University of Nevada

Reno

Aerial Multispectral Videography for Vegetation Mapping and Assessment of Beaver Distribution within Selected Riparian Areas of the Lake Tahoe Basin

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requirements for the degree of

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by

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ABSTRACT

I used multispectral videography to classify 10 streams in the Tahoe Basin, California and Nevada. I mosaicked images before georeferencing and positional accuracy did not decrease relative to a pilot study in the basin. Mosaics were manually separated into 'riparian', 'upland', and 'channel' regions and classified independently, reducing errors caused by spectral overlap among coniferous, deciduous, thick, and thin herbaceous vegetation and between water and shadow. When defining the training data, more than one spectral class defined some information classes. The videography was classified into 11 classes using a step-wise linear discriminant algorithm resulting in average accuracies of 68% and 73% when five cover classes were generalized into two classes. I compared buffer zones of 50, 100, and 200 meters centered on active dams to ones centered on random points. Area estimates of coniferous, deciduous, thick, and thin vegetation were significantly different in at least one of the three buffers.

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INTRODUCTION

Background

Multispectral airborne videography was used to classify and map riparian vegetation within the Lake Tahoe Basin of California and Nevada, to update and enhance current base-line data on riparian habitat. The imagery was obtained on July 17 and 18, 1996. The effort to produce vegetation maps using the imagery constitutes the primary goal of this work. This study stems from a larger project involving the assessment of restoration potential of riparian ecosystems within the Basin, performed through a cooperative effort between the United States Forest Service and University of Nevada Reno with major funding from the California Tahoe Conservancy.

Many species require riparian vegetation habitat. Resource managers need an accounting of this limited resource when designing and implementing management plans affecting watersheds and these habitats. Multispectral videography provides a means for detailed, inclusive, and current inventories. High resolution imagery (less than one meter pixels) allows detailed mapping at large scales. With large onboard hard drives and/or removable storage disks, thousands of images can be collected on a single flight, providing inclusive data sets for regions of interest. After the initial cost of the system, video data is relatively inexpensive to acquire. The costs of film, film processing and conversion to digital form are eliminated. This in turn reduces the cost for re-flying areas to update and maintain data sets. Once the system is acquired, the principal cost for multispectral video data is for aircraft time. There are other advantages to the use of multispectral videography. Once captured, imagery is immediately accessible in digital form and requires no film processing. The near-real-time digital data can be immediately integrated into Geographical Information Systems (GISs) and image processors.

Because videography can also be obtained in very narrow spectral bands (0.005-0.1 microns), data can be classified into information classes useful for many management applications. Several studies show the potential for using multispectral videography to delineate riparian cover types. Franklin (1996) delineated riparian and non-riparian areas within the Tahoe Basin with a reported accuracy of 97%. Bartz (1994) and Redd (1994) successfully classified riparian vegetation into broad cover types in Idaho and Utah, respectively. Videography has been used to distinguish plant species (Everitt et. al., 1987 and Thomasson et. al, 1994), assess vegetation condition (Nixon et. al., 1985) and assess grassland phytomass (Everitt et. al. 1986), and measure the quantity and quality of riverine nesting habitat of piping plovers (*Charadrius melodus*) and least terns (*Sterna antillarum*) Sidle and Ziewitz (1990).

Aside from vegetation mapping, this study documented beaver (*Castor canadensis*) distribution and activity within selected streams in the Tahoe Basin. There are no records referring to beavers in the Sierra Nevada by California fur trappers from the early 1800's (Taylor 1971). The California Department of Fish and Game and the U.S. Forest Service introduced beaver into the Sierra Nevada from 1934 through 1949 to expand and increase fur production (Beier and Burrett 1989).

Within the Eastern Sierra Nevada, beavers have a negative impact on aspen (*Populus tremuloides*) and cottonwood (*Populus trichocarpa*) distribution. Beier and Barret (1987) concluded that aspen and cottonwood may become extinct along the Truckee River if beaver populations are not controlled. Hall (1960) found aspen not to be a renewable resource for beavers. Once it was depleted, beavers shifted to willows which appear capable of withstanding prolonged and heavy utilization (Hall 1960, Kindschy 1985). Distribution and activity data for beavers within the Tahoe Basin will aid resource managers as they address the ecological impacts beavers have in the basin.

Hypothesis Tests

I investigate five hypotheses in this study (only the null hypotheses are listed):

H_{01} : The average accuracy for the classifications using the three band multispectral videography is less than or equal to 17% (expected value for random assignment of pixels to six cover classes). $H1_0 : \bar{x} - 17 \leq 0$

I tested this first hypothesis to determine if the methods used in this study produced classifications of three band multispectral videography with higher accuracies than if pixels were randomly assigned to cover classes.

H_{02} : All estimates for area of coniferous vegetation within buffers with radii of 50, 100, and 200 meters centered on beaver dams are equal to those centered on randomly selected points along the stream channels.

H_{o3}: All estimates for area of deciduous vegetation within buffers with radii of 50, 100, and 200 meters centered on beaver dams are equal to those centered on randomly selected points along the stream channels.

H_{o4}: All estimates for area of thick herbaceous vegetation within buffers with radii of 50, 100, and 200 meters centered on beaver dams are equal to those centered on randomly selected points along the stream channels.

H_{o5}: All estimates for area of thin herbaceous vegetation within buffers with radii of 50, 100, and 200 meters centered on beaver dams are equal to those centered on randomly selected points along the stream channels.

I tested these four additional hypotheses to determine if the vegetation classifications help investigate ecological relationships. Specifically, the relationship of beaver presence, as measured by occurrence of active dams, to area of vegetation types.

Past research has correlated beaver density and presence with percent hardwood vegetation, along with measurements of stream gradient, stream width, stream depth, watershed size and soil drainage (Howard et al. 1985 and Slough et al. 1977). The deciduous classification includes aspen, cottonwood, mountain alder (*Alnus incana*) and multiple species of willow (*Salix spp.*), all of which provide potential food for beaver (Hall 1960). Other potential summer foods include herbaceous aquatic and riparian vegetation (Kindschy 1985) which are included in the herbaceous classes.

Due to time limitations, dams were chosen as buffer centers because of the simplicity of defining buffers to a previously defined point with the Totally New Technology Map and

Image Processing System (TNTmips). Also, some beaver colonies did not maintain lodges, but burrowed in stream banks making center of beaver activity difficult to determine. Dams provided a consistent site to measure but probably lead to the inclusion of areas not utilized by beavers.

The selection of buffers with radii of 50, 100, and 200 meters was based on various research of beaver ecology. Hall (1960) limited his measurements to within 100 feet (30.48 meters) of the stream since at least 90% of beaver cuttings he observed occurred within this zone. Hall's study was conducted along Sagehen Creek, California, which is about 22.5 km north of the Tahoe Basin and similar to streams found in the basin. Many reachers conclude that 100 meters is the maximum distance beavers will travel from water to obtain food (Hodgdon and Hunt 1953, Jenkins 1980). Other researchers, though, have observed beavers traveling 200 yards (182.9 meters) to obtain food (Hammond 1943, MacDonald 1956).

Study Area

The Tahoe Basin lies within the Sierra Nevada in California and Nevada, occupying 1112 square km between the main crest of the Sierras to the west and the Carson Range to the east (Strong 1984). Volcanic activity to the north bridged the two crests, forming the 488 meter deep Lake Tahoe (Webster 1981). Elevations range from 1900 meters at lake level to 3317 meters at Freel Peak. The major rock units found in the Basin are Pre-cretacrous metamorphic, granitic intrusions, Cenozoic volcanic, and Quaternary glacio-fluvial deposits (Burnett 1971).

Elevation, slope, aspect, and soil type strongly influence forest types in the Basin. Generally elevation can delineate the transition of forest types (McClure et al. 1994). Stands of Ponderosa (*Pinus ponderosa*) and Jeffery pines (*P. jeffreyi*) are dominant from 1900 m to 2150 m. Mixtures of White fir (*Abies concolor*), Sugar pine (*P. lambertiana*) and Incense cedar (*Calocedrus decurrens*) grow on wetter sites. Stands of Red fir (*A. magnifica*) and Western white pine (*P. monticola*) with some Jeffery pine occur between 2150 m and 2750 m. Lodgepole pine (*P. contorta*) and Mountain hemlock (*Tsuga mertensiana*) grow on wet sites in this zone. From 2750 m and up a subalpine type includes Whitebark pine (*P. albicaulis*), Mountain hemlock, Western white and Lodgepole pines. Narrow riparian corridors containing Aspen, Cottonwood, Mountain alder (*Almus incana*), American dogwood (*Cornus sericea*), numerous willow species (*Salix spp*.), and herbaceous meadows bisect coniferous forest types.

Ten highest priority perennial streams were selected for mapping. They are Big Meadow, Blackwood, Burton, Cold, Meeks, Taylor, Trout, Upper Truckee, Ward, and Watson (Figure 1).

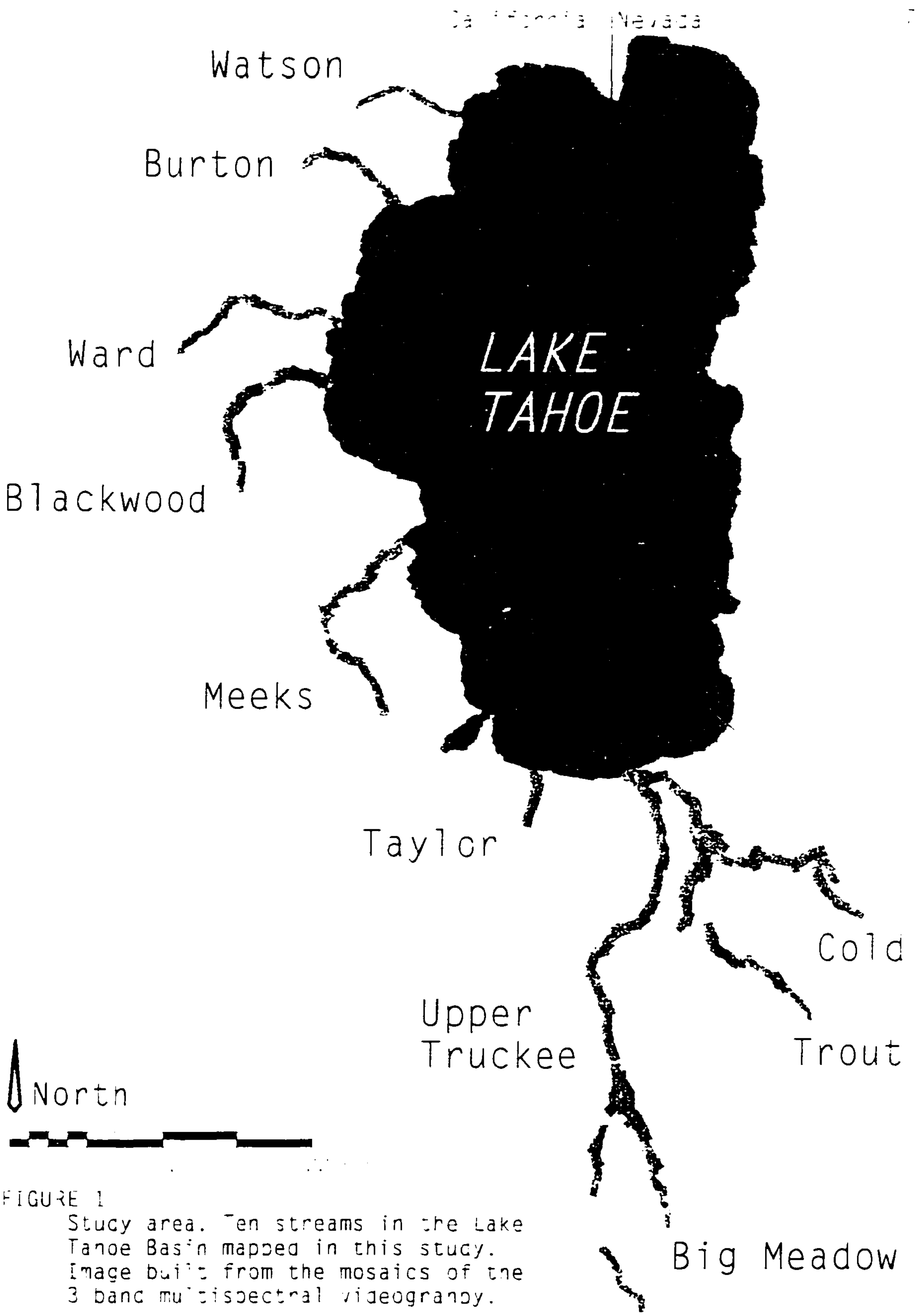


FIGURE 1
Study area. Ten streams in the Lake Tahoe Basin mapped in this study. Image built from the mosaics of the 3 band multispectral videography.

MATERIALS

Videography

A three-camera multispectral digital video imaging system flown from a Cessna 206 turbo fixed wing aircraft obtained the imagery for mapping (Figure 2). The system has three charge coupled device (CCD) analog video cameras with 12.5 mm lens. The cameras are equipped with filters sensitive to either green (0.55-0.565 μm), red (0.625-0.635 μm), or near infrared (0.845-0.857 μm) light energy. The cameras simultaneously captured each scene, which was downloaded to an on-board computer using a 480 x 640 RGB video capture board. The onboard computer has a pentium 100 CPU, and a one gigabyte hard drive that can store about 1000 color infrared (CIR) composite images. Streams were flown from the head waters to the mouths while attempting to remain at an elevation of 610 meters above ground. This proved difficult in the mountainous terrain and resolutions varied from 0.66 to one square meter pixel area. I resampled all images to a constant resolution of one meter for images of 480 by 640 meters. Maintaining proper exposure was difficult because of the constantly changing relative amounts of riparian and adjacent coniferous vegetation as well as the difficulty of setting apertures for each camera during flights.

Kodak Digital CIR Imagery

A set of CIR imagery taken by a Kodak DCS 420 digital camera, flown and captured

(A)

(B)

Figure 2
Images from the 3-band multispectral video system and Kodak DCS 420 digital camera.
A. An image captured by the 3 camera system used in this study. This image has been corrected for both interlace and registration errors.
B. An image captured by the digital camera.

by Cyberdyne Earth Imaging (private contractor) on August 27, 1997, became available later in this study (Figure 2). The 1012 x 1524 images produced by this system have a resolution of 0.3 meters representing an area of 304 by 457 meters. This high quality data was a valuable substitute for ground verification. All information classes defined on the videography can be identified on the Kodak digital CIR imagery through visual interpretation.

Digital Orthophoto Quadrangle (DOQ)

DOQs are digital images made from aerial photographs mosaicked together to cover an area representing a 7.5 minute USGS map. These images are planimetrically correct and are georeferenced by defining the tic marks located in each corner with the positional data accompanying each scene. DOQs have a resolution of two meters and Digital Orthophoto Quarter-Quadrangles (DOQQs) have a resolution of one meter. More information can be found in the product documentation available through the United States Geological Survey (1993).

Field Maps

Field maps for all streams in this study were made from DOQQs, printed at a scale of 1:4500. While walking each stream, I delineated training data for information classes and locations of beaver activity on the appropriate map. Since I georeferenced the videography to the DOQQs, I easily applied these data to the videography.

35mm Photographs

I took photographs while surveying streams. I marked the locations of the photographs and directions of view on the DOQQ field maps. I also took photographs of the streams from the air on a reconnaissance flight surveying the study area. These photos assisted in the interpretation of the videography.

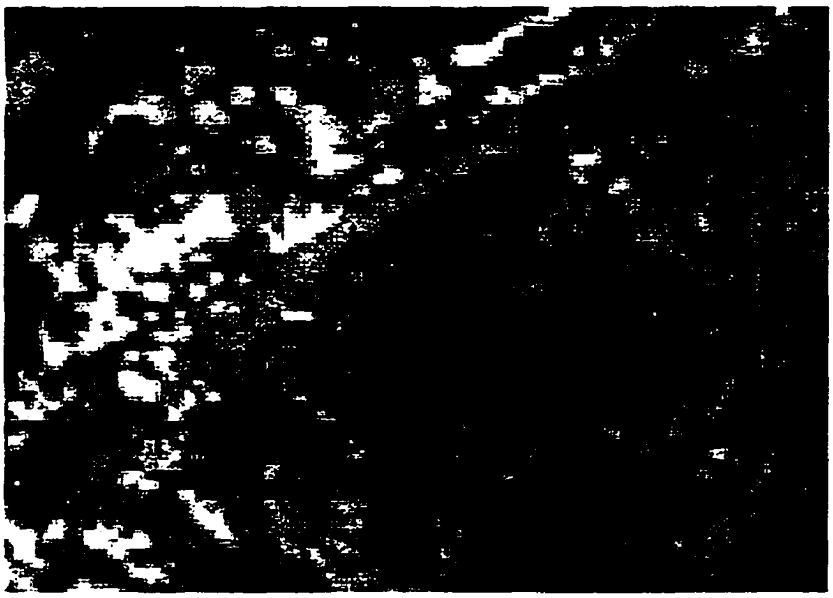
METHODS

Image Preparation

The first phase of image preparation involved the correction of two forms of error. First, I had to make an interlace adjustment (Figure 3). This adjustment involved shifting even rows within the raster files (images) to the left to account for the displacement resulting from movement of the aircraft while the image was being captured. This displacement occurred because our video system first records odd rows then even rows when creating a raster file. In the 1/60 of a second time interval between recording the odd and even rows, the aircraft moved enough so that pixels within the even rows are displaced by one or two pixels. I made this adjustment with a FORTRAN program that allows users to shift pixels in the even rows of raster files to the left or right. For a complete description of this type of geometric distortion see Pickup (1995).

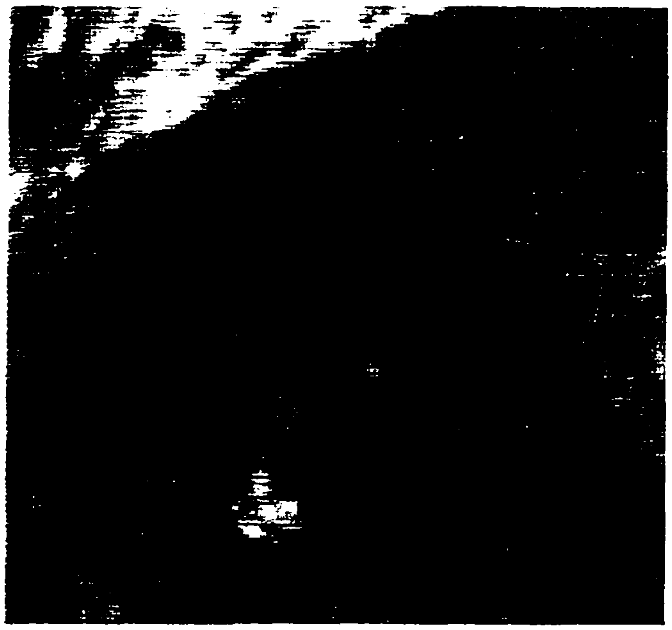
The second adjustment involved correcting for registration errors among the three video cameras (Figure 4). Before correction, a ground point occupied different positions in the three rasters created by the three cameras. Using TNTmips, I corrected this error by copying (positioning) each raster into larger rasters so that a given ground point occupies the same position in each. This process added blank (digital numbers (dn) = zero) rows and columns to the peripheries of the unregistered rasters. Then I trimmed the peripheries of the larger rasters in a way so that all blank rows and columns were removed, and given ground

(A)



(B)

Figure 3
Example of the interlace correction applied to band-1 (near infrared).
A) Image before the interlace correction.
B) Image after the interlace correction.



(A)

(B)

Figure 4
Example of the registration correction.
A. Image before the registration correction.
B. Image after the registration correction.

points would still occupy the same position within the three rasters. Placing pixels in registration gives the proper color combination for a simulated color infrared photo. As a result of this adjustment five rows and seven columns were lost from each of the original three images.

The second phase of image preparation was mosaicking. Mosaicking links sequential images to form a new raster (Figure 5). TNTmips allows a user to define two common points within the two images to be linked, then builds one large raster based on how the user chooses to link the images. In this study, I divided each stream into several mosaics based on contrast between images, habitat, aspect and slope. This allows for classifying similar images while the influence of the aforementioned factors on radiance values is minimized.

Georeferencing was the third phase of image preparation. I georeferenced the mosaics to DOQQs. Georeferencing was accomplished by selecting common points on each and then applying the positional data for the points on the DOQQs to the mosiacs. At least nine points where selected from each mosaic within the riparian zone and along the periphery. Because of time limitations, I chose mosiacking before georeferencing, rather than the reverse order, to speed the process. Surprisingly, this did not lead to a decrease in positional accuracy.

Positional accuracy of the georeferenced mosaics is measured by the root mean square error (rmse). RMSE is a measure of the variation of the positions of points in a georeferenced image to known geological positions and is defined as (Maling 1989):

$$RMSE = \pm \sqrt{\ {}^{1}/_{n-1}[(x_1-x_2)^2 + (y_1-y_2)^2\ ]}$$

FIGURE [illegible]
Mosaic of Taylor Creek made from 11 individual images.

x_1 = true 'north/south' coordinate
x_2 = map 'north/south' coordinate
y_1 = true 'east/west' coordinate
y_2 = map 'east/west' coordinate
n = sample size

When georeferencing an image to a previously georeferenced image, total rmse is defined as (Maling 1989):

$$\text{Total RMSE} = \pm\sqrt{(\Sigma \text{RMSE}_i^2)}$$

(where RMSE_i is the error for each map used in production)

Resampling was the final phase of image preprocessing. Due to topology, changes in flying height, and varying degrees of image obliqueness, pixel resolution was variable within and among images. Images must be resampled and geometrically transformed (warped) to planimetrically correct them. Resampling is the interpolation of new pixel values and geometrical transformation is the differential stretching of an image to change its internal geometry (McCullagh et. al. 1980). I resampled and rectified all mosaics to a common resolution of one meter using a cubic convolution interpolation algorithm and a piecewise affine geometric transformation model.

Preliminary work revealed that the one-meter-resolution imagery was too fine for mapping the desired information classes. Trees were commonly represented by many pixels of varying radiance values, some of which overlapped the radiance values of other information classes. When I classified an image of this resolution, individual trees were not classified into unique classes but rather into a composite of classes. I sought a method to 'smooth' the images so that individual trees were represented by a group of pixels with similar radiance values unique to that information class. To accomplish this, I resampled the images from a resolution of one meter to a resolution of three meters and then resampled from three meters back to one meter (Figure 6). After resampling, a group of pixels with an 'averaged' radiance value represented individual trees and the spectral overlap among information classes was greatly reduced. However, the edges between information classes became slightly less distinct. Typically the differences between radiance values of pixels on opposing sides of edges were sufficiently large so that averaging of edges did not preclude their detection.

Videography for 6% of Trout, 15% of Upper Truckee, 41% of Meeks, and 46% of Cold were not obtained. All of the missed sections with the exception of Trout, occurred in the upper regions of the streams. In these regions, imagery from the Kodak DCS 420 digital camera, if available, was inserted. I georeferenced, resampled, rectified, and mosaicked the Kodak imagery with the same methods used for the videography. Unlike the three-band multispectral videography that senses three narrow spectral regions, the Kodak DCS 420 digital camera has a broad sensitivity ranging from 0.4 um to 1.0 um when fitted with an infrared filter. This imagery was classified independent of the videography to fill in gaps in the maps derived from the videography. Differences in classification accuracies between the two sets of imagery were not tested. First, the imagery collect by each system is of different areas. Second, one of the reasons why the videography was not obtained was due to the sparse riparian vegetation in the these areas which in turn made following the narrow stream channels difficult. In these areas there is less heterogeneity of cover classes, so classifications of these areas would be higher than in the more spectrally complex areas obtained with the

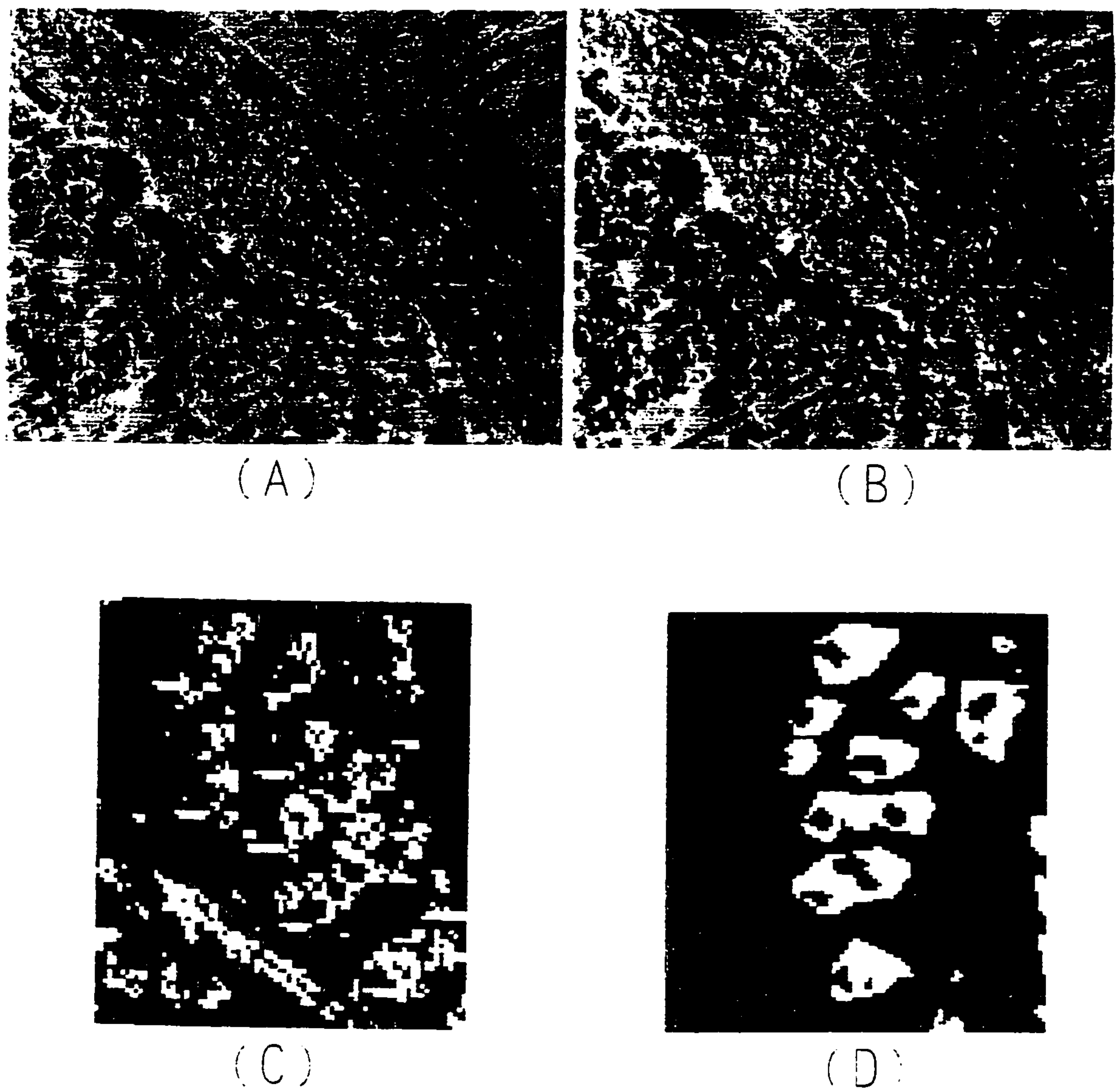


Figure 6

Example of resampling from one meter to three meters and back to one meter.

A Image at original one meter resolution.

B Image after resampling from one meter, to three meters, and back to one meter.

C Portion of a classification of A showing the confusion of the coniferous class (yellow) with the thin herbaceous class (red).

D Portion of a classification of B showing the reduction of confusion of the coniferous class with the thin herbaceous class.

videography.

Classification

To classify imagery, I first defined several regions of interest for each mosaic. In general, these regions can be described as stream channels, coniferous uplands, and riparian vegetation along stream channels. This was necessary because of the spectral overlap between the water class and the shadow class and the overlap between the coniferous class with the deciduous and the herbaceous classes. Within the *feature mapping* module of TNTMips, a region of interest can be drawn over the display of the mosaic and then saved as a raster. Then, during the classification process, the region of interest defines the area of the mosaic to which the classification algorithm is applied. Therefore, stream channels, coniferous uplands and riparian vegetation can be classified separately minimizing the errors of confusion between the water and shadow classes and the conifer class with both the deciduous and herbaceous classes (Figure 7).

The second step involved the creation of a raster of training data to be used with a supervised classification. Within the *feature mapping* module of TNTMips, a raster of training data can be defined over the display of the mosaic. In this process, selected pixels of the training raster are assigned to classes. Class designation is based on the interpretation of field maps, ground photos, and aerial photos.

The third step is to classify the mosaic. I chose a step-wise linear discriminant analysis as the best classification algorithm to use based on the work of Franklin (1996). Each region

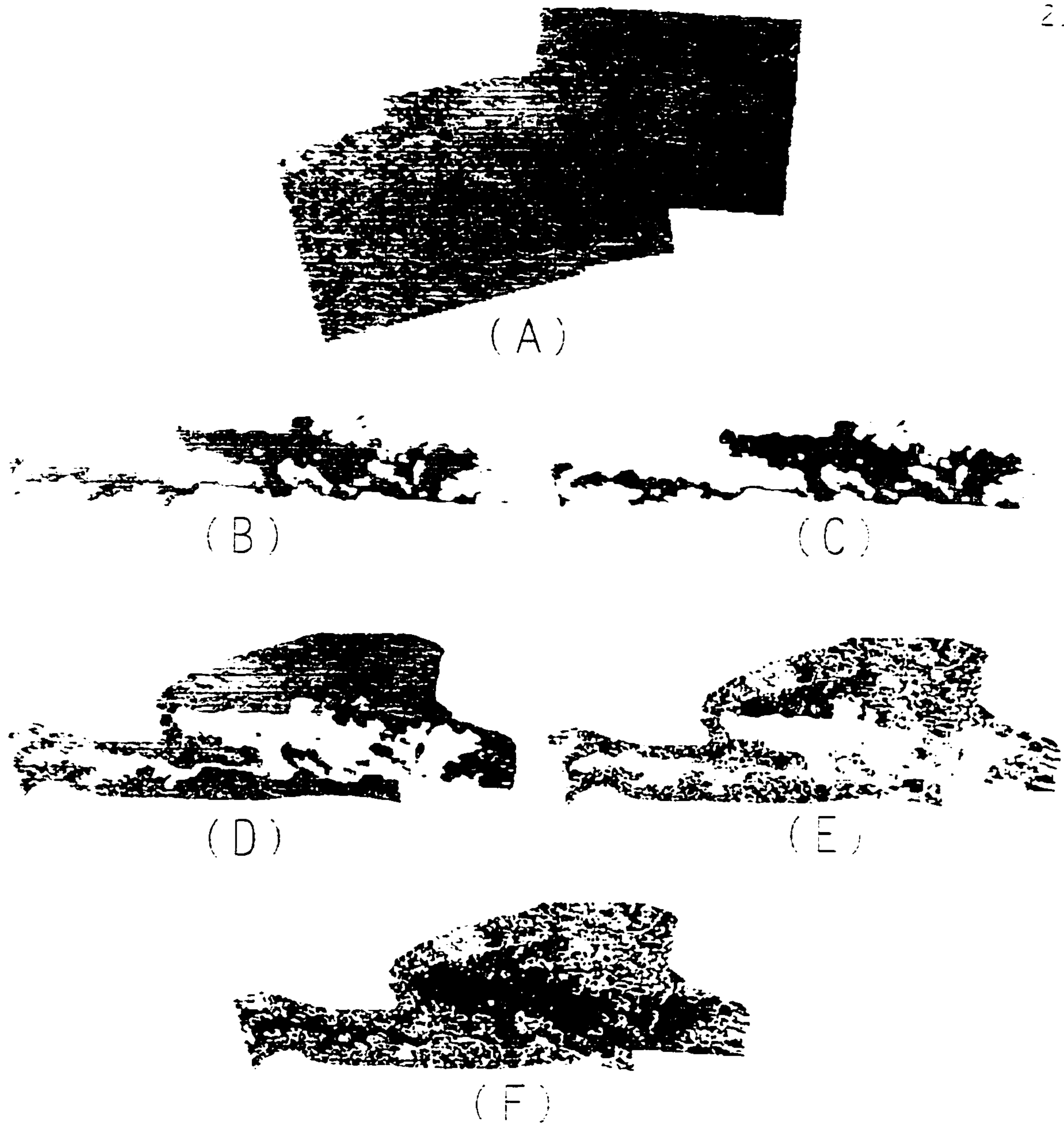


FIGURE 7

Example showing the use of a region of interest in classifying a mosaic.

A. Mosaic of the 3 band multispectral videograph.
B. Mosaic with the upland areas masked out
C. Classification of the mosaic with the upland areas masked
D. Mosaic with the riparian areas masked out
E. Classification of the mosaic with the riparian areas masked
F. Classification after classifications (C) and (E) are combined

Note: Classifying mosaics in this manner help to reduce the error of confusion between the coniferous, deciduous, and other herbaceous classes.

of interest within a mosaic is classified independently, producing a raster with only the area within the region of interest classified. For these rasters, the pixels outside the region of interest are given digital number (dn) values of zero. Then, the independently classified rasters corresponding to the regions of interest in a given mosaic are added together to produce one classification raster representing the whole mosaic.

Finally, like classes have to be grouped into common information classes. When assigning pixels of the training raster to classes, many information classes could not be defined by a single spectral class. To produce accurate maps it is necessary to define some information classes by several spectral classes. For example, the information class for water is defined by two spectral classes: 'shallow' water and 'deep' water. The information class for conifer is defined by three spectral classes: 'crown', 'lighted-side', and 'shaded-side.' Deciduous was defined by four spectral classes and thick herbaceous by two. Because the training rasters define a specific spectral part of the desired information classes, the classification algorithm generated rasters with some information classes represented by more than one digital number. To avoid errors in testing the accuracy of the final classification raster, all desired information classes must be represented by one digital number. An example of this type of error would be classifying a pixel representing the 'dark-side' of a conifer as the 'shaded-side' of a conifer. This type of error is irrelevant because the desired information class was correctly identified.

Accuracy Testing

To test the accuracy of the classification maps produced, I compared ground truth rasters with the classification rasters. I used a stratified random sampling scheme to select pixels to be used in accuracy testing which allows for the same statistical analysis as unrestricted random sampling (Maling 1989). Each mosaic for each stream was divided into equal-size grids for random selection of one pixel per grid. Thus, the entire mosaic was adequately sampled. I developed a region of interest to mask the pixels to be sampled. Because a masked pixel cannot be defined, I defined the adjacent pixel to its left. Then, I built the ground truth raster over a display of the mosaics and region of interest of sampled pixels in the *feature mapping* module of TNTMips. I defined each sampled pixel's information classes through interpretation of the high resolution Kodak DCS 420 imagery, aided with the DOQQ field maps and 35 mm photographs. I could overlay the ground truth raster with the training data raster so that if pixels were used both as training data and sampling points they were identified and replaced with new sample pixels. This removes the bias introduced by using previously defined pixels in accuracy assessment.

Using a Statistical Analysis System (SAS) program written by Franklin (1996), contingency tables were developed to compare the sample pixels within the classification rasters and the ground truth rasters. Total accuracy for the classification raster is defined as the sum of the center diagonal of the contingency table divided by the total sum of sample pixels. Conglalton (1991) describes two other types of accuracy that provide information as to how well cover classes are mapped. First there is producer's accuracy which is a measure of omission error. Omission error describes the error when pixels belonging to a cover class fail to be classified as that cover class. Producer's accuracy is defined by dividing the number of correctly identified pixels for a cover class by the total sum of pixels for that cover class as derived from the ground truth data (the cover class column total in a contingency table). Secondly, there is user's accuracy which is a measure of commission error. Commission error describes the error when pixels are classified to cover class when they actually belong to a different cover class. User's accuracy is defined by dividing the number of correctly identified pixels for a cover class by the total sum of pixels classified into that cover class (the cover class row total in a contingency table).

Data Layers

In this study, I developed GIS data layers for data of three themes. Vegetation maps of eleven cover classes were produced in both raster and vector format. Vector point coverages were made of beaver activity. Buffers centered on beaver dams and random points were cut from the vegetation maps.

Cover Classes

I mapped the videography into eleven cover (information) classes:

coniferous	coniferous trees and shrub understory associated with the coniferous uplands
deciduous	deciduous trees and large deciduous shrubs
thick herbaceous	herbaceous riparian vegetation growing as a thick mass with no bare ground showing between plants
thin herbaceous	herbaceous riparian vegetation growing as a mass with some bare

	ground showing between plants
upland herbaceous	herbaceous vegetation associated with uplands
burnt ground	herbaceous regrowth following a recent fire with black ash showing between plants
bare ground	areas with no or sparse vegetation, sand, gravel, or rocks < 0.5 meters in size
rocks	rocks > 0.5 meters in size
flooded meadow	meadows with standing water
water	lakes, ponds, and streams
shadow	unknown areas with low dn values due to lack of illumination

Coniferous and deciduous species are listed in Appendix Tables 1 and 2, respectively. Various grass, sedge, rush, and forb species form the thick and thin herbaceous classes. Grasses and forbs mostly comprise the upland herbaceous class. Franklin (1996) provides an excellent list of plant species encountered in his study in the Lake Tahoe Basin.

Classifying individual images may have resulted in the mapping of more specific cover classes. As Redd (1994) was able to separate his deciduous class into a cottonwood/Russian Olive class and a willow class, I was able to separate aspen/cottonwood and willow/alder into separate deciduous classes within individual images. However, when I mosaicked individual images together it became impossible to accurately separate the deciduous classes. There is sufficient variation in brightness values for aspen/cottonwood and willow/alder between the individual images that these classes do not exist as unique spectral classes within a mosaic of several images. This variation may be due, in part, to the differences in contrast, slope, aspect and view angle among images.

Beaver Points

I generated data layers for beaver activity points as point vectors georeferenced with

DOQQ field maps to the mosaicked videography (Appendix Table 3). These points are defined as fresh chewing, old chewing, active dams, inactive dams, active lodges and inactive lodges. Since these data were collected during the summer of 1996, the terms fresh and active refer to this period and the terms old and inactive refer to periods before the summer of 1996. I created these files in the *object editor* module of TNTMips, where each point could be defined over a display of the three band multispectral videography as a background.

Dam Buffers

Active dams were chosen as sites to investigate because these structures have a great influence on the ecosystem (Naiman et. al. 1988). These influences include: retainment of sediments, creation of wetlands, modification of nutrient cycling, and modification of riparian zone structure. I created buffer zones having radii of 50, 100, and 200 meters on each point corresponding to the 31 active dams and on 31 randomly selected points. I defined buffer areas around each point in the *prepare-vector-buffer zone* module of TNTMips. Then I clipped out the desired region of the classification raster in the *prepare-raster-combine* module of TNTMips. Then I compared the average total area of coniferous, deciduous, thick and thin herbaceous vegetation between buffer zones centered on dams and those centered on random points using the computer program FRAGSTATS (McGarigal et. al., 1995).

RESULTS

Georeferencing

Mosaicking before georeferencing did not lead to a decrease in positional accuracy. Franklin (1995), using the same software and similar images, georeferenced before mosaicking and reported a rmse of 9.14 meters, determined from ten randomly selected points. Franklin's mosaic has a rmse of 9.00 meters with respect to the DOQQ. The DOQQ Franklin used has a reported rmse of 1.6 meters. For this study, 30 points were randomly selected from the mosaics of the ten streams. The rmse for these mosaics is determined to be 7.61 meters with respect to the DOQQs. The average rmse for the DOQQs used for geoferencing is 2.3 meters, making the total rmse for the mosaics and vegetation maps produced 7.96 meters.

Classifications

All ten streams were classified using step wise linear discriminant analysis, a supervised classification algorithm available in TNTMips. Franklin (1996), who worked with similar images within the Tahoe Basin, found this algorithm to produce the classifications with the highest accuracies. Classification accuracies are listed in tabular form. I also include a brief description of the vegetation characteristics for each stream reach. Field teams, staffed by the UNR and the Lake Tahoe Basin Management Unit (LTBMU) of the USFS, divided each stream into reaches based on channel morphology according to the Rosgen classification system (Rosgen 1994). Channel morphological characteristics were measured at representative cross sections of reaches and included: bankfull width, mean bankfull depth, entrenchment ratio, bed material, and gradient. A reach is defined as a part of a stream in which these measurements remain generally consistent or in a repeating pattern such as with a pool riffle sequence. A second accuracy table reports classification accuracy when the classifications are generalized by combining the thick herbaceous and thin herbaceous classes into one herbaceous class and combining the upland herbaceous, bare ground, and rock classes into one upland class.

Big Meadow Creek

I defined the following vegetation and cover classes for Big Meadow Creek: coniferous, shadow, thick herbaceous, thin herbaceous, deciduous, upland herbaceous, bare ground, and water (Tables 1 and 2; Appendix Figure 1).

Stream morphology classification, and hence the first reach, started immediately above the second intersection with Highway 89 instead of at the confluence with the Upper Truckee River. From the confluence with the Upper Truckee to the first intersection with Highway 89, the vegetation consists mostly of conifers with some deciduous vegetation along the stream channel. Upstream from the first intersection there is a large meadow of thick herbaceous vegetation with scattered willows along the channel. From the end of the meadow to second the intersection with Highway 89, the vegetation consists mainly of conifers. The first defined reach extends 560 meters from the intersection to the start of a second larger meadow. The vegetation along this reach is coniferous with scattered deciduous species, mainly alder, along the channel. The reach is steep with a narrow riparian corridor. The second reach extends 1260 meters through the entire meadow. The large meadow consists of thick herbaceous vegetation with some deciduous willows close to the channel. The upper part of the reach extends into an aspen/coniferous mixed stand. The next four reaches are a combined 1019 meters and are very similar to each other with the vegetation along these reaches consisting mainly of conifers with deciduous vegetation (alders) restricted to a steep narrow riparian corridor. Stream reach classification ended at the confluence of smaller immeasurable channels. The vegetation upstream from this point consists mostly of conifers and deciduous along a narrow channel. There are a few small meadows with thick herbaceous vegetation.

There are no active beaver colonies along this creek. A few very old beaver chewed

			Ground Truth Pixels									
		class values	10	15	20	25	30	40	55	60	total	user's accuracy (%)
Classified Pixels	coniferous	10	**73**	6	1	1	10	0	0	0	92	79
	deciduous	15	9	**21**	2	0	2	0	0	0	35	60
	thick herb.	20	1	0	**29**	1	0	0	0	0	31	94
	thin herb.	25	1	2	1	**6**	0	0	0	0	10	60
	upland herb.	30	5	0	1	1	**8**	0	0	0	15	53
	bare ground	40	0	0	0	1	4	**3**	0	0	8	38
	water	55	0	0	0	0	0	0	**0**	0	0	—
	shadow	60	7	1	0	0	1	0	0	**35**	44	80
	total		96	30	34	10	25	3	0	37	235	
	producer's accuracy (%)		76	70	85	60	32	100	–	95		74% total accuracy

Table 1: Contingency table for Big Meadow Creek with all cover classes

		class values	Ground Truth Pixels 10	15	herb	up	55	60	total	user's accuracy (%)
	coniferous	10	**73**	6	2	10	0	1	92	79
	deciduous	15	9	**21**	2	2	0	1	35	60
Classified Pixels	**herb.**		2	2	**37**	0	0	0	41	90
	upland		5	0	3	**15**	0	0	23	65
	water	55	0	0	0	0	**0**	0	0	—
	shadow	60	7	1	0	0	0	**35**	44	80
	total		96	30	44	28	0	37	235	
	producer's accuracy (%)		76	70	84	54	–	95		77% total accuracy

Table 2: Contingency table for Big Meadow Creek with the generalized Herbaceous and Upland classes.

stumps were found along the stream in vicinity of the first meadow between the highway intersections.

Combining thick and thin herbaceous into one herbaceous class and upland herbaceous and bare ground into one upland class improved the overall accuracy from 74% to 77%. Erroneous classification of upland herbaceous as bare ground caused most of this difference. The low accuracies for the upland herbaceous and upland classes are due to confusion with the coniferous class. There is no measure of accuracy for water because no sampling occurred in this class. The water cover class represents only a small fraction of the Big Meadow Creek classification.

Blackwood Creek

I defined the following vegetation and cover classes for Blackwood Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, rock, water and shadow (Tables 3 and 4; Appendix Figure 2).

The first reach extends 385 meters from the mouth to just below Highway 89 and is typified by deciduous vegetation immediately around the stream channel, bordered by conifers and some upland herbaceous vegetation further out. Above the highway, the second reach extends approximately 1510 meters upstream, and is characterized by a similar vegetation pattern. Midway through the reach, a sloping meadow with mostly deciduous vegetation and some thick herbaceous vegetation occurs along the northern bank of the channel, and upland herbaceous vegetation occurs along the higher southern banks. Mostly deciduous vegetation with some thick herbaceous patches characterize the third, 170 meter, reach. Conifers increase away from the stream, along with standing dead trees and downed logs. For 283 meters, the banks along reach four are steep cut banks, often slumping and unstable. Most vegetation along the channel is deciduous with patches of thin herbaceous. Patches of thick herbaceous vegetation occur south of the stream. For the next 1329 meters along the fifth

			Ground Truth Pixels										
		class values	10	15	20	25	30	40	45	55	60	total	user's accuracy
	coniferous	10	**69**	11	1	16	1	0	3	0	4	105	66
	deciduous	15	17	**72**	2	18	1	0	0	0	3	113	64
	thick herb.	20	0	3	**2**	1	0	0	0	0	0	6	33
Classified	thin herb.	25	8	2	0	**22**	5	2	0	0	0	39	56
Pixels	upland herb.	30	4	1	0	8	**4**	2	0	0	0	19	21
	bare ground	40	0	0	0	1	3	**9**	1	0	0	14	64
	rocks	45	0	0	0	0	5	0	**5**	0	0	10	50
	water	55	1	0	0	0	1	0	0	**17**	3	22	77
	shadow	60	13	1	0	0	0	0	0	2	**35**	51	69
	total		112	90	5	66	20	13	9	19	45	379	62 %
	producer's accuracy (%)		62	80	40	33	20	69	56	89	78		total accuracy

Table 3: Contingency table for Blackwood Creek with all cover classes

and sixth reaches, the vegetation is similar to reach four with the addition of bare gravel patches. Reach seven extends approximately 2490 meters, ending above the small pond remaining from gravel mining. Within this pond there is an active beaver lodge. Along the lower part of this reach inflow along the southern riparian zone feeds a meadow with deciduous and some thick herbaceous vegetation. Mostly deciduous vegetation with conifers away from the channel and bare gravel patches next to the channel characterize the remainder of reach seven.

Reach eight extends for 179 meters and ends beneath a large concrete structure (fish ladder). This reach is characterized by gravel bars with patches of thin herbaceous and deciduous vegetation. Above the concrete structure, the stream has been diverted into a straightened channel. Reach nine is the old channel winding 255 meters north of the straightened channel. Mostly conifers with some scattered deciduous occur along the dry stream bed including several large cottonwoods. Reach 10 extends from the fish ladder upstream for 1336 meters above the fish ladder, along the straightened channel, and beyond the diversion of the original channel. Along the straightened section, conifers with a few isolated deciduous trees and upland herbaceous vegetation border the channel. The upper half of reach 10 shows greater diversity in vegetation, including more deciduous and small patches of thin herbaceous bordered by conifers. In the upper most part of reach 10, the riparian zone widens and deciduous vegetation becomes more prevalent. A relatively narrow riparian corridor characterizes the 374 meters of reach 11, with deciduous vegetation along the stream bordered by conifers. Reach 12 extends for 1051 meters and has a similar

		Ground Truth Pixels								
		class values	10	15	**herb**	**up**	55	60	total	user's (%) accuracy
	coniferous	10	**69**	11	17	4	0	4	105	66
	deciduous	15	17	**72**	20	1	0	3	113	64
Classified	**herb.**		8	5	**25**	7	0	0	45	56
Pixels	**upland**		4	1	9	**29**	0	0	43	67
	water	55	1	0	0	1	**17**	3	22	77
	shadow	60	13	1	0	0	2	**35**	51	67
	total		112	90	71	42	19	45	379	
	producer's accuracy (%)		62	80	35	69	89	78		65% total accuracy

Table 4: Contingency table for Blackwood Creek with the generalized Herbaceous and Upland classes

vegetation pattern as reach 11, with the addition of a large rocky region in the upper part just beyond where the South Fork of Blackwood enters. No videography was obtained for the last four reaches (13-16) along the Middle Fork of Blackwood Creek. There is an active beaver colony in the upper portion of reach seven. In the lower portion of reach seven, fresh beaver chewings and dams were noted. Abundant beaver chewings were also found along reach 10.

The combining of thick and thin herbaceous and the combining of upland herbaceous, bare ground, and rocks only slightly increased accuracy from 62% to 65%. A major reason the total accuracy remains low after generalizing is the confusion of the herbaceous class with both the deciduous and coniferous classes.

Burton Creek

I defined the following vegetation and cover classes for Burton Creek: coniferous, shadow, thick herbaceous, thin herbaceous, deciduous, upland herbaceous, bare ground and water (Tables 5 and 6; Appendix Figure 2).

The first reach extends 1415 meters from Star Harbor to 80 meters beyond the intersection with Highway 28. There is a large meadow with thick herbaceous vegetation in the center and aspens and willows along the edges. The second reach extends 370 meters and has thick and thin herbaceous vegetation with scattered stands of aspen, willow and conifers. The 641 meter riparian zone of the next two reaches narrows and contains deciduous and patches of thick and thin herbaceous vegetation surrounded by conifers. The fifth has thin herbaceous and upland herbaceous vegetation with few patches of deciduous vegetation in a narrow 915 meter riparian zone. The vegetation is mostly coniferous with deciduous trees close to the stream channel along the 216 meters of the sixth reach. There are numerous dead and fallen conifers lining the banks of this section. The upper part of the seventh reach includes patches of thick herbaceous vegetation. Reach eight extends 627 meters and consists mostly of conifers with deciduous species in a narrow riparian corridor. Reach nine flows for

			Ground Truth Pixels									
		class values	10	15	20	25	30	40	55	60	total	user's (%) accuracy
	coniferous	10	**257**	16	4	6	15	2	0	10	310	83
	deciduous	15	10	**117**	14	18	2	1	0	2	164	71
	thick herb.	20	10	45	**82**	58	6	0	0	0	201	41
Classified	thin herb.	25	3	19	10	**79**	8	1	0	0	120	66
Pixels	upland herb.	30	19	4	1	9	**46**	7	0	0	86	54
	bare ground	40	7	0	0	4	9	**25**	0	0	45	56
	water	55	0	0	0	1	0	0	**31**	0	32	97
	shadow	60	39	8	0	0	0	0	0	**66**	113	58
	total		345	209	111	175	86	36	31	78	1071	
	producer's accuracy (%)		74	56	74	45	54	69	100	85		65% total accuracy

Table 5: Contingency Table for Burton Creek with all cover classes

207 meters ending at a spillway for a reservoir and has vegetation similar to reach eight with more small patches of herbaceous vegetation. Reach 10, 110 meters, contains a narrow band of thick herbaceous vegetation with scattered willows, bounded by conifers. Along the next reach, 11, the thick herbaceous band widens for 70 meters. Reach 12 extends for 1220 meters through a large meadow. Along the southern part of the meadow small inflows trickle toward the stream, feeding the meadow vegetation. In the upper section of this reach, deciduous vegetation predominates along the channel, while conifers, many dead or dying, become abundant along the slightly sloping southern banks. Reach 13 starts at the culvert by the dirt road and extends 138 meters through stands of dying conifers. These stands of dying conifers continue into reach 14. Beneath the dead trees, a mix of thick herbaceous and deciduous vegetation marks the area. The reach flows for 114 meters and ends when the channel splits into multiple flow paths and no distinct main flow could be determined. This marks the end of the reach classification of Burton Creek, though the riparian zone continues. Further on, there is another meadow with both thick and thin herbaceous vegetation with scattered willows bounded by coniferous and upland herbaceous vegetation.

There are no active beaver colonies along Burton Creek. I observed several old beaver chewed stumps along the southern bank of reach 10.

For Burton Creek, the combining of thick and thin herbaceous and upland herbaceous with bare ground increases total accuracy from 65% to 73%. A large part of this difference can be attributed to misclassification of 58 pixels of thin herbaceous as thick herbaceous. Producer's accuracy for the deciduous class is low at 56% and is likely due to spectral

		Ground Truth Pixels								
		class values	10	15	**herb**	**up**	55	60	total	user's (%) accuracy
	coniferous	10	**257**	16	10	17	0	10	310	83
	deciduous	15	10	**9717**	32	3	0	2	164	71
Classified	**herb.**		13	64	**229**	15	0	0	321	71
Pixels	**upland**		26	4	14	**87**	0	0	131	66
	water	55	0	0	1	0	**31**	0	32	97
	shadow	60	39	8	0	0	0	**66**	113	58
	total		345	209	286	122	31	78	1071	
	producer's accuracy (%)		74	56	80	71	100	85		73% total accuracy

Table 6: Contingency Table for Burton Creek with the generalized Herbaceous and Upland classes

similarity with the thick herbaceous class, and to a lesser degree, confusion with the thin herbaceous class. However, the user's accuracy for deciduous is good at 71%. This indicates that 71% of the pixels classified as deciduous were actually deciduous.

Cold Creek

I defined the following vegetation and cover classes for Cold Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, and shadow (Tables 7 and 8; Appendix Figure 1).

The first reach extends 1797 meters through a meadow characterized by thick herbaceous vegetation throughout and willows along the upper end of the reach. For the next 662 meters, reaches two through four are similar having conifers on the banks, and deciduous vegetation in the channel. Conifers form a canopy over the channel in the next two reaches, five and six, for a combined 1257 meters. The next six reaches, 7 through 12, extend for a total of 2803 meters and are similar with the vegetation cover also characterized by conifers on the banks, but having some deciduous scattered along the channel. Stream channel classification was discontinued due to lack of access to private property. Further upstream the deciduous component increases. After a ninety degree bend by the stream to the south, another large meadow starts with thick herbaceous vegetation.

There were no active beaver colonies found. However, fresh feeding sites were found

		class values	Ground Truth Pixels 10	15	20	25	30	40	55	60	total	user's (%) accuracy
	coniferous	10	**43**	15	0	2	6	2	0	2	70	61
	deciduous	15	4	**13**	0	0	0	0	0	0	17	77
	thick herb.	20	0	0	**19**	0	0	0	0	0	19	100
Classified	thin herb.	25	2	2	3	**3**	0	0	0	0	10	30
Pixels	upland herb.	30	1	1	0	0	**8**	1	0	0	11	73
	bare ground	40	0	0	0	0	1	**5**	0	0	6	83
	water	55	0	0	0	0	0	0	**9**	0	9	100
	shadow	60	7	0	0	0	1	0	0	**22**	30	73
	total		57	31	22	5	16	8	9	24	172	
	producer's accuracy (%)		75	42	86	60	50	63	100	92		71% total accuracy

Table 7: Contingency Table for Cold Creek with all cover classes

		class values	Ground Truth Pixels 10	15	**herb**	**up**	55	60	total	user's (%) accuracy
	coniferous	10	**43**	15	2	8	0	2	70	61
	deciduous	15	4	**13**	0	0	0	0	17	76
Classified	**herb.**		2	2	**25**	0	0	0	29	86
Pixels	**upland**		1	1	0	**15**	0	0	17	88
	water	55	0	0	0	0	**9**	0	9	100
	shadow	60	7	0	0	1	0	**22**	30	73
	total		57	31	27	24	9	24	172	
	producer's accuracy (%)		75	42	93	63	100	92		74% total accuracy

Table 8: Contingency Table for Cold Creek with the Herbaceous and Upland classes

along reach two and numerous old dams and old feeding sites occurred throughout reaches four and five.

The combining of the thick and thin herbaceous classes and the combining of upland herbaceous with bare ground slightly improved total accuracy from 71% to 74%. Most of the error for this classification can be attributed to the fact that 58% of the deciduous ground truth pixels were misclassified as coniferous resulting in a low producer's accuracy for deciduous at 42%. Interestingly, the user's accuracy for deciduous is good, indicating that of what was classified as deciduous was correct 76% of the time.

Meeks Creek

I defined the following vegetation and cover classes for Meeks Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, burnt, bare ground, rocks, and shadow (Tables 9 and 10; Appendix Figure 3).

The first reach of Meeks Creek is a small harbor with boat docks at the lower end. The upper part has scattered deciduous bushes on the banks and issurrounded by conifers and upland herbaceous vegetation. Reach two starts at the west side of Highway 89 and extends for 3050 meters. The lower part of the reach has alders close to the stream channel with thick and thin herbaceous vegetation with scattered willows and young conifers further away. On the southern side of the stream there is a mix of alders and conifers. Many conifers appear stressed and dying. The upper part of the reach was recently burned and the vegetation within the burnt area is herbaceous. Here the rejuvenating vegetation is thin with much black ash showing between plants. The third reach extends for 829 meters amid thick conifers with some deciduous patches along the channel. In the next two reaches, rocks, conifers, and a few scattered patches of deciduous vegetation characterize the narrow 300 meter long riparian corridor. Reach six and seven are a combined 730 meters and are composed of thick stands of deciduous vegetation with small patches of thick herbaceous vegetation. Reach eight is 467 meters long and is characterized as having many dead and dying conifers. At ground level thick herbaceous and deciduous vegetation occurs. Reaches 9 and 10 are similar with a narrow 196 meter long riparian corridor dominated by a coniferous overstory and deciduous understory. For the next 2480 meters, reaches 11 through 17 are similar and can be described as rocky with conifers away from the channel and scattered deciduous patches along the channel. Reach 18 extends for 71 meters through thick herbaceous vegetation, changing to deciduous in the upper part of the reach along the stream. Reach 19 is 38 meters long and has deciduous vegetation along the channel surrounded by conifers. For the next 709 meters, reach 20 through 23 are similar in having vegetation along the channel characterized by conifers and bare rocky patches. Reach 24 is 300 meters long and has a meadow with thick herbaceous vegetation and scattered dead conifers in the lower part. The upper part of the reach has more deciduous vegetation along the channel, bounded by conifers further away from the stream. Reach 25 extends for 175 meters and has a closed canopy of conifers. Bare rocky patches with some conifers typify the next two reaches, 26 and 27, which combine for a total of 400 meters. Reach 28 is 677 meters long and traverses through two meadows separated by a pond. These meadows have thick herbaceous vegetation with

		Ground Truth Pixels											
	class values	10	15	20	25	30	35	40	45	55	60	total	user's (%) accuracy
coniferous	10	**115**	24	4	8	13	0	0	2	0	5	171	67
deciduous	15	15	**50**	6	10	1	0	1	0	0	1	84	60
thick herb.	20	4	10	**20**	5	3	2	1	0	0	0	45	44
Classified thin herb.	25	11	3	1	**25**	8	2	0	1	0	0	51	49
Pixels upland herb.	30	7	2	0	2	**22**	1	3	3	0	0	40	56
burnt	35	2	0	0	0	0	**17**	0	0	0	0	19	90
bare ground	40	1	0	0	0	5	0	**6**	2	0	0	14	43
rocks	45	2	0	0	0	12	0	1	**9**	0	0	24	38
water	55	1	0	2	0	0	0	1	0	**147**	0	151	97
shadow	60	26	0	0	0	0	0	0	0	1	**51**	78	65
total		184	89	33	50	64	22	13	17	148	57	677	
producer's accuracy (%)		63	56	60	50	34	77	46	53	99	89		68% total accuracy

Table 9: Contingency Table for Meeks Creek with all cover classes

scattered deciduous vegetation. The last three reaches, 28, 29 and 30, extend for 1068 meters and are characterized as having rocky bare patches and conifers.

There is an active beaver colony at the bottom of reach two. Fresh beaver feeding sites were found along reaches two and eight. Old beaver activity is evident along reaches 2, 12, 24 and 28.

Combining the thick and thin herbaceous classes and combining the upland herbaceous, the bare ground, and the rock together increased total accuracy from 68% to 73%. Most of this improvement can be attributed to the confusion between the upland herbaceous, bare ground, and rock classes. The deciduous class and both riparian herbaceous classes have low producer's and user's accuracies due to the confusion between them and the confusion with the coniferous class.

		Ground Truth Pixels									
		class values	10	15	**herb**	35	**up**	55	60	total	user's (%) accuracy
	coniferous	10	**115**	24	12	0	15	0	5	171	67
	deciduous	15	15	**50**	16	0	2	0	1	84	60
Classified Pixels	**herb.**		15	13	**51**	4	13	0	0	96	53
	burnt	35	2	0	0	**17**	0	0	0	19	81
	upland		10	2	2	1	**63**	0	0	78	89
	water	55	1	0	2	0	1	**147**	0	151	97
	shadow	60	26	0	0	0	0	1	**51**	78	65
	total		184	89	83	94	22	148	57	677	
	producer's accuracy (%)		63	56	61	67	77	99	89		73% total accuracy

Table 10: Contingency table for Meeks Creek with the generalized Herbaceous and Upland classes

Taylor Creek

I defined the following vegetation and cover classes for Taylor Creek: coniferous, shadow, thick herbaceous, thin herbaceous, deciduous, upland herbaceous, bare ground, water, and flooded meadow (Tables 11 and 12; Appendix Figure 1).

The first part of the stream extends 477 meters to just below Highway 89 at the pedestrian bridge. The vegetation consists of large alders, tree willows and aspens with a herbaceous understory. The herbaceous areas near the lake are quite wet, but drier thin herbaceous areas occur upstream and away from the stream. A few cottonwoods and aspens are located just south of Highway 89 at the bottom of reach two . The riparian vegetation for the rest of reach two is a mix of alder and willow with some thin herbaceous vegetation closely confined to near the stream areas. There is a relatively large aspen dominated riparian area found along an unnamed tributary emptying into the stream at the far end of this reach

		class values	10	15	20	25	30	40	50	55	60	total	user's (%) accuracy
			Ground Truth Pixels										
Classified Pixels	coniferous	10	**220**	39	6	0	42	1	0	3	4	315	70
	deciduous	15	10	**176**	10	9	6	0	0	1	1	213	83
	thick herb.	20	9	83	**113**	15	0	0	3	0	0	223	51
	thin herb.	25	7	16	26	**26**	3	1	0	0	0	79	33
	upland herb.	30	23	0	0	1	**80**	8	0	0	0	112	71
	bare ground	40	4	0	0	3	21	**46**	0	2	0	76	61
	flooded	50	0	0	6	2	2	7	**16**	12	0	45	36
	water	55	2	0	0	0	0	0	12	**197**	1	212	93
	shadow	60	46	14	0	0	9	0	0	0	**72**	141	51
	total		321	328	161	56	163	63	31	215	78	1416	
	producer's accuracy (%)		69	54	70	46	49	73	52	92	92		67% total accuracy

Table 11: Contingency Table for Taylor Creek with all cover classes

just before draining from Fallen Leaf Lake.

There is one active beaver colony within reach one. Some old beaver chewed stumps were found at both the beginning and end of reach two.

The combining of the thick and thin herbaceous classes and the combining of the upland herbaceous class with the bare ground class improves accuracy from 67% to 72%.

		class values	10	15	herb	up	50	55	60	total	user's (%) accuracy
			Ground Truth Pixels								
Classified Pixels	coniferous	10	**220**	39	6	43	0	3	4	31	70
	deciduous	15	10	**176**	19	6	0	1	1	213	83
	herb.		16	99	**180**	4	3	0	0	302	60
	upland		27	0	4	**155**	0	2	0	188	82
	flooded	50	0	0	8	9	**16**	12	0	45	36
	water	55	2	0	0	0	12	**197**	1	212	93
	shadow	60	46	14	0	9	0	0	**78**	141	51
	total		321	328	217	226	31	215	78	1416	
	producer's accuracy (%)		69	54	83	69	52	92	92		72% total accuracy

Table 12: Contingency table for Taylor Creek with the generalized Herbaceous and Upland classes

The deciduous class has a low producer's accuracy of 54% due to its confusion with thick herbaceous. The user's accuracy, though, is good at 83% indicating that 83% of the pixels classified as deciduous were deciduous. The cover class flooded has low producer's and user's accuracies with most of the error being attributed to its confusion with water.

Trout Creek

I defined the following vegetation and cover classes for Trout Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, flooded meadow, water, and shadow (Tables 13 and 14; appendix figure 1).

The first reach extends for 609 meters and is the lower part of the meadow just prior to entering Lake Tahoe. Numerous overflow channels are evident in the meadow. The cover class is mainly flooded meadow. Reach two is 1573 meters long and consists mostly of thick herbaceous vegetation with some patches of flooded meadow. For the next 3861 meters, reaches three and four are lined with deciduous vegetation, with some thick herbaceous vegetation along the remainder of the riparian corridor to the south of the stream. Above Highway 50 the riparian corridor narrows. The vegetation for the next 1583 meters, within reach five, continues to be a thick herbaceous meadow along the channel with some scattered deciduous patches, bordered by conifers. At the end of Reach five, conifers encroach into the narrowing corridor and dominate. Patches of thick herbaceous vegetation still occur along with a few spots of deciduous vegetation. Reach six extends for 643 meters and has some deciduous and thick herbaceous along the channel surrounded by conifers. There is a thick

	Ground Truth Pixels	class values	10	15	20	25	30	40	50	55	60	total	user's (%) accuracy
	coniferous	10	**91**	4	1	3	15	1	0	0	11	126	72
	deciduous	15	3	**9**	3	3	1	0	0	0	1	20	45
	thick herb.	20	1	15	**69**	12	0	0	1	0	0	98	70
Classified Pixels	thin herb.	25	2	6	5	**24**	3	1	0	0	0	41	59
	upland herb.	30	3	0	1	1	**8**	3	0	0	0	16	50
	bare ground	40	0	0	0	0	2	**12**	0	0	0	14	86
	flooded	50	1	0	5	0	0	0	**6**	6	0	18	33
	water	55	0	0	1	0	0	0	1	**7**	0	9	78
	shadow	60	20	1	1	0	2	0	0	1	**60**	85	71
	total		121	35	86	43	31	17	8	14	72	427	
	producer's accuracy (%)		75	26	80	56	26	71	75	50	83		67% total accuracy

Table 13: Contingency table for Trout Creek with all cover classes

herbaceous meadow with small scattered patches of willows along the 384 meter channel of reach seven. For the next 1028 meters, reach eight is characterized by thick herbaceous meadow that is broken up by a few small isolated stands of conifers. Reach nine extends for 1582 meters and the lower part is similar to reach eight, while conifers from a covered canopy along the upper part. The 710 meter riparian zone in reach 10 is similar to the lower part of reach nine and is surrounded by conifers and upland herbaceous vegetation. Reach 11 extends for 1430 meters. At the confluence with Saxon Creek dense herbaceous vegetation predominates around the channel and conifers away. For the next 5915 meters, from reaches 12 through 23, the channel gradient increases and the vegetation is mostly conifers with some bare patches. Reach 24 extends for 1409 meters and flows through a large meadow of thick herbaceous vegetation. In places, the stream flows through small coniferous stands. The last reach, 25, is 2260 meters long. The southern bank along the this reach consists of mainly bare

		Ground Truth Pixels									
		class values	10	15	**herb**	**up**	50	55	60	total	user's (%) accuracy
	coniferous	10	**91**	4	4	16	0	0	11	126	72
	deciduous	15	3	**9**	6	1	0	0	1	20	45
Classified	**herb.**		3	21	**110**	4	1	0	0	139	79
Pixels	**upland**		3	0	2	**25**	0	0	0	30	83
	flooded	50	1	0	5	0	**6**	6	0	18	33
	water	55	0	0	1	0	1	**7**	0	9	78
	shadow	60	20	1	1	2	0	1	**60**	85	71
	total		121	35	129	48	8	14	72	427	
	producer's accuracy (%)		75	26	85	52	75	50	83		72% total accuracy

Table 14: Contingency table for Trout Creek with the generalized Herbaceous and Upland classes

rocky patches with some conifers. On the northern sloping banks a similar pattern exists, except for a zone of herbaceous vegetation and alders fed by spring discharges into the stream. The survey ended in a flooded meadow with no distinct channel.

There is a new beaver dam in reach 9. Old beaver dams were noted in reaches four, five and seven. Old beaver activity was observed in reaches 4, 5, 6, 8, 9, 10 ,11, 13, 14 and 15 .

Combining of thick with thin herbaceous and upland herbaceous with bare ground improved total accuracy from 67% to 72%. The fact that 28% of the thin herbaceous pixels were classified as thick herbaceous accounts for most of this improvement. The producer's accuracy for deciduous is very poor with 43% of the deciduous pixels being classified as thick herbaceous and 17% being classified as thin herbaceous. As with Taylor Creek, there is confusion between the flooded cover class and water resulting in a low producer's accuracy of 50% for the water class and a low user's accuracy of 33% for the flooded classes.

Upper Truckee

I defined the following vegetation and cover classes for the Upper Truckee River: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, rock, water, and shadow (Tables 15 and 16; Appendix Figure 1).

The first reach flows for 1638 meters along the Tahoe Keys Marina and through meadows of thick herbaceous vegetation with stands of willows. The second reach extends for approximately 1640 meters, passing under Highway 50. This reach courses mostly through meadows of thick herbaceous vegetation with stands of willows. The lower half of the reach displays more diversity, with patches of conifers and some upland herbaceous vegetation amid the meadow. Beyond the highway, the channel has willows along the banks, and the meadow consists almost entirely of thick herbaceous vegetation. The third reach starts at the old bridge crossing site and extends 750 meters to the start of a channelized section along the airport. There is herbaceous vegetation along the lower part of the reach on the western side. The eastern side has upland herbaceous vegetation with some patches of sagebrush/grass. Reach four extends for 4513 meters. The lower parts, alongside the airport, are channelized with rock reinforced banks. Along the upper and middle sections, the stream meanders freely. Vegetation of the lower section has coniferous vegetation along its eastern side and a mix of thick and thin herbaceous on the western side. The middle section of the reach runs through a meadow of thick herbaceous vegetation. Further upstream, conifers increase and are more abundant directly along the channel margins. The fifth reach extends 3210 meters beneath Highway 89 and past the public golf course. The lower section, reaching to the highway, can be generalized as having coniferous vegetation with small herbaceous and deciduous patches along the channel. Just to the west of the highway, there is an upland herbaceous region, followed by the manicured vegetation (classified as thick herbaceous) of a golf course. Just north of the golf course, along the confluence with Angora Creek, there is a large meadow with thick herbaceous vegetation. At times, the river does not flow directly along the golf course and courses through regions marked by mostly coniferous and some deciduous vegetation. The reach ends shortly above the golf course, amid mostly conifers with patches of thin herbaceous and some deciduous vegetation. Within reach six conifers predominate, especially further away from the channel. Many patches of thick herbaceous, deciduous and upland herbaceous vegetation occur throughout this 1584 meter reach. Reach 7 extends for 2900 meters roughly divided by Highway 50. The stream appears more confined by high terraces that support an open coniferous woodland. Along the terrace flat, upland herbaceous vegetation occurs, while within the riparian corridor small patches of herbaceous vegetation occur. The 2460 meter riparian corridor widens out along the eighth reach into a thick herbaceous meadow bordered by conifers. For the next 3403 meters, increased deciduous vegetation occurs along the channel in reaches 9 through 14. Along Reach 13 a meadow with thick herbaceous vegetation exists along the stream channel. Reach 15 extends 565 meters and ends just beyond the bridge crossing at an USGS gauging station. There is a thick herbaceous meadow along this reach beyond a deciduous section. The 434 meters of reach 16 are characterized mostly by large aspens and cottonwoods at the lower section and smaller deciduous vegetation in the upper section.

Beyond reach 16, the Upper Truckee steepens extending up to Meiss Meadows. Within this section, forty separate reaches are identified for a combined length of 8710 meters. Vegetation along this steeper Upper Truckee section is mostly coniferous, rocks, and bare ground with patches of upland vegetation away from the stream. Scattered patches of deciduous vegetation occur alongside depositional reaches. Videography was not obtained for the upper half of this section.

Reach 57 marks the beginning of Meiss Meadows and runs 171 meters through a mix of mostly deciduous and some thick and thin herbaceous vegetation surrounded by conifers, upland herbaceous vegetation, and rocky patches. For the next 580 meters, the vegetation along reaches 58 through 63 is similar to reach 57. Reach 64 extends for 580 meters and flows through a meadow with thick herbaceous vegetation. Between a pond west of Meiss Lake and the Upper Truckee, there is a large patch of thin herbaceous vegetation that bounds

			Ground Truth Pixels										
		class values	10	15	20	25	30	40	45	55	60	total	user's (%) accuracy
	coniferous	10	**160**	11	0	7	18	2	0	2	7	207	77
	deciduous	15	13	**62**	22	5	0	0	0	1	1	104	60
	thick herb.	20	12	32	**81**	32	4	2	0	0	2	165	49
Classified	thin herb.	25	12	7	32	**56**	17	1	0	0	0	125	45
Pixels	upland herb.	30	18	0	3	19	**31**	6	0	0	1	78	40
	bare ground	40	1	0	0	7	21	**36**	0	2	0	67	54
	rocks	45	0	0	0	0	2	1	**0**	0	0	3	0
	water	55	0	0	0	0	1	0	0	**92**	2	95	97
	shadow	60	10	2	0	0	3	0	0	1	**54**	70	77
	total		226	114	138	126	97	48	0	98	67	914	
	producer's accuracy (%)		71	54	59	44	32	75	–	94	81		63% total accuracy

Table 15: Contingency table for Upper Truckee Creek with all cover classes

reach 64 with large stands of willows throughout this section. Willows predominate the next 42 meters of the stream in reach 65. For the next 431 meters, reaches 66 through 70 have mainly thin herbaceous vegetation with some deciduous patches along it. The next eight reaches, 71 through 78 extend for 2900 meters and are dominated by thick stands of willows, surrounded by thin herbaceous vegetation changing to upland herbaceous further away from the stream. The final reach, 79, is 240 meters and briefly goes subterranean at one point. The riparian zone narrows upstream with small patches of thick and thin herbaceous and deciduous vegetation.

Three active beaver colonies were located. One was at the confluence with Angora Creek (reach 5). Another is located along reach 23 and the final region was along reach 64 in Meiss Meadows. I also noted fresh activity in the form of chewings along reaches 4, 6, 14, and 16. The active dam noted during the 1995 stream morphology classification in reach 14 was no longer present, but fresh chewings were found. I also noted old dams in reaches 4, 6, 8, 15, 24, and 25.

			Ground Truth Pixels							
		class values	10	15	**herb**	**up**	55	60	total	user's (%) accuracy
	coniferous	10	**160**	11	7	20	2	7	207	77
	deciduous	15	13	**62**	27	0	1	1	104	60
Classified	**herb.**		24	39	**201**	24	0	2	280	72
Pixels	**upland**		19	0	29	**97**	2	1	148	66
	water	55	0	0	0	1	**92**	2	95	97
	shadow	60	10	2	0	3	1	**54**	70	77
	total		223	114	264	145	98	67	914	
	producer's accuracy (%)		71	54	76	67	94	81		74% total accuracy

Table 16: Contingency table for Upper Truckee Creek with the generalized Herbaceous and Upland classes

The combining of the thick and thin herbaceous and the combining of the upland herbaceous, rock, and bare ground classes improved total accuracy from 63% to 74%. This large improvement is due to the high level of confusion between the thick and thin herbaceous classes and the confusion between the upland herbaceous class with the bare ground class. The producer's accuracy for deciduous is low at 54% because 28% of the ground truth pixels for deciduous were misclassified as thick herbaceous.

Ward Creek

I defined the following vegetation and cover classes for Ward Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, water, and shadow (Tables 17 and 18; Appendix Figure 2).

The first reach of the Ward Creek extends for 790 meters and is dominated by conifers with some deciduous vegetation. The 6781 meter riparian zone of the second reach consists of mostly deciduous vegetation bounded by some conifers in the lower part of the reach. In the central part of the reach, some thick herbaceous patches exist away from the channel and conifers become more predominant. Further upstream small patches of thick herbaceous vegetation are scattered within the mix of conifers and deciduous vegetation. Inflow from a tributary creates a thick herbaceous zone toward the upper end of the reach. The third reach is 851 meters and consists of a mix of conifers and deciduous vegetation with patches of bare rock. The final reach, four, continues 719 meters through the mix of bare rock and conifers.

There are two active beavers colonies along reach two, one in the central portion and the other in the upper portion. The beaver colony in the central part of the reach is on a small unmarked tributary 10 meters south of Ward Creek. The beaver colony in the upper part of the reach is on a small unmarked tributary 20 meters north of Ward Creek. There are inactive beaver dams and an inactive lodge between the two active colonies. Like the two active colonies, these dams and lodge are not on Ward Creek but on a small unmarked tributary 20 meters north of the channel. Fresh feeding sites were found along the lower portion of reach two and downstream from the upper colony site. Old feeding sites were found along reaches two, three, and four.

Combining the thick and thin herbaceous classes and combining the upland herbaceous and the bare ground classes improves total accuracy from 69% to 72%. The user's accuracy for the thick and thin herbaceous classes is low, implying that of the classified pixels only 11% of the thick herbaceous and 31% of the thin herbaceous are correctly classified. The shadow

			Ground Truth Pixels									
		Class values	10	15	20	25	30	40	55	60	total	user's (%) accuracy
Classified Pixels	coniferous	10	**75**	3	0	2	3	0	1	1	85	88
	deciduous	15	3	**35**	1	2	0	0	0	0	41	85
	thick herb.	20	4	2	**1**	2	0	0	0	0	9	11
	thin herb.	25	4	3	2	**5**	2	0	0	0	16	31
	upland herb.	30	4	0	0	1	**5**	1	0	0	11	46
	bare ground	40	0	0	0	0	3	**6**	0	0	9	67
	water	55	0	0	0	0	0	0	**10**	1	11	91
	shadow	60	21	4	0	0	0	0	3	**22**	50	44
	total		111	47	4	12	13	7	14	24	232	
	producer's accuracy (%)		68	75	25	42	39	86	71	92		69%total accuracy

Table 17: Contingency table for Ward Creek with all cover classes

		class values	10	15	herb	up	55	60	total	user's (%) accuracy	
			Ground Truth Pixels								
	coniferous	10	**75**	3	2	3	1	1	85	88	
	deciduous	15	3	**35**	3	0	0	0	41	85	
Classified Pixels	**herb.**		8	5	**10**	2	0	0	25	40	
	upland		4	0	1	**15**	0	0	20	75	
	water	55	0	0	0	0	**10**	1	11	91	
	shadow	60	21	4	0	0	3	**22**	50	44	
	total		111	47	16	20	14	24	232		
	producer's accuracy (%)		68	74	63	75	71	92		72%	total accuracy

Table 18: Contingency table for Ward Creek with the generalized Herbaceous and Upland classes

class also had a low user's accuracy of 44% indicating that of the pixels classified as shadow only 44% are correct. The producer's accuracy for shadow is high at 92% indicating that 92% of the shadow within the imagery was correctly identified.

Watson Creek

I defined the following vegetation and cover classes for Watson Creek: coniferous, deciduous, thick herbaceous, thin herbaceous, upland herbaceous, bare ground, water, and shadow (Tables 19 and 20; Appendix Figure 2).

The first five reaches of Watson Creek are similar in vegetation characteristics. The riparian zone of this 2973 meter section is narrow and steep. Deciduous vegetation occurs along the channel and is bordered by conifers and upland herbaceous vegetation. Imagery for the lower portion of reach 6 was not captured. Reach six extends for 1157 meters and has deciduous vegetation along the channel with a thick herbaceous meadow on the northern bank of the upper part. Conifers and upland herbaceous vegetation make up the southern border.

			Ground Truth Pixels									
		class values	10	15	20	25	30	40	55	60	total	user's (%) accuracy
Classified Pixels	coniferous	10	**231**	22	2	18	23	0	0	6	302	77
	deciduous	15	13	**138**	0	2	2	0	0	1	156	89
	thick herb.	20	8	8	**21**	5	0	0	0	0	42	50
	thin herb.	25	3	9	2	**10**	0	0	0	0	24	42
	upland herb.	30	14	1	0	6	**43**	2	0	0	66	65
	bare ground	40	0	0	0	1	12	**11**	0	0	24	46
	water	55	1	0	0	0	0	0	**60**	0	61	98
	shadow	60	84	1	0	0	6	0	1	**90**	182	50
	total		354	179	25	42	86	13	61	97	857	
	producer's accuracy (%)		65	77	84	24	50	85	98	93		71% total accuracy

Table 19: Contingency table for Watson Creek with all cover classes

For the next 809 meters, the channel continues to be dominated by deciduous vegetation in reach seven and along small tributaries that flow into Watson. Small patches of thin herbaceous vegetation occur and the border of the riparian zone is coniferous and upland herbaceous vegetation. A subterranean flow connects Watson Lake and Watson Creek and no riparian vegetative corridor exists between them.

There are no active beaver colonies within Watson Creek and no past evidence of beavers was found

Combining the thick and thin herbaceous classes and combining the upland herbaceous with the bare ground class only improved total accuracy from 71% to 73%. This increase is slight at 2% because of the confusion between the thick and thin herbaceous classes and the upland herbaceous and bare ground classes is low. The producer's accuracy for upland herbaceous is low at 24% due to its confusion with the coniferous class.

		class values	Ground Truth Pixels 10	15	herb	up	55	60	total	user's (%) accuracy
	coniferous	10	**231**	22	20	23	0	6	302	76
	deciduous	15	13	**138**	2	2	0	1	156	88
Classified	**herb.**		11	17	**38**	0	0	0	66	57
Pixels	**upland**		14	1	7	**68**	0	0	90	76
	water	55	1	0	0	0	**60**	0	61	98
	shadow	60	84	1	0	6	1	**90**	182	49
	total		354	179	67	99	61	97	857	
	producer's accuracy (%)		65	77	57	69	98	93		73% total accuracy

Table 20: Contingency table for Watson Creek with the generalized Herbaceous and Upland classes

Buffer Comparisons

I compared vegetation area totals from 50, 100, and 200 meter buffers centered on beaver dams with those centered on randomly selected points using a SAS program written by Fernandez (1996) for the comparison of two population means (Table 21). The comparisons determine if the two population means are significantly different from each other. Of the twelve comparisons, eight are significant. The 100 and 200 meter buffer totals for thin herbaceous vegetation approach significance with p-values of 0.0518 for both (Table 21).

Within radii of 50, 100, and 200 meters, significantly more deciduous vegetation surround beaver dams than randomly selected points along the stream channels. Beaver dams also are surrounded by significantly more thick herbaceous vegetation within a 100 and 200 meter radius and significantly more thin herbaceous vegetation within a 50 meter radius. Within radii of 50 and 100 meters, significantly less coniferous vegetation surround beaver dams than randomly selected points along the stream channel.

		Conifers	Deciduous	Thick Herb	Thin Herb.
50 meters	Dam	0.145**	0.206**	0.113	0.122*
Buffers	Random	0.222**	0.110**	0.073	0.077*
100 meters	Dam	0.616*	0.682**	0.516*	0.424 (p=0.0518)
Buffers	Random	0.817*	0.353**	0.284*	0.280
200 meters	Dam	2.308	1.757**	1.527*	1.397 (p=0.0518)
Buffers	Random	2.476	0.961**	0.888*	0.883

Table 21: Average area in hectares of vegetation types within buffers centered on beaver dams or randomly selected points along stream channels. Values marked by ** indicate a significant difference a alpha = 0.01. Values marked by * indicate a significant difference at alpha = 0.05.

Deciduous vegetation totals are significantly higher in buffers centered on beaver dams and are probably influenced by the fact that the deciduous vegetation cover class contains many of the primary foods for the beaver. These include willows, aspens, and cottonwoods. The fact that the coniferous vegetation totals are significantly lower in buffers centered 50 and 100 meters around beaver dams, in part, may be influenced by the idea that areas which support conifers are areas that support less deciduous vegetation. The fact that the thick herbaceous vegetation totals are significantly higher in buffers centered 100 and 200 meters around beaver dams is probably due to the fact that the water table is higher and creeks have greater access to their floodplains behind the dams. This in turn provides areas that support lush stands of grass, sedges, and rushes that are the primary vegetation types that make up the thick herbaceous cover class. The fact that the thin herbaceous vegetation totals are significantly higher in the 50 meter buffer and approach significance in the 100 and 200 meter buffers may in part be due to the same reasons as for the thick herbaceous cover class.

DISCUSSION

Hypothesis Test (H_{o1})

The null hypothesis (H_{o1}), the average accuracy for the classifications of the three band multispectral videography is less than or equal to 17%, was tested using a SAS program written by Fernandez (1996) for testing a population mean. This test determines the probability of the difference between a population average and a given value being equal to zero. I tested the average accuracies for classifications with all cover classes and classifications with the generalized herbaceous and upland classes.

The average accuracy for the classifications using 3-band airborne multispectral videography with all cover classes equals 67.7% with a standard deviation of 3.74. The probability that the classification accuracy is less than or equal to 17% is 0.0001. The 95% confidence interval of this average is between 65.02% and 70.38%.

The average accuracy for the classifications using 3-band airborne multispectral videography with the generalized herbaceous and upland classes equals 72.5% with a standard deviation of 3.03. The probably that this classification accuracy is less than or equal to 17% is also 0.0001. The 95% confidence interval for this average is between 70.33% and 74.67%.

From the results of either test, we reject the null hypothesis in favor of the alternative hypothesis ($H1_a$) and conclude that the average accuracy for the classifications of the three band multispectral videography is greater than 17%. This indicates that the methods employed in this study are capable of providing maps of greater accuracy than the random assignment of pixels to cover classes.

Redd (1994) classified four 3-band multispectral video images into broad riparian cover classes using a maximum likelihood classification algorithm and obtained accuracies of 66.6, 71.8, 51.8 and 88.8 percent (Appendix Table 5). The producer's and user's accuracies for his cover classes were variable among images as they were among streams in this study (Appendix Table 4).

Bartz (1993) had success classifying 3-band multispectral videography into broad riparian cover classes using both semi-supervised and supervised classification algorithms, though did not identify the specific algorithms. She did not report total accuracy but listed omission and commission error rates for cover types for each classification method. Omission and commission errors were converted to producer's and user's accuracy to facilitate comparisons (Appendix Table 6). Generally, Bartz obtained higher accuracies than in this study. Some of the difference can be attributed to her ability to resolve two forms of radiometric error. One is varying brightness caused by varying sun angle. Objects within overlapping regions of two sequential images will have brightness values that vary between images due to differences of sun angle (King 1991, Bartz 1994). This problem was overcome by mosaicking images with 50% overlap and trimming approximately 12.5% of the edges, reducing the variation of brightness values within information classes. The other error, vignetting, is caused by the lens walls absorbing and blocking radiation so that light decreases towards the edges of the images (King 1995, Bartz 1994). This in turn causes a decrease in brightness values within information classes as distance from the image center increases.

Franklin (1995) classified 2165 ha of riparian habitat in the northeastern region of the Lake Tahoe Basin into broad riparian classes with a total accuracy of 42%. Using a step-wise linear discriminant algorithm, he classified a mean-filtered DOQQ, a standard deviation raster of the DOQQ, and the NDVI derived from a four-band multispectral videography system. If his moist and wet meadow classes are combined, total accuracy increases to 60%.

Hypothesis Tests (H_{02}-H_{05})

From the results of the comparison of two population means between buffers centered on beaver dams and those centered randomly along stream channels (Table 22), we reject the null hypotheses two through five ($H2_o$-$H5_o$). We therefore accept the alternative hypotheses two through five ($H2_a$-$H5_a$) and conclude that at least one of the estimates of area for coniferous, deciduous, thick herbaceous, and thin herbaceous vegetation within buffers with radii of 50, 100, or 200 meters centered on beaver dams is not equal to those centered on randomly selected points along the stream channels.

MacDonald (1956) studying beavers in Colorado determined 1.6 ha of aspen, 4.8 ha of willow, or combinations of these in lesser amounts is needed to sustain a colony of six beavers. The 1.757 ha estimate of average total area of deciduous vegetation in 200 meter buffers centered on active dams is above MacDonald's threshold but is mostly represented by willows and alders. Half of these estimates, however, include areas on the downstream side of dams and may be areas not utilized by beavers. Comparing buffer zones along a segment upstream of new dams, old dams and random points would be a better way to examine relationships of beaver presence with vegetation and the possible sustainability of sites.

Recommendations

Selecting a filter of another spectral band width may have improved accuracy. The green (0.55-0.65 μm) and red (0.625-0.635 μm) bands show a high degree of correlation (Table 22). This implies that there is redundancy of information between the green and red bands. The green band should be replaced for it has a higher R^2 value with the infrared band than the red band has with the infrared band. Using three independent bands would provide more information possibly leading to higher classification accuracies. Preferably the selection of bands should be based on field radiance readings of target cover classes. King and Vlcek

	COEFFICIENT OF DETERMINATION (R^2)		
STREAM	BAND1/BAND2	BAND1/BAND3	BAND2/BAND3
Big Meadow	0.337	0.540	0.850
Blackwood	0.207	0.368	0.767
Burton	0.142	0.306	0.766
Cold	0.417	0.522	0.892
Meeks	0.363	0.442	0.851
Taylor	0.183	0.279	0.843
Trout	0.223	0.401	0.870
Upper Truckee	0.155	0.283	0.860
Ward	0.263	0.405	0.859
Watson	0.206	0.385	0.824

Table 22: Correlation of determination values for simple linear regressions between the three spectra bands used in this study. Band1 = infrared (0.845-0.857 μm), band2 = red (0.625-0.635μm), and band3 = green (0.55-0.565 μm). Note the high correlations for band2/band3.

(1990) determined that the following four bands contributed most to data variance: blue-green (0.43-0.47 μm), green-yellow (0.53-0.57 μm), deep red (0.68-0.72 μm), and near-infrared (0.78-0.82 μm).

Restoration Potential

Restoration procedures using vegetation are designed to place a beneficial vegetation cover on the riparian areas. The benefits include soil stability, decreasing floodwater velocities through increased surface roughness, and increased sediment deposition (Walck 1994).

The vegetation maps produced from this thesis and the information being collected in the dissertation by Butt (1998) would provide excellent data layers for a future GIS study analyzing the restoration potential for selected Lake Tahoe Basin Streams. Butt has made morphological measurements and classified segments of streams into reaches. The stream channels, defined by reaches, have been digitized over a display of the mosaics of the three band multispectral videography. The morphological data for each reach has been linked to the digitized reaches as attribute files. Using a GIS, queries selecting for reaches with morphological characteristics of degraded stream channels could be performed. Then these reaches could be displayed with the vegetation maps so that measurements and visual interpolation of vegetation structure along the channels could be made. This would help to target sites where the appropriate restoration action involves manual re-vegetation, such as the planting of willows.

CONCLUSION

The three band multispectral videography provided an adequate data source for the mapping of the riparian vegetation and neighboring upland vegetation along selected streams in the Lake Tahoe Basin. The methods described in this study provided a means for classifying vegetation with an accuracy 67.7% for all eleven cover classes and 72.5% with the generalized herbaceous and upland classes. Naturally, users of these vegetation maps need to be aware of the accuracy of particular streams and particular cover classes. Accuracies for cover classes were not consistently similar for all streams (Appendix Table 4).

Beaver distribution, measured by active dams, has a positive association with deciduous, thick herbaceous, and thin herbaceous vegetation and a negative association with coniferous vegetation. The ability to detect this expected trend demonstrates the potential use of these vegetation maps in riparian habitat management. Threshold values for area estimates for combinations of certain vegetation classes could be used to identify stream segments that may potentially support beavers. This would provide resource managers with information to help prioritize and focus field time for surveying beaver distribution and activity.

In regard to georeferencing, I demonstrated that mosaicking several images before georeferencing did not lower positional accuracy. This can lead to a significant savings in time without a sacrifice to positional accuracy. TNTMips only allows a user to define two control points when mosaicking two non-georeferenced images. Image processing systems that allow more than two control points when mosaicking non-georefernced images may produce maps with even lower positional error.

APPENDIX

Scientific Name	Common Name
Abies concolor	White Fir
Abies magnifica	Red Fir
Calocedrus decurrens	Incense Cedar
Pinus contorta	Lodgepole Pine
Pinus jeffreyii	Jeffery Pine
Pinus lambertiana	Sugar Pine
Pinus monticola	Western White Pine
Tsuga mertensiana	Mountain Hemlock

Table 1: Species list for the Coniferous cover class

Scientific Name	Common Name
Alnus incana	Mountain Alder
Cornus seicea	American Dogwood
Populus trichocarpa	Black Cottonwood
Populus tremuloides	Quaking Aspen
Salix eastwoodiae	Eastwood's Willow
Salix exigua	Coyote Willow
Salix geyeriana	Geyer's Willow
Salix jepsonii	Jepson's Willow
Salix lasiandra	Pacific Willow
Salix lemmonii	Lemmon's Willow
Salix scouleriana	Scouler's Willow

Table 2: Species list for the deciduous cover class

STREAM	Feed<96	Feed=96	Dam<96	Dam=96	Lodge<96	Lodge=96
Big Meadow	nr	—	—	—	—	—
Blackwood	2,5,6,7, 11,12	6,7,11, 12	3,7,11	5,7,11	3	7
Burton	10	—	—	—	—	—
Cold	4,5	2	4,5	—	—	—
Meeks	2,6,12, 24	1,2,6, 8	2,8,27	1,2	—	—
Taylor	1,2	1	—	1	—	—
Trout	4,5,6,8, 9,10,11, 13,14,15	5,6,9, 13,14, 15,16	4,5,6,7, 8,9,10, 13	5	5	—
Upper Truckee	2,3,4,5, 6,8,9,10, 12,14	4,5,6, 8,23	4,5,6,7, 8,14,15, 24,25	4,5,6,7, 8,13,15, 16,23	—	5,23
Ward	2,3,4	2	2	2	2	2
Watson	—	—	—	—	—	—

Table 3: Beaver data. Numbers in the columns indicate the reach where data occurs. Feed = sites where beaver chewings were observed, Dam = beaver dams, Lodge = beaver lodges. 96 refers to the summer of 1996.

							PRODUCER'S/USER'S ACCURACY								
STREAM	**TOTAL**	**COM**	**10**	**15**	**20**	**25**	**herb**	**30**	**35**	**40**	**45**	**upland**	**50**	**55**	**60**
BIG MEADOW	74	77	76/79	70/60	85/94	60/60	84/90	32/53	nc	100/38	nc	54/65	nc	ns/ns	95/80
BLACKWOOD	62	65	62/66	80/64	40/33	33/56	35/56	20/21	nc	69/64	56/50	69/67	nc	89/77	78/69
BURTON	65	73	74/83	56/71	74/41	45/66	80/71	54/54	nc	69/56	nc	71/66	nc	100/97	85/58
COLD	71	74	75/61	42/77	86/100	60/30	93/86	50/73	nc	63/83	nc	63/88	nc	100/100	92/73
MEEKS	68	73	63/67	56/60	60/44	50/44	61/53	34/56	77/90	46/43	53/38	77/89	nc	99/97	89/65
TAYLOR	67	72	69/70	54/83	70/51	46/33	83/60	49/61	nc	73/61	nc	69/82	52/93	92/93	92/51
TROUT	67	72	75/72	26/45	80/70	56/59	85/79	26/50	nc	71/86	nc	52/83	75/33	50/78	83/71
UP. TRUCK.	63	74	71/77	54/60	59/49	44/45	76/72	32/40	nc	75/54	ns/0	67/66	nc	94/97	81/77
WARD	69	72	68/88	75/85	25/11	42/31	63/40	39/46	nc	86/67	nc	75/75	nc	71/91	92/44
WATSON	71	73	65/77	77/89	84/50	24/42	57/57	50/65	nc	85/46	nc	69/76	nc	98/98	93/50

Table 4

List of classification accuracies for Tahoe Basin Streams using 3 band multispectral videography. TOTAL = accuracy of classification with of cover classes, COM = accuracy of classification with the generalized herbaceous and upland cover classes, 10 = coniferous, 15 = deciduous. 20 = thick herbaceous, 25 = thin herbaceous, herb. = (20&25), 30 = upland herbaceous, 35 = burnt ground, 40 = bare ground, 45 = rocks, upland = (30,40&45), 50 = flooded meadow, 55 = water, 60 = shadow, ns = cover class not sampled, and nc = cover class not classified .

Cover Classes	Producer's/User's Accuracies Sheep Bridge Image	Beaver Dam Wash Image	Dutch John Image	*Little Hole Image
Grass	77/71	70/60	35/76	89/76
Sand & Rock	48/79	69/57	82/38	46/100
Water	79/72	78/100	76/100	89/99
Upland Veg.	NC	NC	38/28	79/71
Dense Riparian Veg.	NC	63/55	50/54	69/77
Shadow	51/90	NC	78/19	0/0
Sage	48/26	ns/ns	NC	NC
Tamarisk	0/ns	76/89	NC	NC
Cottonwood/Russian Olive	69/58	NC	NC	NC
Willow	ns/ns	NC	NC	NC

Table 5 : Producer's and user's accuracies obtained from contingency tables reported in Redd (1994). NC denotes cover class not classified in image and ns denotes cover class not sampled.
* Accuracies listed from the Little Hole image are derived from a contingency table for the results of a minimum distance algorithm. A contingency table for the maximum likelihood algorithm was not given.

Cover Classes	Producer's/User's Accuracies Semi-Supervised mosaic #2	Semi-Supervised mosaic #1	SS-Corrected mosaic #2	SS-Corrected mosaic #1	Supervised
Water	100/100	80/100	80/100	100/100	100/100
Senescent Herbs	-	86/86	76/71	47/70	83/93
Soil	100/37	93/77	93/79	93/50	93/77
Deciduous	53/36	63/36	73/61	87/62	79/58
Herbaceous	46/83	44/76	64/85	64/85	76/88
Wetsoil	-	-	*100/0	100/100	100/100
Road	100/100	-	100/100	100/100	100/100
Shadow	100/100	100/100	*100/0	100/100	100/100

Table 6 : Producer's and user's accuracies obtained from Omission and Commission tables reported in Bartz et. al (1994).
* Omissions of 0% and Commissions of 100% were not explained.

FIGURE 1
Reaches for the streams for the southern portion of the Tahoe Basin. The numbers indicate the reach number.

FIGURE 1
Reaches for the streams in the western portion of the Tahoe Basin. The numbers indicate the reach number.

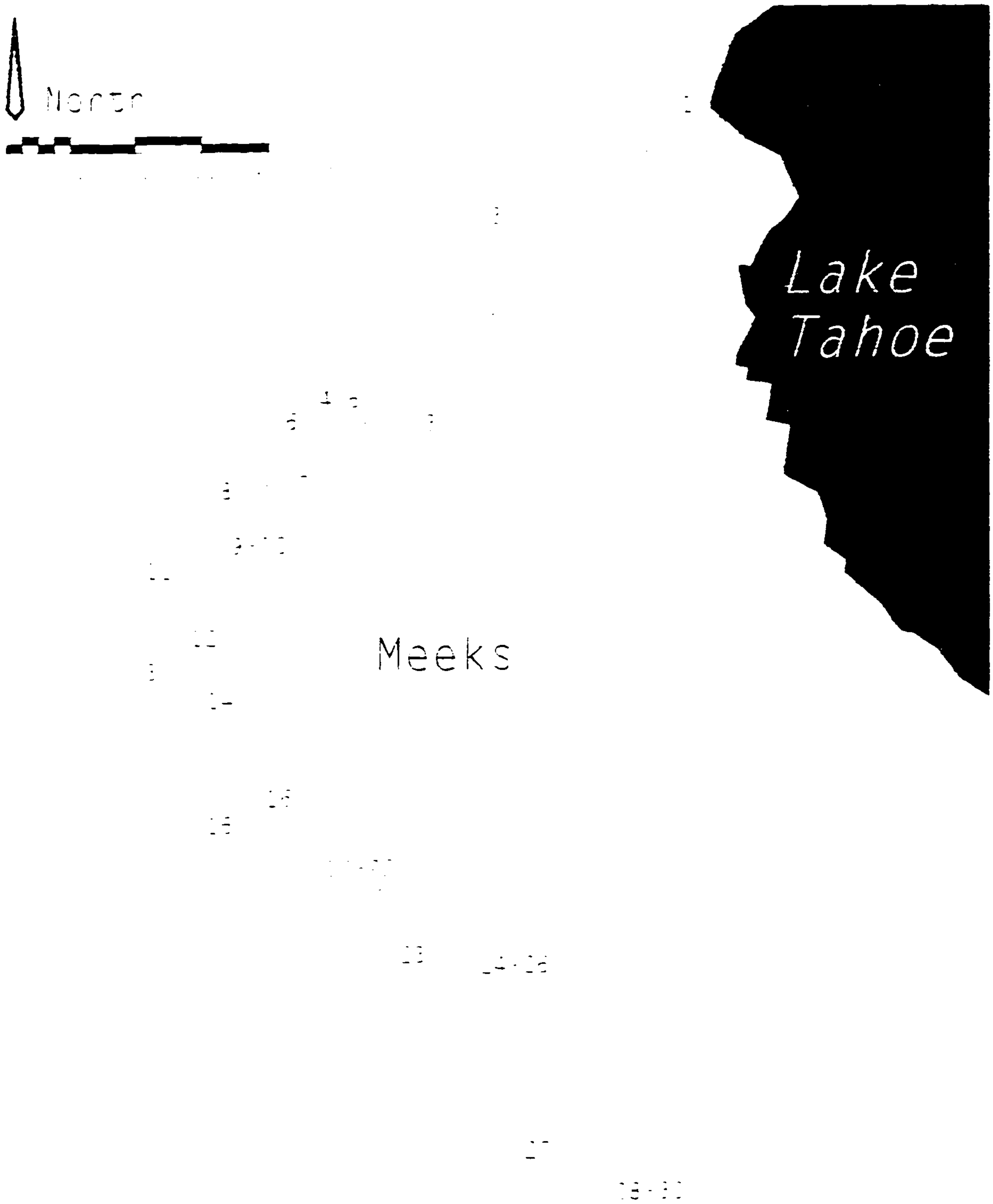


FIGURE [illegible]
Reaches for Meeks Creek. The numbers indicate the reach number.

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