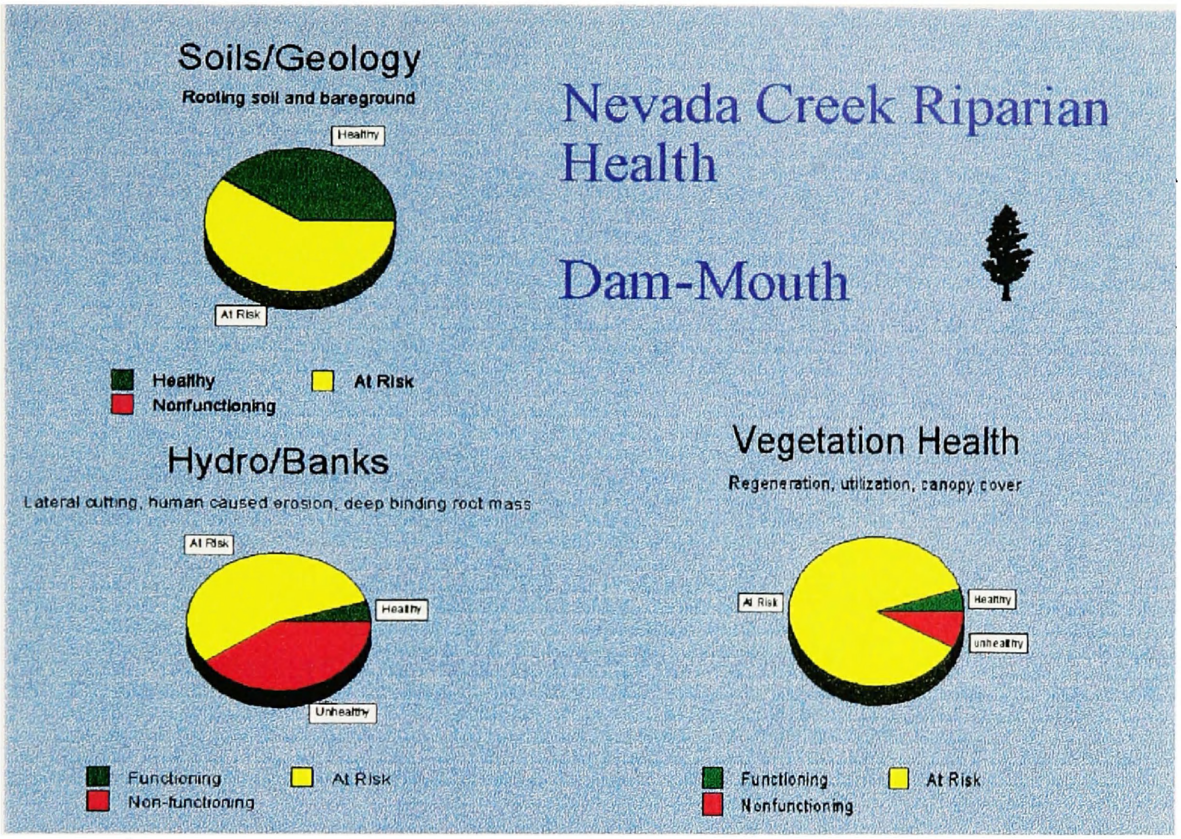

Figure 10 Distribution of three different riparian health scores for Nevada Creek

The upper portion of Nevada Creek is unhealthy or non-functioning. This is due to the lack of riparian shrubs along the banks, minimal deep binding root masses and 80% lateral erosion. Riparian shrubs, such as *Salix* spp. and *Cornus stolonifera*, have deep penetrating roots which help hold stream banks together and slow lateral erosion. In some places in the upper portion below Nevada Dam, lateral erosion is occurring in spite of the presence of riparian shrubs. This is probably due to the volume, velocity, duration and quality of water being released from the dam. High velocity flows with very little sediment can erode streambanks that are not accustomed to those flows. Soil is more erodible if it is saturated for long periods of time. As experiments following the Glenn Canyon release showed, flood stage flows carrying sediment will deposit sediment and help build banks while a steady high flow can cause bank erosion. Table 10 illustrates the scores of riparian health for each management unit.

Rating percent = (Actual Score/Possible Score X 100)

Descriptive Category:

100-80 Healthy (Proper Functioning Condition)

79-60 At Risk

<60 Unhealthy (Non-functioning)

Table 9 Vegetation, soils/geology, hydrology/streambank and total riparian health scores for Nevada Creek by management unit, ordered by stream post

Stream mile	Management Unit	Vegetation Health	Soils/Geology	Hydrology/ Streambank Health	Total Health
31	State Land	71	100	87	86
30.6	John Stitt	25	83	27	32
30	Jay Stitt	25	83	27	32
29.3	Up Wineglass	63	83	33	54
28.6	Up Hatch	72	66	45	56
27.4	Hatch	75	75	33	61
26.3	Mid Wineglass	75	66	66	70
24.7	Mannix hay	66	83	50	63

Stream mile	Management Unit	Vegetation Health	Soils/Geology	Hydrology Streambank Health	Total Health
23.1	D. Mannix	58	83	75	70
22.2	Wineglass	75	83	54	68
20.8	Low Wineglass	75	83	46	65
17.7	Mannix above Helmville	57	83	75	70
16.4	McKee	66	83	75	74
15.6	Up Geary	57	83	42	56
13.6	Mannix below Helmville	75	92	75	78
12.3	Low Mannix	75	92	75	78
9.7	Low Geary	75	92	75	78
8.9	Up Potts	71	83	50	65
7.7	Gravely	57	75	50	59
7.0.	Gravely wetland	92	92	83	89
6.8	Meyers	63	83	42	75
4.7	F&G Potts	71	83	50	65
4.2	MDFWP	62	67	42	52
3.1	Bradshaw	62	67	42	52

Eroding banks

In 1994, Nevada Creek landowners and agency personnel mapped the eroding banks along Nevada Creek. During field verification of the imagery eroding banks along Nevada Creek were marked. I used this information to map the eroding banks in the PAMAP GIS and produced a report of how many meters of eroding banks there were by management unit (Appendix D). Bank erosion is accelerated when banks are trampled by livestock and elk, when flows exceed the hydrologic regime the creek has adjusted to, and when vegetation along the banks is lacking deep binding roots that hold the banks together. From the dam to Helmville, Nevada Creek is approximately 9,000 meters long with approximately 18,000 meters of bank. Of the 18,000 meters, 9,338.8 meters of banks were eroding. From Helmville to the confluence with the Blackfoot River there were 8,062 meters of eroding banks out of a possible 54,000 meters of streambank.

Monture Creek

The upper portion of Monture Creek was very healthy with small areas of human caused disturbance. The overstory was *Picea* spp., *Cornus stolonifera*, *Alnus incana* or *Salix* spp. In some places, the understory consisted of various *Carex* species, but in other places, the understory was mostly introduced grasses such as *Poa pratensis*, *Bromus inermus* and *Phleum pratense*. In the Two Creeks Ranch pastures, several areas had been cleared of *Salix* spp, *Alnus incana* and other riparian vegetation. Some of the cleared areas had thick infestations of *Cirsium arvense* (Canadian thistle). Small patch cuts of *Picea* spp trees had also occurred along the banks of the stream. In the absence of a deep binding root mass the stream was eroding laterally. In the upper Two Creeks pastures, *Cornus stolonifera* was less plentiful though still present and *Crategus* spp and *Prunus virginiana* were growing in the understory. The large *Salix* spp. communities on the Monture Hereford Ranch and Two Creeks Ranch did not appear to receive disturbance from livestock and provided a haven for nesting waterfowl, deer and elk. Impacts to the riparian area increased from the Monture Hereford Ranch down to Highway 200.

The Monture Creek riparian area is Not Functioning approximately one mile upstream or a half mile downstream from where Highway 200 crosses the creek. The fishing access owned by Montana Department of Fish, Wildlife and Parks is At Risk and then improves slightly on the Heart Bar Heart Ranch, where it meets the confluence of the Blackfoot River. Some of the riparian area on the Heart bar Heart Ranch has been fenced and is in an upward trend. Table 10 lists the vegetation, soils/geology, hydrology/streambank and total riparian health by management unit for Monture Creek.

Table 10 Vegetation, soils/geology, hydrology/streambank and total riparian health by management unit for Monture Creek ordered by stream mile post

Stream Mile	Management Unit	Vegetation Health	Soils/Geology	Hydrology/Streambank health	Total Health
13.6	Forest Service	83	75	88	83
11.5	2 Creeks	76	75	83	80
7.5	up Monture	76	83	92	82
5.7	low Monture	50	67	62	58
3.5	Highway 200	50	67	60	57
2.2	MDFWP	63	75	63	65
1.8	Heart Bar Heart Ranch	71	75	63	70

MANAGEMENT IMPLICATIONS

Nevada Creek

Most of the Nevada creek riparian zone is either At Risk or Not Functioning. Riparian shrubs and *Carex* spp. help filter sediments from overland flow, increase infiltration and prevent excessive lateral erosion. A closed canopy of shrubs and trees provides shade to the stream to maintains cooler temperatures in mid-summer. In many places along Nevada Creek, riparian shrubs such as *Salix boothii, Salix drummondii* and *Cornus stolonifera* occur only on one side of the creek or are sparse on both sides. Very few riparian dependent shrub or tree seedlings are surviving. This is a result of active management by the private landowners who mow and clear willows in the active floodplain to maintain their productive hayfields. To increase the filtering and sponge effect and decrease lateral erosion of Nevada Creek, the width of the area with riparian dependent shrubs should be allowed to increase.

An excessive amount of lateral erosion is occurring along Nevada Creek even in the presence of thick *Salix boothii* and *Salix drummondii* communities. This is probably due to an sustained duration of elevated flows from the Nevada Creek Dam. Most of the lateral erosion occurs from Stitt's Ranch down stream through the Wineglass Ranch. After the Helmville bridge, lateral erosion appears to occur only along the outside of meanders that are not protected with willows. Elevated flows over an extended period of time can create excessive erosion because the creek channel is not accustomed to those types of flows and will try to adjust by widening and deepening to accommodate more water.

When streambanks remain saturated from high flows for extended periods of time, they are more susceptible to failure or erosion. Management of the dam to more closely mimic the natural hydrograph of Nevada Creek would allow streambanks to dry during the summer months when they are being used by livestock and would be less susceptible to failure. It is important to allow banks to dry in the fall before they freeze so that they are not as susceptible to ice shearing and failure from freezing and thawing. However, low flows should be managed to maintian the recommended minimum flow for trout.

On the Bradshaw Ranch and Montana Department of Fish Wildlife and Parks lease land and other areas where livestock have been temporarily excluded, restoration of the riparian shrub community could be accelerated by planting native willows along the banks from local cuttings. Cuttings of *Salix boothii* respond well and have a high survival rate. Cuttings should be taken in the early spring before the willows leaf out and planted immediately or left to soak in water until they can be planted. The cuttings should be planted so that part of the stem is in the water table.

Nevada Creek water is high in suspended sediment, tannins, organic matter and phosphorus. Water temperatures are high and may reach temperature lethal to trout. Increasing the canopy cover of riparian dependent shrubs along the stream will help keep water temperatures down. However, return overland flows from irrigated fields should also be monitored and kept to a minimum. Return flows from irrigated fields have been spread over a large area and tend to increase in temperature before they return to the creek. This water can increase the temperature in the Creek and carry more sediments, tannins, and organic matter.

To increase infiltration and decrease overland flows into the creek, ground cover should be increased in the watershed uplands. Higher ground cover will also decrease the amount of sediment exported to the stream. Decreasing overland flow, increasing riparian dependent shrubs, managing stream flows to mimic the natural hydrograph and decreasing sediment input into the stream will allow the stream to increase its depth, decrease its width, decrease water temperatures and increase its habitat complexity for trout.

Monture Creek

With the exception of some small clearcuts on the banks of the stream, upper Monture creek is healthy. Where the trees were cut, the roots of the trees have died and excessive lateral erosion is occurring. In some places on the Two Creeks and Monture Hereford Ranches, large areas of *Salix* spp. have been cleared and drained to create pastures. These cleared areas decrease the filtering ability of the riparian area to prevent excessive sedimentation. Some of the cleared areas are sources of *Cirsium arvense* and *Centaurea* spp. infestations. Careful planning should be conducted to allow the cleared areas within 100 meters of the stream to return to riparian vegetation.

From the Two Creeks Ranch to Monture Hereford ranch, several places have severe cut raw banks which are contributing sediment into the stream. In places, this erosion may be within the natural dynamics of the stream. However, in other places, livestock grazing has reduced riparian shrubs such as *Salix* spp. and *Cornus stolonifera*. Each of these banks should be investigated and considered for stabilization. Revegetation of the riparian shrubs or trees along the base of the eroding areas will develop some deep binding root mass to slow lateral erosion and trap sediment entering the stream.

From the lower part of Monture Hereford Ranch to the fishing access, the width of the riparian shrub community along the banks should be increased. This could be accomplished by temporarily excluding livestock and planting cuttings along eroding banks. On the Heart Bar Heart Ranch, the riparian vegetation has been fenced off and will recover with less livestock pressure and rest.

CONCLUSION

Remotely sensed imagery is a tool that land managers can use to interpret information about a landscape. The accuracy of the interpretation depends on the quality of the images and the knowledge the interpreter has about the area. Airborne acquired imagery has the advantage that it is acquired relatively close to the earth's surface so information does not have to be filtered through miles of haze and clouds as is the case with satellite imagery. ADAR imagery can be collected at different levels of resolution (.25 x .25 m^2 - 10 x 10 m^2 pixel), depending on the land managers objectives and data needs. The spectral reflectance values are recorded on a histogram of 256 values.

The more variable the reflectance is, the less variable the differences between similar reflectance values will be. In Monture Creek, there was a wide range between the spectral reflectance values of the vegetation. This resulted in a lower computer assisted classification accuracy and lower differentiation between the means of spectral reflectance values of riparian shrubs. In Nevada Creek, the range of vegetation spectral reflectance values was narrower, which resulted in better computer assisted classification accuracy and differentiation between the means of spectral reflectance values of riparian shrubs. Before images are acquired the manager should have a clear objective for acquiring the imagery and some knowledge about the relative amount of variability of features on the landscape. The higher topographic and vegetation heterogeneity on the landscape, the more specific the objectives will have to be.

Computer assisted classification will group pixels and help the interpreter recognize patterns. Unsupervised classification is a process which requires very little prior knowledge about the features in the image. The computer groups pixels together into classes with similar spectral values. The disadvantage of this process is that it may not reflect actual attributes that the manager can identify on the ground. In Monture Creek I used a Euclidean distance decision rule of 20, 30 and 40. Using a Euclidean distance of 20 created over 50 classes, many which did not correlate to vegetation type differences. Using a Euclidean distance of 40 grouped all the riparian shrubs into two or three classes. I used a Euclidean distance of 30 to classify the images in both Nevada and Monture Creeks.

Supervised classification requires knowledge about the ground and the user should have a predetermined group of classes. In this process the user trains the computer to recognize specific groups of spectral reflectance values before the classification process. The preliminary results of supervised and unsupervised classification of ADAR imagery in Nevada Creek and Monture Creeks demonstrated that supervised classification is more accurate than unsupervised training. This is consistent with other researchers results working with satellite imagery (Congalton 1991, Craighead and others 1982, Jennings 1996, Walsh 1980).

Once vegetation types have been classified and field verified, ADAR imagery can provide important information about riparian vegetation health and degree of ground cover. Riparian vegetation can be mapped using ADAR imagery and preliminary evaluations concerning riparian vegetation health can be made. Factors such as the width of the riparian vegetation in comparison to the width of the existing floodplain can be detected on the imagery. Eroding banks and bare soils in the riparian zone, factors that lead to excess sedimentation can also be detected on the imagery. In Nevada Creek, I was able to provide information about the hectares of willows, bareground and *Juncus* spp. wetlands by management unit. In Monture Creek the hectares of riparian vegetation by management unit could be calculated.

However, all remotely sensed imagery must be field verified and this imagery is no exception. Highlighted differences in spectral reflectance values can aid the user with interpretation, but spatial and textural attributes are also still an important feature during imagery interpretation. In Nevada Creek, an irrigated hayfield and *Salix boothii* had similar reflectance values but because the spatial and textural distribution of those reflectance values were different, the user could easily differentiate between the two vegetation types.

As more technology around remotely sensed imagery continues to develop, land managers will be able to map and differentiate features on the imagery that were not previously discernible. Airborne acquired imagery offers the advantage that long linear features can be recorded and interpreted. The use of this new technology may offer an accurate and efficient method to classify riparian vegetation which can be entered into a geographical information system. Changes in vegetation and aquatic habitat may be monitored with repeated flights over an area over time. Because ADAR imagery can be acquired at a variety of pixel resolutions, this technology may prove to be a useful tool to accurately and efficiently classify vegetation on a regional scale.

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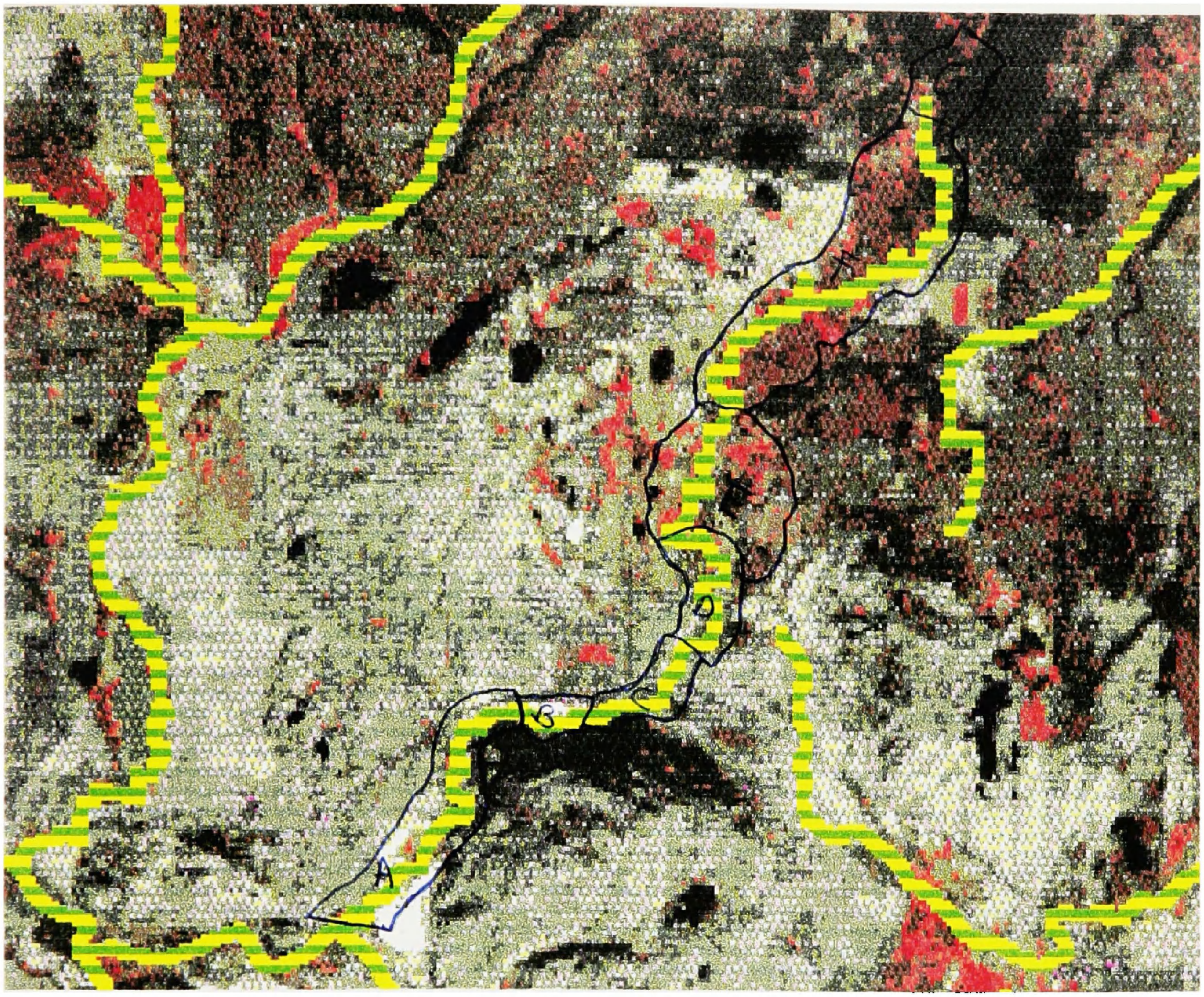
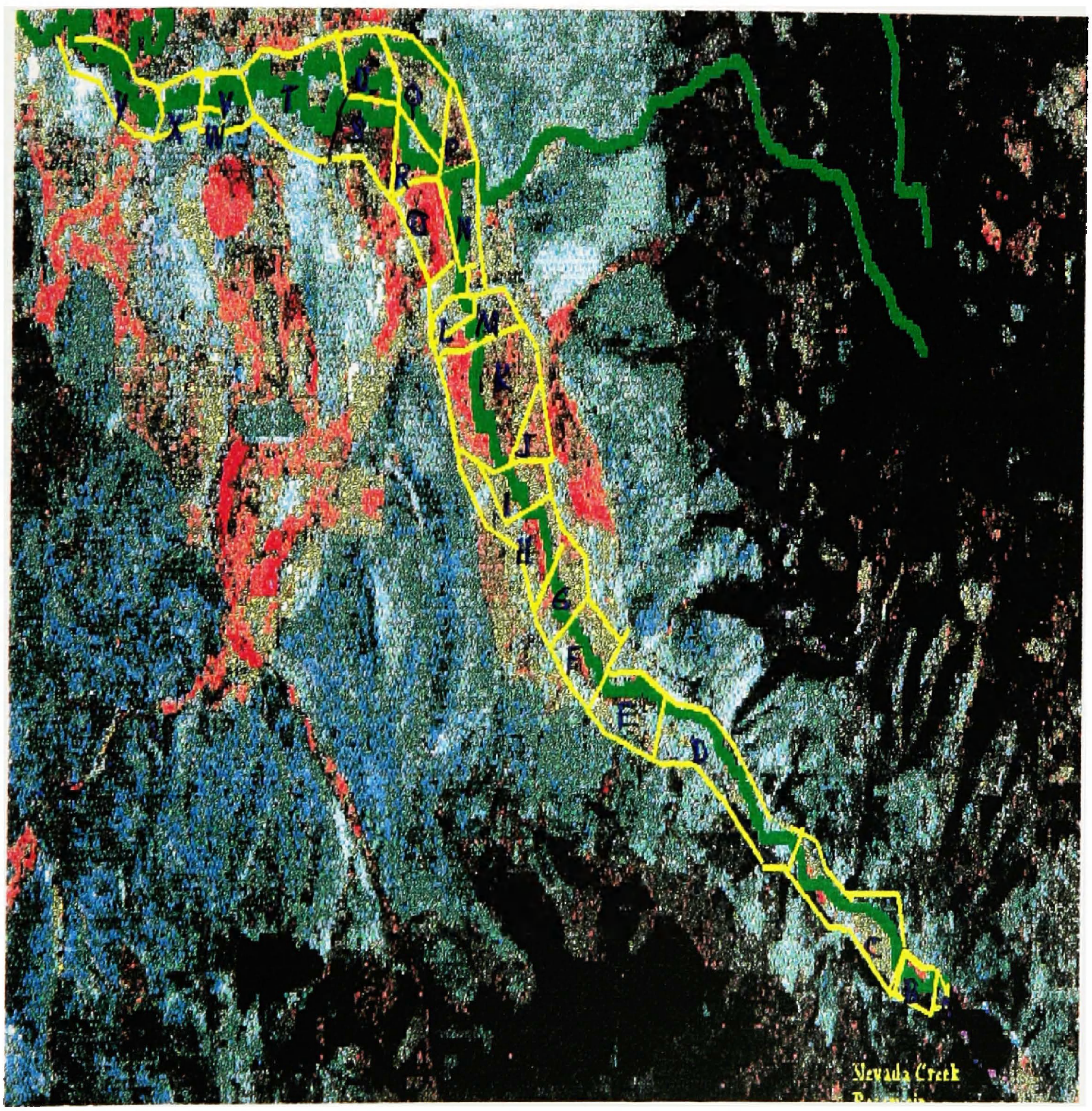
Appendix A
Management Units of Nevada and Monture Creeks

Monture Creek Management Units



A - Heart Bar Heart
B - MDFWP Fishing Access
C - Highway 200
D - Low Monture
E - Up Monture
F - 2 Creeks Ranch
G - Forest Service

Nevada Creek Management Units



Nevada Creek Management Units

A - State Land
B - John Stitt
C - Jay Stitt
D - Up Wineglass
E - Up Hatch
F - Hatch
G - Mid Wineglass
H - Mannix Hay
I - Mannix Pasture
J - D. Mannix
K - Wineglass
L - Low Wineglass

M - Mannix above Helmville
N - McKee
O - Up Geary
P - Mannix below Helmville
Q - Low Mannix
R - Low Geary
S - Up Potts
T - Gravely
U - Gravely wetland
V - Meyers
W - F&G Potts
X - MDFWP
Y - Bradshaw

Appendix B
Plant community field form

Field Verification Form
February, 1996

Stream Reach location ______________________________

Image File #____________ Polygon #____________ %GC ____

Habitat Type by %
of Polygon ______________________________

____

Transect #____ ______________________ %CC of Woody Veg ____

Species	% Canopy	Relative Density	Distribution	Hieght (approx) Woody veg

Transect #____

Species	% Canopy	Relative Density	Distribution	Hieght (approx) Woody veg

Comments ______________________________

Appendix C
Riparian Health Form
(Developed by Paul Hansen for the BLM)

1994 MONTANA BLM/MRWA HEALTH FORM (WITHOUT PFANKUCH)
RIPARIAN WETLAND (LOTIC WETLAND) FORM

The following administrative information is taken directly from the Riparian (Lotic) Wetland inventory form.

— ADMINISTRATIVE INFORMATION —

1) BLM Resource Area:__________ 2) Project (Allotment):__________ 3) Area or Stream: __________

4) Observer(s):__________ 5) Date:__________ 6) Polygon Number:__________

7) Location T:__________ R:__________ Sec:__________ 1/4 Sec:__________ 1/4 1/4 Sec: __________

8a) Riparian Wetland Type (Indicate the appropriate choice: 1; 2; 3; 4; 5; 6; 7; 8; 9; 10; Other):__________

__________ 8b) River Miles (channel length):__________ 9) Size (acres):__________

20) Habitat Type(s), Community Type(s) or Dominance Type(s)	% of Polygon (Cover Class Codes)	Successional Stage or Comments

— HEALTH AND FUNCTION INFORMATION —

Category	Possible Score	Actual Score
VEGETATION		
1. Tree Regeneration (#10)	3	____
2. Woody Decadent and Dead Amounts (#10 & 12)	3	____
3. Utilization Of Trees And Shrubs (#11 & 12)	3	____
4. Shrub Regeneration (#12)	3	____
5. Total Canopy Cover Of Woody Species (#19b)	3	____
6. Combined Canopy Cover Of Four Plant Lifeforms (#19c)	3	____
7. Total Area Occupied By Noxious Weed Species (#21c)	3	____
8. Total Area Occupied By Undesirable Herbaceous Species (#22)	3	____
VEGETATION SUBTOTALS	____	____
SOILS/GEOLOGY		
9. Amount Of Fine Material Present To Hold Water And Act As A Rooting Medium (#41)	6	____
10. Percent Of Polygon With Human-Caused Exposed Soil Surface (#42a & b)	6	____
SOILS/GEOLOGY SUBTOTALS	____	____

Montana BLM/MRWA

July 20, 1994

HYDROLOGY/STREAMBANK

11. Percent Of Streambank With Active Lateral Cutting (#28b)	6	____
12. Percent Of Streambank Altered By Human-Caused Disturbances (#34a)	6	____
13. Percent Of Streambanks With A Deep, Binding Root Mass (#35)	6	____
14. Stream Channel Incisement (#40)	6	____
HYDROLOGY/STREAMBANK SUBTOTALS	____	____

ADDITIONAL MANAGEMENT CONCERNS

16. Streambank Susceptibility Rating — Using The Streambank Rock Volume (#30) And Streambank Rock Size (#30) Criteria, Indicate The Appropriate Choice (Well Armored; Susceptible To Degradation; Highly Susceptible To Degradation): ____________________

17. Trend Comments. Indicate The Appropriate Choice (Improving; Degrading; Static; Status Unknown):________

________ ***Explain:*** ____________________

____

____

____

(Actual Score/Possible Score) X 100 = Rating Percent **Descriptive Category**[1]

VEGETATION	(___/___) X 100	= ______	____________
SOILS/GEOLOGY	(___/___) X 100	= ______	____________
HYDRO/BANKS	(___/___) X 100	= ______	____________
TOTAL	(___/___) X 100	= ______	____________

RATING PERCENT	DESCRIPTIVE CATEGORY
100-80	Healthy (Proper Functioning Condition)
79-60	At Risk
<60	Unhealthy (Non-functioning)

[1] Where two of the Descriptive Categories are lower than the total Descriptive Category, the Total Descriptive Category will be lowered one category. For example, if Vegetation and Soils/Geology have 19 and 8 points (79% and 67%), but Hydrology/Streambank has 22 points (92%), the total points would be 49 (Total Rating Percent = 82%; Healthy [Proper Functioning Condition]). However, the overall Descriptive Category would be lowered to At Risk (rather than Healthy), due to two subgroups being At Risk.

Appendix D
Meters of eroding bank by management unit for Nevada Creek and Nevada Spring Creek

```
Map Name        : 34_46  Dam to Wineglass Ranch

Scan 1 processed  217 elements
============================================================
Polygon Identifier : 1     D. Manix
Count                    :          5
Eroded Length      :    92.93 m     Total Length : 1019.2 m
============================================================
Polygon Identifier : 2      Manix bro
Count                    :         10
Eroded Length      :   318.69 m Total Length : 934.0 m
============================================================
Polygon Identifier : 3       Manix hayfield
Count                    :         19
Eroded Length    :    374.23 m Total Length : 875.26 m
============================================================
Polygon Identifier : 4       Middle Wineglass
Count                    :         13
Eroded Length     :    547.82 m   Total Length : 601.2
============================================================
Polygon Identifier : 5      Lower Hatch
Count                    :         36
Eroded Length     :    976.34 m Total length : 3030.25 m
============================================================
Polygon Identifier : 6    Upper Hatch
Count                    :         28
Eroded Length    :   1120.53 m Total Length 1897.2
============================================================
```

```
Count                         :         15
Eroded Length     :    141.33 m   Total Length :  729.9 m
============================================================
Polygon Identifier : 4   Manix below Helmville
Count                         :         5
Eroded Length    :     50.27 m   Total length : 1648.5 m
============================================================
Map Name       : 65_74 Manix - Potts
Scan 1 processed  130 elements
============================================================
Polygon Identifier : 1  Lower Manix bro
Count                         :         3
Eroded Length       :     66.22 m   Total Length : 1713.1 m
============================================================
Polygon Identifier : 2 lower Geary bro
Count                         :        15
Sum Length                    :    389.85 m
============================================================
Polygon Identifier : 3  upper Potts
Count                         :        20
Total Length  :    441.02 m    Total Length : 1669.4 m
============================================================
Polygon Identifier : 4  Gravely
Count                         :        31
Eroded Length  :   1103.48 m    Total Length : 3713.18 m
============================================================
Polygon Identifier : 5  F&G Potts
Count                         :        48
Eroded Length   :   3586.21 m     Total Length : 5819.0
============================================================
Map Name       : 75-85 Nevada spring creek - Blackfoot river
Scan 1 processed  101 elements
============================================================
Polygon Identifier : 1   Nevada spring/upper Potts
Count                         :         4
Eroded Length    :     70.01 m   Total Length : 586.2 m
============================================================
Polygon Identifier : 2   Nev. spr. lower Potts
Count                         :         0
Eroded Length        :     .00 m     Total Length :   307.8 m
============================================================
Polygon Identifier : 3  Blackfoot River Ranch
Count                         :        17
Eroded Length  :    649.93 m   Total Length :  1804.0 m
```

```
Polygon Identifier : 7  Upper Wineglass
Count                    :         32
Eroded Length  :   1281.56 m Total length 3534.7 m
===========================================================
Polygon Identifier : 8   Jay Stitt
Count                    :         36
Eroded Length  :    941.48 m   Total length 2715.5 m
===========================================================
Polygon Identifier : 9  John Stitt
Count                    :         33
Eroded Length  :   1265.16 m Total Length 2270.3 m
===========================================================
Polygon Identifier : 10  State Land
Count                    :          3
Eroded Length  :     83.21 m   Total Length 1442.5
===========================================================

Map Name       : 47_56
Scan 1 processed   70 elements
===========================================================
Polygon Identifier : 1   Upper pasture/ Lower wineglass
Count                    :         28
Eroded Length  :    803.56   Total Length 4397.1 m
===========================================================
Polygon Identifier : 2  Lower pasture/Lower wineglass
Count                    :         20
Eroded Length   :  691.48 m Total Length 3118.9 m
===========================================================
Polygon Identifier : 3  D. Manix
Count                    :         20
Sum Length  :   510.78 m   Total Length 1749.6 m
===========================================================
Map Name       : 57_64 McKee - Potts
Scan 1 processed   72 elements
===========================================================
Polygon Identifier : 1   Manix above Helmville
Count                    :         12
Eroded Length   :    214.65 m   Total Length :  939.1 m
===========================================================
Polygon Identifier : 2  McKee
Count                    :          7
Eroded Length   :    116.35 m Total Length :  786 m
===========================================================
Polygon Identifier : 3  Upper Geary bro
```

==

Polygon Identifier : 4   Gravely
Count   :   3
Eroded Length   : 120.79 m   Total Length : 4525.6 m

==

Polygon Identifier : 5 Nev. spr./ F&G Potts
Eroded Length :   226.57 m   Total Length   : 1307.3 m

==

Polygon Identifier : 6 Stranahan
Count   :   1
Eroded Length :   15.08 m   Total Length :   182.2 m

==

Polygon Identifier : 7   Lower F& G Potts
Count   :   29
Eroded Length   :   1960.56 m   Total Length :   6310.6 m

==

Polygon Identifier : 8 BFR/Nev. spr. cr.
Count   :   16
Eroded Length   : 559.03 m   Total Length : 4049.7 m

==

Polygon Identifier : 9 Meyers Ranch
Count   :   4
Eroded Length : 301.42 m   Total Length   :   637.76 m

==

Polygon Identifier : 10   F&G Potts House site
Count   :   1
Eroded Length :   23.95 m   Total Length   511 m

==

Polygon Identifier : 11 MDFW&P
Count   :   21
Eroded Length :   1196.39 m   Total Length 1978.3 m

==