National Park Service
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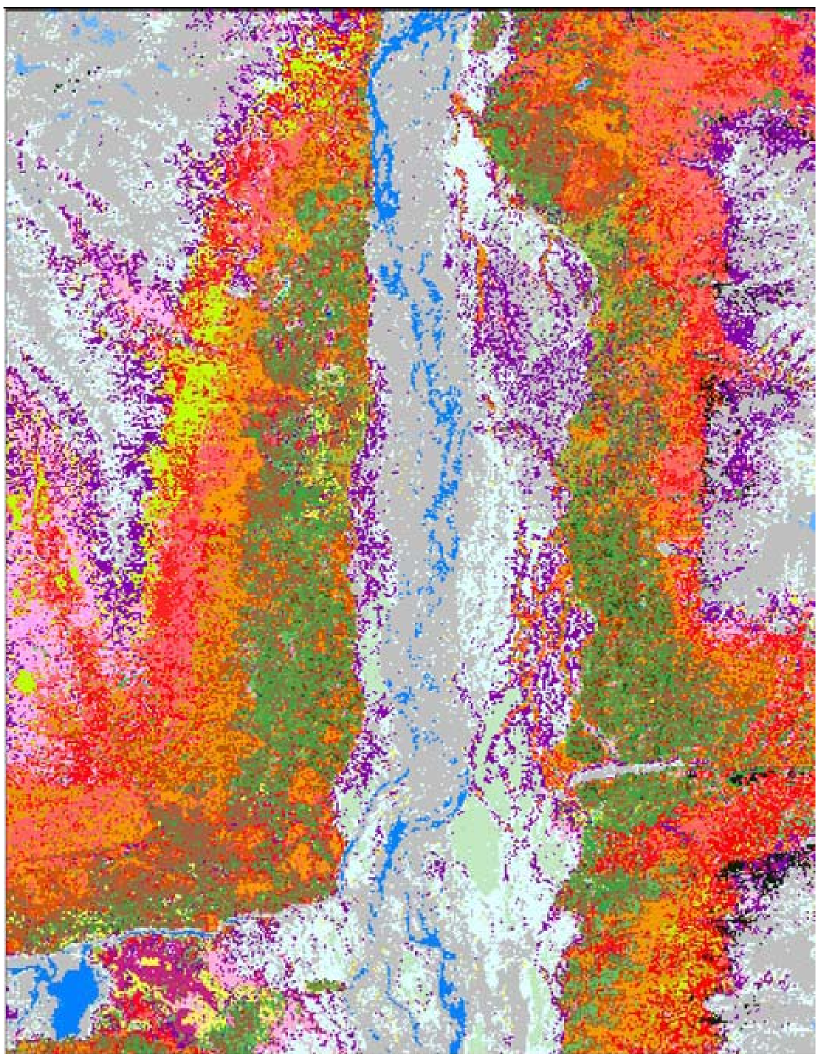
Wrangell-St. Elias National Park and Preserve Landcover Mapping Project

Final Report

Natural Resource Technical Report NPS/WRST/NRTR—2008/095



ON THE COVER
Portion of landcover map classification.
Graphic by: Geographic Resource Solutions

Wrangell-St. Elias National Park and Preserve Landcover Mapping Project

Final Report

Natural Resource Technical Report NPS/WRST/NRTR—2008/095

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Introduction

The Wrangell-St. Elias Land Cover Mapping Project was a National Park Service project conducted under Delivery Order #D9925030016 under Contract #GS10F0451N. This Task Order's project background and objectives included:

"The Alaska Regional Office (AKRO) of the National Park Service (NPS) seeks to develop a digital land cover map of Wrangell-St. Elias National Park and Preserve (WRST). This project is part of the Inventory and Monitoring Program (I&M) of NPS, which seeks to provide reliable and consistent scientific information to assess the status and trends in condition of National Park ecosystems. Land cover mapping is conducted under the inventory portion of I&M Program with the goal of providing basic vegetation information that is useful for making resource management decisions on a Park-wide basis. This mapping is intended to provide data that will conform to NPS standards, be compatible with other I&M Program mapping programs, and provide information required for the design of monitoring programs within the National Parks. The map can be expected to provide input to habitat evaluation, fire fuels modeling, as well as provide valuable baseline information about vegetation. It is recognized that the size and remote character of Alaska's National Parks requires that mapping be done at coarser resolution than other non[-]Alaskan I&M vegetation mapping efforts within the NPS system. However, this effort shall be compatible with those efforts and may form the basis for more detailed mapping efforts in the future."

The Wrangell-St. Elias National Park and Preserve (WRST) Land Cover Mapping Project was initiated in October, 2003 in an effort to upgrade and improve vegetation/land cover information for this region. Projects of this nature covering millions of acres are typically based on satellite imagery and provide generalized categorical values and class information. The AKRO also recognizes that the WRST Land Cover Mapping Project has to be compatible with similar efforts, but also wishes that the WRST mapping effort form the basis of more detailed mapping efforts in the future. Land cover mapping efforts involving the use of traditional remote sensing methodologies generally produce static categorical data products that lose all detailed information at the pixel level. This loss of information has seriously limited the usefulness and accuracy of previous image classification mapping efforts, making it difficult to truly verify existing classification results or to derive new map data using reclassification logic or rule-based aggregation processes. As a direct result, such map products have limited adaptability to diverse resource management needs, which may require different, more detailed information than that delivered in a single categorical land cover map.

Seeking a more powerful and versatile product, the AKRO issued a Work Order to Geographic Resource Solutions (**GRS**) to develop a land cover classification map of Wrangell-St. Elias National Park and Preserve. The project was to benefit from **GRS**'s land cover mapping techniques, which enable the development and maintenance of detailed original land cover data throughout map development processes and delivery of a final map data set that retains this highly detailed "bird's-eye view" level of information in the form of a land cover database. Generalized land cover maps may then be derived from this detailed land cover database. In addition, alternative more directed detailed maps may be derived from the land cover database as needed.

The WRST Land Cover Mapping Project was undertaken by **GRS**, in association with the ABR Inc. (ABR), and with support from the AKRO. **GRS** directed training site selection, navigation, and verification components of field data collection efforts, as well as all image data acquisition, preparation, training, evaluation, and classification efforts that led to the creation of the delivered land cover data sets. ABR provided expertise regarding vegetation classification, land cover type description, and ecosystem characterization during ground and aerial data collection efforts, as well as input and feedback regarding post-field class descriptions and classification-related issues. AKRO personnel participated in ground vegetation transects and aerial surveys, managed field data collection logistics, and provided project coordination and review.

Project Area

Wrangell-St. Elias National Park and Preserve (WRST) is approximately 18-million acres in size, spanning the Wrangell-St. Elias and Chugach mountain ranges in southeastern Alaska. WRST encompasses a diversity of vegetation and landforms in a landscape that is largely unchanged by human development. The southern portions of the Park border the coastline of the Gulf of Alaska with a climate moderated by the ocean. The Chugach Range parallels the coast in this region and separates the coastal portion of the Park from the inland portion. These mountains include many glaciers and several peaks as high as 8000' elevation. The Wrangell Mountains and St. Elias Mountains form the main ridge of the Park extending several hundred miles from the northwestern portion of the Park at Mt. Drum to the southeastern portion of the Park near Mt. Hubbard. Six mountains in this range extend over 15,000 feet in elevation and numerous extensive glaciers and ice fields are found throughout this region of the Park. The northeastern portions of WRST are somewhat more moderate in relief with many high flattened tabletop plateaus interspersed among the mountains and are typically more arid than the other regions of the Park.

The project area included all portions of Wrangell-St. Elias National Park and Preserve, including a 10-mile buffer adjacent to WRST, where possible (Figure 1). Field data collection and verification was conducted within the actual WRST boundaries; however, the mapping effort was performed on the entire project area.

Figure 1: Wrangell-St. Elias Land Cover Mapping Project Area

Project Methodology

The methodology **GRS** used during this mapping project employed many of the basic components of typical image processing projects. Satellite imagery of the subject area was acquired and prepared for classification; “ground truth” information describing the variety of land cover types present in the Wrangell-St. Elias National Park & Preserve were acquired; image classification training sets representative of the different land cover components were developed and tested; supervised and unsupervised classification techniques were applied to the satellite imagery; resulting classification pixel data sets were merged to form a detailed and accurate pixel map of the project area; and raster modeling techniques were applied to refine land cover estimates. However, these workflow processes were not applied in what might be considered a traditional or textbook sense during this project; the development of highly detailed and accurate pixel data, as undertaken in this project, requires a different approach to image processing. In order to provide a thorough understanding of the processes used during this project, each component of **GRS**’s land cover mapping methodology will be described. Major phases of this methodology include Data Acquisition and Preparation, Field Training Site Data Collection, Image Classification Training Set Development, Image Classification, Raster Modeling, and Land Cover Pixel Map Development.

Data Acquisition and Preparation

The initial phase of this project started in November, 2003 and involved acquiring and preprocessing of the imagery prior to the collection of any field data or “ground truth.” This setup phase of the project included three significant tasks, which are a) acquisition and correction of the satellite imagery, b) acquisition of ecoregion areas, and c) identification of candidate image classification field training sites.

Completion of these three tasks was integral to the successful development of comprehensive and accurate training data sets and subsequent image classification efforts. Completion of these tasks greatly enhanced field data collection efforts by reducing the total number of sites required for the classification effort, as well as the number of sites subsequently rejected as unsuitable due to confusion or suspect data. Reduction of field data collection needs is a significant concern in a project such as the Wrangell-St. Elias Land Cover Mapping Project, due to the WRST Project Area’s limited access, extremely large size, high cost of data acquisition, and short windows of field data collection activities. Such data preparation efforts are a key factor in eliminating potentially invalid, confused, and redundant training sites and developing the comprehensive and representative project training data set necessary to develop an accurate and detailed land cover map.

<u>Image Acquisition and Correction</u>

Landsat satellite imagery was acquired from the EROS data center in Soiux Falls, S.D. A total of seven Landsat mosaiced images (16 scenes) and three individual Landsat scenes were acquired to provide comprehensive cloud-free coverage of the project area – seven Landsat TM-7 ETM+ images and three Landsat TM-5 images. Table 1 lists specific acquisition information about these images.

Table 1: LANDSAT Imagery Available for WRST Land Cover Mapping Project

IMAGE	SENSOR	PATH	ROW(s)	DATE	GMT	SUN ELEVATION	SUN AZIMUTH	PIXEL SIZE(m)
6118	TM7-ETM+	61	18	7/14/1999	2018	50.14	156.83	28.5
6378	TM7-ETM+	63	17,18	8/31/2000	2028	36.57	162.10	28.5
63678	TM5	63	16,17,18	8/5/1999	2014	43.62	154.78	28.5
6418	TM7-ETM+	64	18	9/10/2001	2032	33.61	162.42	28.5
6467a	TM7-ETM+	64	16,17	8/4/1999	2036	44.03	160.61	28.5
6467s	TM7-ETM+	64	16,17	9/10/2001	2031	31.80	164.35	28.5
6516	TM5	65	16	8/3/1999	2027	44.13	154.56	28.5
6567	TM7-ETM+	65	16,17	8/3/2002	2037	44.02	158.95	28.5
65678	TM5	65	16,17,18	8/3/1999	2027	44.13	154.56	28.5
6767	TM7-ETM+	67	16,17	8/1/2002	2049	44.52	158.77	28.5

These ten images were delivered to **GRS** in NLAPS format, and contained all eight spectral bands (1, 2, 3, 4, 5, 6, 7, and 8), although only bands 1, 2, 3, 4, 5, and 7 were used in this project. Each original image band was translated into Intergraph/Image Analyst-compatible TIFF format band for review and evaluation of actual image coverage and quality. No digital elevation data were delivered with these ten images.

Evaluation of the acquired imagery confirmed the need to utilize only nine of the original ten images in order to cover the entire WRST Project Area, as it was not necessary to use image 6516. Review of the imagery indicated the need to generate cloud cover masks for most of the images, as significant portions of these images were affected by the presence of cloud cover, contrails, haze, smoke, and other image anomalies (individual band data was missing or misaligned in small portions of 6467s). These affected images were 6378, 63678, 6467a, 6467s, 6567, 65678, and 6767. Image evaluation also confirmed the presence of striping in portions of scenes TM5 images 63678 and 65678. Striping was particularly conspicuous over open water surfaces as well as barren mountainous areas. De-striping of these images was performed by the EROS Data Center. These images were redelivered and re-imported for use in the project.

An additional concern with respect to the imagery involved potential classification problems due to the spectral differences caused by the senescence of vegetation; scenes 6378, 6418, 6467s were all acquired late in the season (August 31 or later) and spectral data from this 'late' imagery was thought to be of a poorer quality than the imagery acquired earlier in the growing season. Due to these concerns, **GRS** understood that these scenes might be replaced by the AKRO with more current imagery (in the latter stages of the project), should the AKRO and **GRS** determine acquisition of this imagery would be beneficial to the Project. However, as the project progressed no suitable replacement imagery was acquired and all nine original images were used in this mapping effort. In addition, with the exception of 6378, scenes 6467s and 6418 contributed relatively minor amounts of coverage in this mapping effort as there was cloud-free coverage from the other scenes acquired earlier in the season. While image 6378 played a larger role in this projects mapping efforts, much of this scenes coverage concerned snow covered ice fields, glaciers, and barren mountains in the southeastern portion of the Park, so this scene provided adequate coverage for this project (the major impact of use of this imagery can be seen in the final map as there were areas mapped as "terrain shadow" due to the low sun elevation angle present when these scenes were acquired). Figure 2 illustrates the coverage (footprints) of the imagery used in this mapping effort. All project images and data layers/sets developed throughout the project were created in or re-projected to match the original imagery projection parameters shown in Table 2.

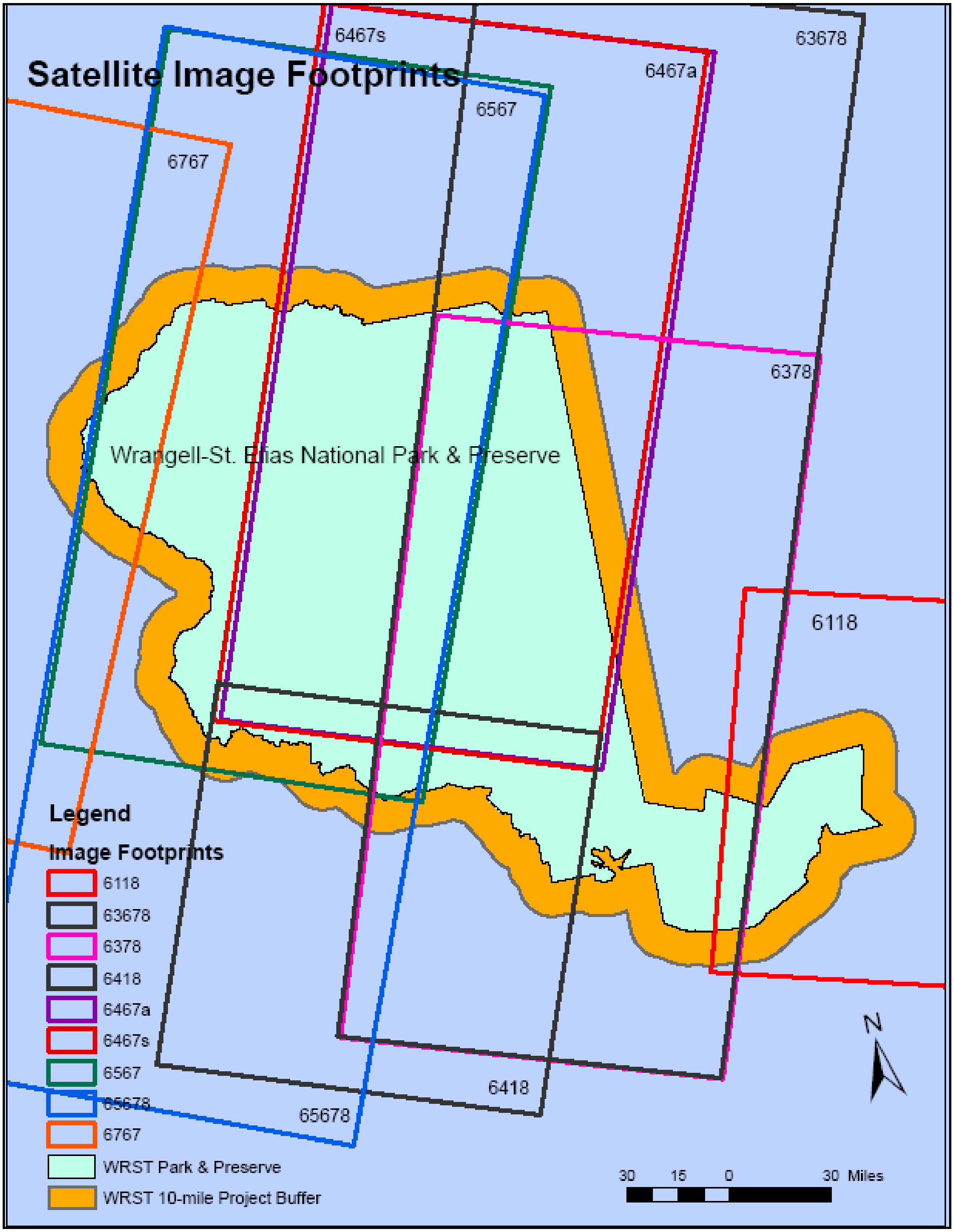

Figure 2: WRST Satellite Image Footprints

Table 2: Wrangell-St. Elias Project
Map Projection Parameters

Parameter	Value
Projection	Albers
Units	Meters
Datum	NAD27
Spheroid	Clarke1866
X shift	0.0000000
Y shift	0.0000000
First Standard Parallel	55 00 0.000
Second Standard Parallel	65 00 0.000
Central Meridian	-154 0 0.000
Central Parallel	50 00 0.000
False Easting	0.00000
False Northing	0.00000

After reviewing all imagery and extracting image-specific information regarding sun elevation and sun azimuth angle, **GRS** proceeded to process the imagery in preparation for training site development and classification applications. This preparation involves the correction (adjustment) of the images for differential illumination due to the topographic influences of slope and aspect.

Integral to the **GRS** workflow is the use of imagery that has been corrected with respect to differential illumination resulting from the influences of slope and aspect. During past projects **GRS** evaluated several methods of image normalization and presently uses the Backwards Radiance Transformation Correction (BRTC) based on a non-Lambertian assumption and a Minnaert constant (Civco 1989) (Colby 1991) to correct the imagery. This technique uses estimates of slope and aspect from a co-registered digital elevation model (DEM), and image acquisition sun-angle and azimuth parameters to normalize the images for differential illumination caused by terrain relative to the sensor. This correction method minimizes the effect of aspect and slope, but maintains the signatures of the different land cover types, thereby resulting in more accurate classification information (Geographic Resource Solutions 1993). In addition to improving the consistency of the classification, **GRS** has determined that adjustment often results in the reduction of the number of training sets required to classify a given land cover condition. This is a significant factor when undertaking data collection efforts in very remote, rugged, and inaccessible areas, such as Wrangell-St. Elias National Park & Preserve.

DEMs used during the image geo-correction process were acquired after delivery of the original imagery. The original DEMs used were a set of seamless USGS NED data sets that covered the entire project area (the size of the project area necessitated downloading the NED data for smaller areas as one download for the entire area was not possible). These were re-projected and re-sampled to 28.5 m pixel size using the bilinear convolution algorithm to match the WRST Project (AKRO) projection parameters (Table 2) and image specifications (Table 1). Each individual DEM were subsequently merged into a single project area DEM, which was used to generate slope, aspect, and incidence angle data sets that corresponded to pixels in the raw imagery (Note: DEM, slope, and aspect map data used in this project for this purpose are included on the delivery CD-ROM as ArcInfo grid data sets).

GRS then used our proprietary process called ***GRS_illumcor*** to adjust each band of the imagery for the effects of differential illumination. Adjustment coefficients were based on processing each scene, exclusive of large bodies of water or areas of snow, ice, or cloud cover as these features have been shown to negatively affect correction results. The coefficients used to correct the imagery are listed in Table 3. All images were corrected and normalized to assure that corrected data was distributed within the bounds of the 0-255 digital value limits. Corrected imagery were checked relative to the raw imagery to determine overall correctness of the process. Cross-tabulation matrices were generated and checked to determine the presence/absence of ‘data shadows’ in the normalized bands. These would have indicated extreme and inappropriate adjustments during the adjustment process that typically result from differences in the registration of the DEM data and the satellite imagery.

Table 3: Illumination Correction Coefficients

Image Band	6118	63678	6378	6418	6467a	6467s	6567	65678	6767
1	0.1911	0.26201	0.19754	0.15875	0.19354	0.00885	0.18809	0.19001	0.13439
2	0.26035	0.36888	0.36207	0.33904	0.3128	0.20631	0.28575	0.28493	0.19054
3	0.25098	0.40017	0.44086	0.42289	0.33217	0.35239	0.26449	0.29638	0.1347
4	0.39995	0.75207	0.65907	0.88391	0.84042	0.80197	0.75571	0.8324	0.48331
5	0.48033	0.8208	0.84939	1.03188	0.94933	1.33967	0.73102	0.83047	0.38992
7	0.38977	0.69264	0.75485	0.83939	0.73589	1.16034	0.5408	0.64239	0.26724

In this project, these type data might also result from the resampling (bilinear convolution) of the original DEM data that was performed to reproject the imagery to the proper Albers projection – the resampled data might appear smoothed and less rugged than original DEM data acquired at the original 1 arc-second (approximately 30 meter) resolution. These resampled data might possibly cause some alignment issues with the original satellite imagery. No such artifacts were found in the data during the examination of the cross tabulation reports. The adjusted imagery were also examined for "hot spots", which are also indicative of areas of misalignment between the DEMs relative to the imagery. "Hot-spots" are small areas of pixels that have approached the maximum digital value (255) of the 8-bit data. They occur most frequently in areas of extreme slope facing away from the sun where lighter digital values are present. They most often result from misalignment of the imagery and the DEM data (the "hot-spot" is really an illuminated area in the imagery overlaying a dark slope in the DEM data). In some cases, the DEM data is simply wrong, leading to the over-correction (brightening) of the imagery thereby forming the "hot-spot" (see Figure 3).

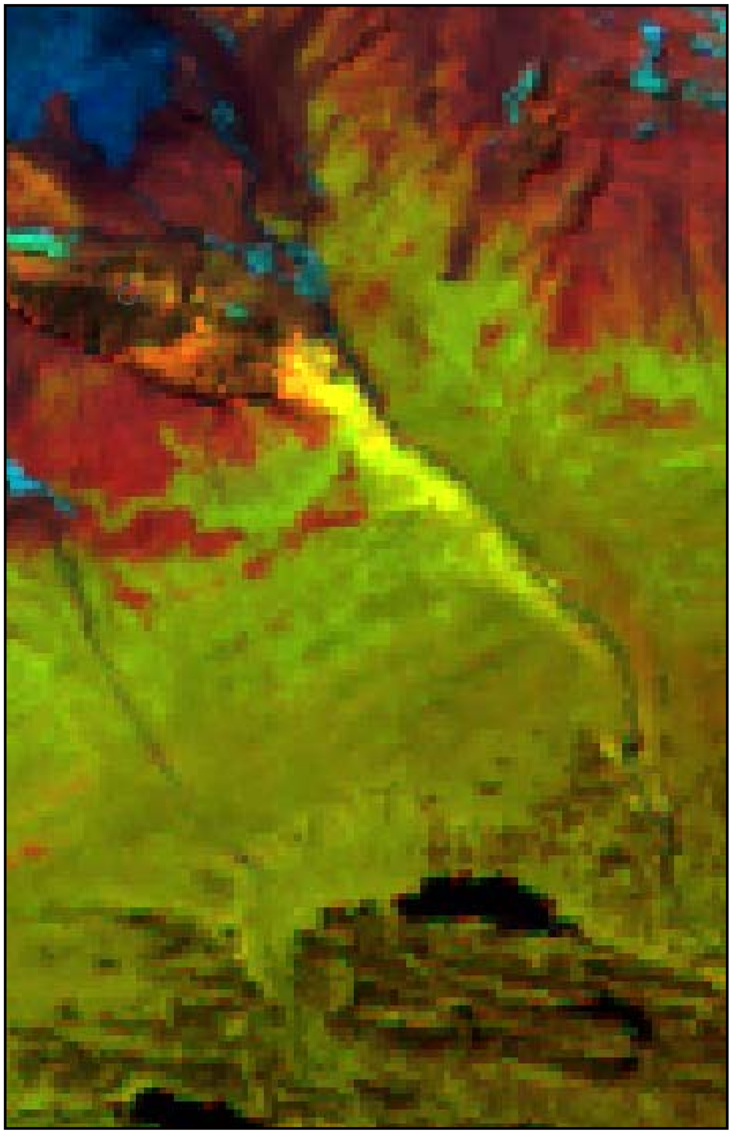

Figure 3: "Hot-spot" in the imagery

Imagery and DEMs were processed and results were reviewed until the most suitable correction results were obtained. While some minor "hot-spots" remained, no major misalignment problems across large areas between the DEM data and imagery were identified that would have seriously impacted the use of these data in this project.

Some elevation data mismatches were observed within the DEM data after merging the individual DEMs into a project-wide DEM. This edge mismatch tended to occur primarily on the US-Canadian border along the southeastern boundary of WRST. As this primarily affected areas outside WRST, this type of problem was not viewed as a significant issue in this mapping effort. Some erroneous DEM data were identified that did affect the illumination correction and subsequent mapping efforts. A particular problem in areas involving recent glacial activity is that the DEM data are outdated and do not reflect the current status/elevation of lands in these areas. In some cases glaciers (sloped features) have melted into lakes (flat features) resulting in areas where water appears to be mapped on slopes often greater than 10%. In other cases the location of the leading edge of the glacier, represented as

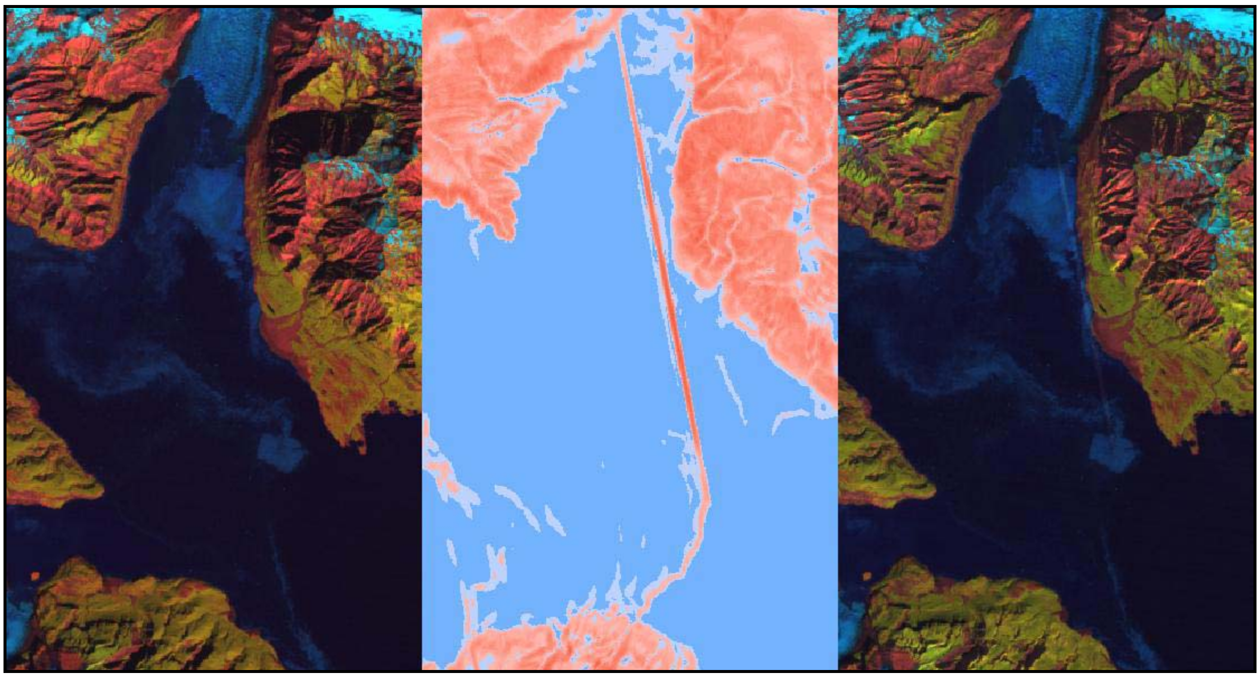

Figure 4: DEM Cliff in Icy Bay Vicinity with Raw and Corrected Imagery

a cliff, has moved between the time the DEM was created and the imagery was acquired (see the edge of the Hubbard Glacier in the Yakutat area). In other cases the DEM data are just wrong. Figure 4 represents the DEM data in Icy Bay where a very linear 300-600 foot high cliff that creates slopes as high as 50 degrees is present in the data set. This cliff appears as the red band proceeding from north to south in the middle of Icy Bay in Figure 4. Such DEM data errors and misalignments resulted in areas of high slope/aspect and resulted in “hot-streaks” and/or small areas of abnormally bright pixels in portions of the imagery. Such “hot-streaks” varied between one to ten pixels in width, and sometimes more than a mile in length. In other areas the terrain was so steep that even our adjustment process could not bring any data out of these areas (terrain shadows) or the data that were developed in these areas were highly suspect. These types of DEM artifacts affected extremely small extents of the project area and did not affect the development of signatures for valid vegetation cover classes, since no training areas were developed in areas characterized as “hot-spot” artifacts or terrain shadows. Some of these very dark pixel areas were subsequently classed as “Water” or dense “White Spruce” classes due to the spectral similarity of these areas of dark data and “Water” or dense “White Spruce” signatures. These pixels were subsequently modeled to “Terrain Shadow” in the final pixel classification map.

One last issue that became apparent while performing the illumination correction was that several bands in image 6118 were saturated. Saturation occurs when the digital values in a band overflow the maximum value (255) of the range of digital numbers. This situation arose because this band was acquired in a low gain mode due to all the snow and ice fields present in the scene. However, this situation caused problems in bands sensitive to vegetation (like the near infrared band 4) in vegetated regions, where areas of fast growing herbaceous vegetation resulted in digital values greater than 255 which were reset to the maximum value of 255, thereby losing potential discrimination amongst the types of vegetation reflecting these high amounts of reflectance. Loss of this type of information cannot be reacquired (fortunately, while this was an issue/problem during the initial phases of this project it does not appear that it compromised the ability to type the different types of vegetation/land-cover in this image).

An example of image adjustment is shown in Figure 5. This figure represents a subset of raw and corrected imagery in Wrangell-St. Elias National Park. It demonstrates how the correction process adjusts for the effects of differential illumination in the imagery. The effects of differential illumination and correction can be seen along the opposite aspects along both the east/west and north/south oriented ridges. The adjusted images show data of more similar spectral content on both sides of the opposite facing slopes as pixels on less illuminated slopes are brightened while pixels on highly illuminated slopes are dimmed. The overall impact of this process is that there is less confusion amongst different land cover types and greater agreement of spectral signatures between similar land cover types that occur on different slopes and aspects. The end result is that fewer training sites are needed to develop the image training sets to classify the spectrum of land cover types and that there is less confusion between different land cover types.

<u>Ecoregion Section Areas</u>

A land cover mapping project of this nature requires the development of training data sets that are representative of the entire range of land cover types that are present in the project area. Ideally, all of the training sites in a project area would have distinct spectral signatures corresponding to different land cover characteristics. **GRS** stratifies the project area prior to field data collection efforts in an effort to recognize the diversity and relative magnitude of the different land cover types present in the project area. Unfortunately, stratification of the entire project area using an ISODATA classifier does not often provide for suitable representation of the many different land cover types of interest. Some types, such as Coniferous Forest, may be clustered into just a few ISODATA classes while other classes such as Water or Barren may be represented by too many different ISODATA classes (size of a cluster is important in this process and small, less frequently occurring types may be clustered into a single larger type during the process). The resulting stratification may be too generalized for some land cover types and excessive for other types – and therefore may not be a suitable grouping of the range of potential land cover types of interest that might be used for field data sampling. In order to develop additional strata for the limited types, an initial higher-level stratification by ecotype sections is applied to each scene. During the data preparation stage of this project ISODATA classes were developed for each ecotype section to increase the number of land cover type strata that may subsequently be sampled and used in the land cover classification.

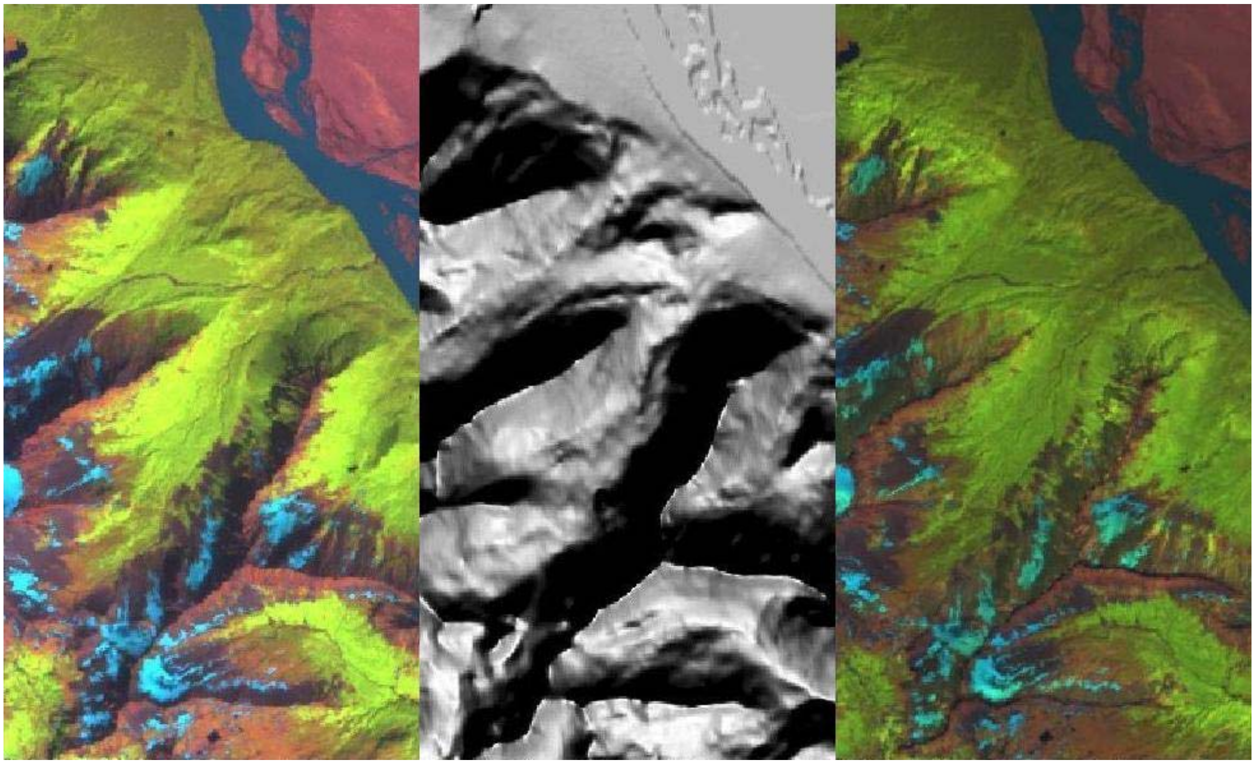

Figure 5: Illumination Adjustment - Raw Image / Shaded Relief / Corrected Image

Ecotype section boundaries developed for the WRST Project Area by Swanson (2001) were provided by the AKRO and made available to **GRS** in digital format for use in this project. These ecotype section boundaries represented 16 different major ecotype sections throughout the WRST Project Area. After consulting AKRO and ABR vegetation experts to determine the most appropriate use of these ecotype section areas, two of the geographically distinct areas of land cover characteristics were split into smaller subsections, resulting in 18 ecotype subsections (see Figure 6). Refinement primarily concerned the development of a separate section to represent the different vegetation characteristics thought to exist in the Bremner River area within the Northern Chugach Mountains section. These 17 ecotype sections were used for the initial stratification of the image data set that would be used in subsequent training data development efforts. The second refinement was made later in the project during classification efforts when it became necessary to break out the riverine portions of the Bering-Malaspina Forelands section from the rest of the section.

Candidate Image Classification Training Sites

The principal objective of this task was to develop a set of candidate training areas that would maximize field data collection efforts during the time periods allotted for aerial survey of field sites. This would be accomplished by eliminating the collection of data from invalid or heterogeneous spectral sites, redundant sites, and sub-minimum size sites while at the same time developing a training data set representative of the large area being mapped, both in terms of the diversity of land cover types present and the geographic distribution of those types. Areas suitable for aerial survey would be identified prior to field data collection efforts to maximize efforts during the limited time available for field data collection.

Image Stratification

The creation of a pool of potential/candidate training sites relies on stratification of the project area. The project area is stratified into many different classes, where each class represents a grouping of spectrally similar pixels; through stratification, areas of spectral homogeneity that represent different land cover characteristics are identified.

The goal of image stratification is to group the project area spectral data into a large number of different classes, each representative of a somewhat unique set of land cover features that need to be sampled and represented in the final data set. Stratification yields two significant results. One result is that the diversity of the sample area is represented in the stratified image. A second result is that the frequency or relative magnitude of each class is estimated by the number of pixels that are assigned to each individual class. After stratification the potential diversity of the area and the relative significance, in terms of size, of each class may be determined. This information enables the development of training data representative of all the diverse land cover data present in the area, while not under sampling some classes and over sampling others.

During stratification, much of the same data is processed that will also be processed during the subsequent classification efforts. The image data is the foundation of this effort and ecotype section area data is used to differentiate different portions of the project area within each image. Ecotype sections are introduced to form an initial level of stratification, while the ISODATA classification within the ecotype region is a second level of stratification that assures that many strata representative of the diversity of land cover types throughout the project area will be developed. A large number of classes are developed during the ISODATA classification processing within each area of interest (ecotype section). Between 30-50 training classes per ISODATA classification are typically developed, and sometimes as many as 60-75 training classes are developed in each image/ecosection data set. If initial classification efforts result in too few or too many classes, the ISODATA classification statistical parameters are reset and the imagery is reclassified to develop the desired number of ISODATA classes. Too few classes will yield sample areas with too much variability, whereas too many classes may result in a very heterogeneous data set with areas too small to realistically identify and sample in the field.

Development of unsupervised classification data was completed for each of the nine images using ZI Imaging's Image Analyst software in a Bentley Systems' MicroStation environment. **GRS** used an ISODATA clustering algorithm based on a minimum Jeffries-Matusita (J-M) distance of 1.4 and an initial random seeding of 20 classes to generate unsupervised classes within the ecotype sections present within each image. For each image, illumination corrected spectral bands 1, 2, 3, 4, 5, and 7 were processed. The application of ecotype section masks limited the spectral variability found within any particular region and enhanced the identification of separable classes throughout the classified ecosections. Clustering parameters used in unsupervised classifications ensured high homogeneity of resulting classes. Careful review of the J-M distance reports generated for each scene confirmed sufficient separability of the unsupervised classes.

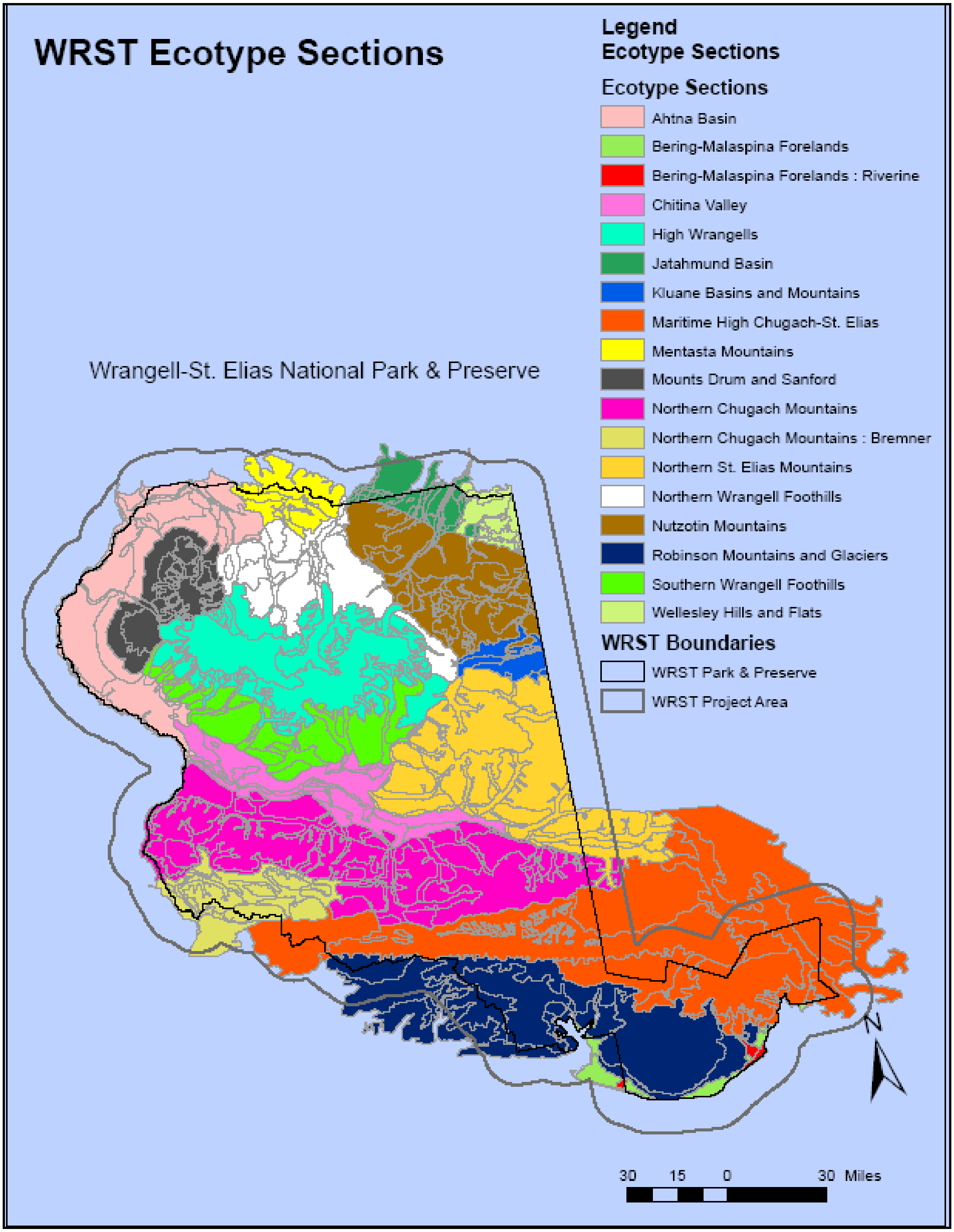

Figure 6: WRST Ecotype Section Areas

These ISODATA training data sets were then applied to the satellite imagery using both a supervised maximum-likelihood classifier as well as a minimum distance classifier. This resulted in two class maps for each area of interest (ecosection) within a scene. During initial aerial survey efforts during the summer of 2004 based on ecotype section stratification, **GRS** found that such a specific level of stratification as the ecosection was not necessary, as there was significant overlap of similar strata between different ecosections. Stratification for subsequent aerial survey efforts was based on ISODATA training classes developed using a more simplistic stratification that attempted to segregate potential types by the level and type of vegetation present at any particular location. This was accomplished by developing a Normalized Difference Vegetation Index mask (the ration of (B4 – B3)/(B4 + B3)) for each image and training on the areas with values less than or equal to 124 separately from those areas with NDVI greater than 124. Stratification (training) based on the NDVI grid was an attempt to basically segregate the images into areas with vegetation as opposed to areas lacking vegetation. This level of stratification generated more classes per image (approximately 250), but fewer classes overall (due to less redundancy of similar classes in different ecosections).

Candidate Site Selection

The end result of the stratification process is a set of ISODATA class raster maps that contain pixels that have been stratified into the many different spectrally homogeneous classes. Two sets of maps existed for each area of interest that was stratified, one based on a maximum-likelihood classifier and the other based on a minimum-distance classifier. These data sets were then processed and pertinent database information was developed to guide the selection of potential candidate training site areas. Each corresponding set of maximum-likelihood and minimum distance class maps was overlaid to determine areas where the same class value occurred in the same pixel location in both maps. These are the areas estimated to be most spectrally homogeneous and consistent in spectral reflectance, as they had the same value using different classifiers. Pixels lacking the same value in both class maps were set to a NULL value. The grid processing yielded a new grid data set of ISODATA classes, each having a unique identifier, iso_class number, and pixel frequency. Only areas at least 20 pixels in size were retained in this data set. These data were loaded into a table (candidate_trsites) for subsequent processing. A total of 1,072,624 unique areas were identified. A small selection of data from the candidate_trsites table is shown in Table 4. Pixel frequency values may be used to filter areas too small to sample, as well as describe the distribution of the project area, or ecosection area, by ISODATA class. The distribution of pixels by ISODATA class was generated by simply summing the pixel frequency by ISODATA value. Pixel frequency by ISODATA class for ecosection

Table 4: Candidate_trsites Table Data

Id#	iso_class	#pixels
...		
896151	2019	48
896152	2020	50
896153	2012	29
896154	**2020**	**78**
896155	**2016**	**446**
896156	2010	20
896157	2009	30
896158	2019	56
896159	2019	34
896160	**2010**	**410**
896161	2012	31
896162	**2020**	**405**
896163	2010	31
896164	2019	37
896165	**2020**	**86**
896166	2020	29
896168	2019	44
896169	2020	53
896170	2009	22
896171	**2020**	**83**
896172	**2017**	**67**
896173	2020	23
896174	2012	31
896175	2017	26
896176	2014	24
896177	2020	38
896178	2012	22
896179	2014	28
896180	2019	23
...		

2, the Bering-Malaspina Forelands is shown in Table 5. This information was useful in the identification of the relative abundance of the different classes and the identification of both common and scarce ISODATA classes. Frequently occurring ISODATA classes are readily distinguished from scarce ISODATA classes. Scarce ISODATA classes were identified and targeted for sampling.

Table 5: Pixel Frequency by ISODATA Class

Iso Class	Frequency	Pct(%)	Cumul. Pct(%)
3101	24670	3.76%	3.76%
3102	20921	3.19%	6.95%
3103	23144	3.53%	10.48%
3104	31231	4.76%	15.25%
3105	42020	6.41%	21.65%
3106	42551	6.49%	28.14%
3107	33692	5.14%	33.28%
3108	25732	3.92%	37.20%
3109	29360	4.48%	41.68%
3110	36586	5.58%	47.26%
3111	11890	1.81%	49.07%
3112	8853	1.35%	50.42%
3113	7089	1.08%	51.51%
3114	22467	3.43%	54.93%
3115	6603	1.01%	55.94%
3116	25757	3.93%	59.87%
3117	23601	3.60%	63.47%
3118	24494	3.74%	67.20%
3119	33112	5.05%	72.25%
3120	23467	3.58%	75.83%
3121	9343	1.42%	77.26%
3122	21133	3.22%	80.48%
3123	19006	2.90%	83.38%
3124	22422	3.42%	86.80%
3125	17221	2.63%	89.42%
3126	9957	1.52%	90.94%
3127	16077	2.45%	93.39%
3128	18053	2.75%	96.15%
3129	4615	0.70%	96.85%
3130	10274	1.57%	98.42%
3131	10386	1.58%	100.00%
Total	655727		100.00%

The next step in the sample area selection process was to filter out the areas thought to be too small to sample. The minimum size (number of pixels) sample site will obviously be related to the resolution of the imagery being processed. The most important aspects of this minimum size limit are that the sample site is large enough to use as a supervised image classification training site, the site can be easily located in the field by the field crew, and the site can be distinguished from the surrounding land cover types. There is no point in selecting a sample site that is too small to use as part of the supervised classification training set, or that cannot be found or identified in the field when performing an aerial survey from a helicopter. For this project, a minimum size training site area of 60 pixels, or approximately 13.0 acres was selected. Areas meeting this minimum size were readily identified by performing a simple query of the ISODATA class database based on the size attribute of each contiguous area. This query had the following construct:

select id, iso_class from candidate_trsites where pix_count >= 60

Several records that met these criteria are shown as **bold** type in Table 4. Identification of areas larger in size than this minimum size reduced the number of ISODATA class areas from over one million areas to 245,665 potential sample areas that were all at least 60 pixels in size. This reduced set of candidate areas was checked to determine that it was still representative of all the ISODATA classes present in the stratified ISODATA data and to assure that all ISODATA classes were represented in the candidate_trsite table. The database check that was performed to determine that all ISODATA classes were represented in the candidate sample data set was performed using a database query of the following construct:

select iso_class, count(*) from candidate_trsites
group by iso_class
order by iso_class

and then checking that the results agreed with the number of training classes in the training data sets.

This check did not identify any missing ISODATA classes. All ISODATA classes had at least one sample area that met the minimum size limit. A total of **3,165** ISODATA classes were identified in the different stratifications that were performed.

The next step was to determine if any ISODATA classes were extremely rare (few in number) or small (size less than 60 pixels), such that sampling these areas might be difficult. It was important to identify and include scarce or small classes in the candidate database so there would be sufficient coverage of the many land cover types present in the project area. Scarce and small classes were identified using the following queries:

select iso_class, count(*) from candidate_trsites where px_cnt >= 60
group by iso_class order by iso_class

select iso_class, count(*) from candidate_trsite where px_cnt >= 60
group by iso_class having count(*) < 5 order by iso_class

The first query identified **2,831** classes indicating that 334 classes only occurred in areas of size smaller than 60 pixels. These 334 candidate sites are considered **small** sites. The second query identified an additional 270 iso_classes that did not occur in more than 5 locations in groups of at least 60 pixels. These were considered **scarce** iso_classes - those having less than 5 candidate sample sites of the minimum 60 pixel size throughout the entire project area. Additional candidate areas were then generated for these ISODATA classes by decreasing the minimum size limit from 60 pixels to 45 pixels, or approximately 10.0 acres. 94 additional sample areas representing small or scarce ISODATA classes were added to the candidate sample site database. By continuing to drop the minimum size requirement to lower thresholds (45, 30, and 20 pixels) candidate sites were identified as small or rare and flagged in the database, to identify their presence in subsequent database query operations. A total of 307 candidate sites were identified as small sites using this approach. Small sites were flagged by setting a database table column value to reflect the scarcity of the class using an SQL statement like the following statement:

update candidate_trsites set visit_status=45 where px_cnt >= 45 and px_cnt < 60
and visit_status is NULL
and iso_class not in (select iso_class from candidate_trsites where visit_status > 0 group by iso_class having count(*) >= 5)

Scarce or rare candidate sites were identified by selecting those iso_classes that had a very low (<5) number of occurrences in the data set. A total of 297 sites were identified as rare sites using the following SQL statement:

update candidate_trsites set visit_status=visit_status + 100
where iso_class not in (select iso_class from candidate_trsites group by iso_class having count(*) >= 5)

Information regarding scarcity and size of iso_class sites was very useful in prioritizing sample sites when actually selecting the specific training data sample sites that would comprise the sampling plan during the field data collection sampling efforts. Small and rare sites were represented with labels of different colors when plotted on the field maps to assist in their identification during planning efforts.

The next step in this process was to move from the grid world into the vector world, in order to integrate and manipulate the candidate sample unit data in a graphic context. To accomplish this conversion process, two steps were necessary. First, the ISODATA class map was reclassed to form a candidate area grid map - all pixels in areas that were not candidate sample units were reset to a value of 0 (NODATA), while all other pixel values remained the same. The resulting grid map represented only those areas that had been determined to be candidate training data collection sites. A portion of the resulting grid is shown in the left side of Figure 7. This candidate area grid was then vectorized to form a vector database representing the candidate sample areas. Other data, such as ISODATA class labels, were developed to enhance the training site information. These area boundaries and corresponding labels, including areas symbolized as rare or small (see blue labels in Figure 8) could then be overlaid on the imagery, as shown in the right side of Figure 7. The resulting database represented the initial set of candidate training sites that would be used to plan field data collection efforts.

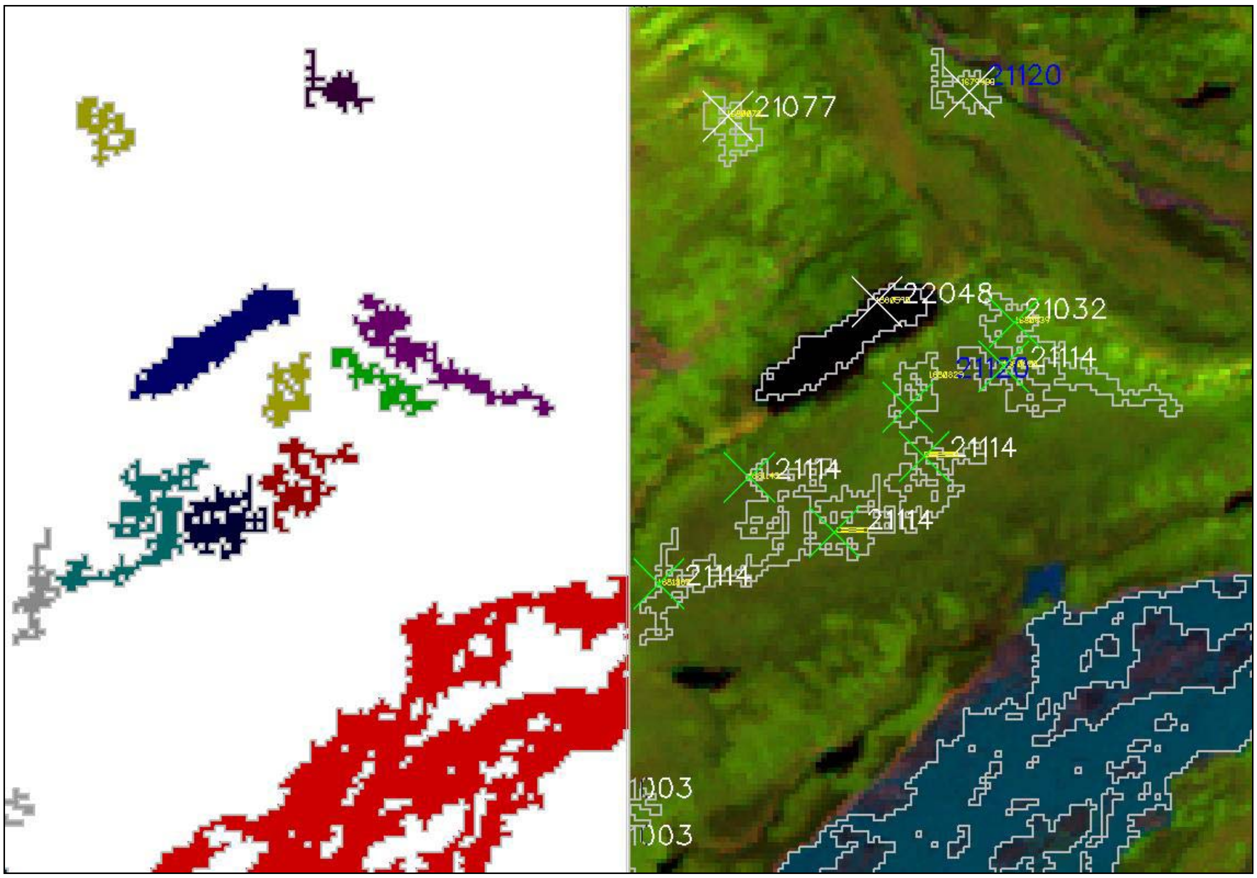

Figure 7: Candidate Training Sites

Candidate Site Field Maps and Data

A series of 1:47,500 scale (20” X 15”) color maps were developed to facilitate training area location and navigation in the field. Maps showed candidate training area polygons, iso_class numbers, and 400’ elevation contour lines, over a 5, 4, 2 RGB composite built from the LandSAT imagery. A total of 132 field maps were generated and uniquely labeled using a row-column code with origin on the upper left corner of the project area grid. Two copies of each map were produced, one for the aerial survey crew and the other for the ground survey crew.

All maps were laminated for protection and to enable flight planning and notations directly on the map with permanent color pens. A portion of one of these field maps (I2) is shown in Figure 8.

Efforts were made to determine potential training site locations that covered the spectrum of significant land cover types within the project area before starting field data collection efforts. All unsupervised areas meeting homogeneity and size requirements were kept as part of the pool of candidate training sites, in order to enable changes to the sampling plan while in the field due to time and fuel limitations. Additional training site characteristics were also generated; site specific estimates of slope, aspect, and elevation themes were developed for each candidate site using grid overlay processes. X,Y coordinate values representing each training site were also loaded into the database table. These training area coordinates were used for navigation and positional confirmation using GPS receivers in the field. Location of training areas in this manner allowed for careful flight planning and more efficient and safer access to field plots. The pool of candidate sites was completed and mapped.

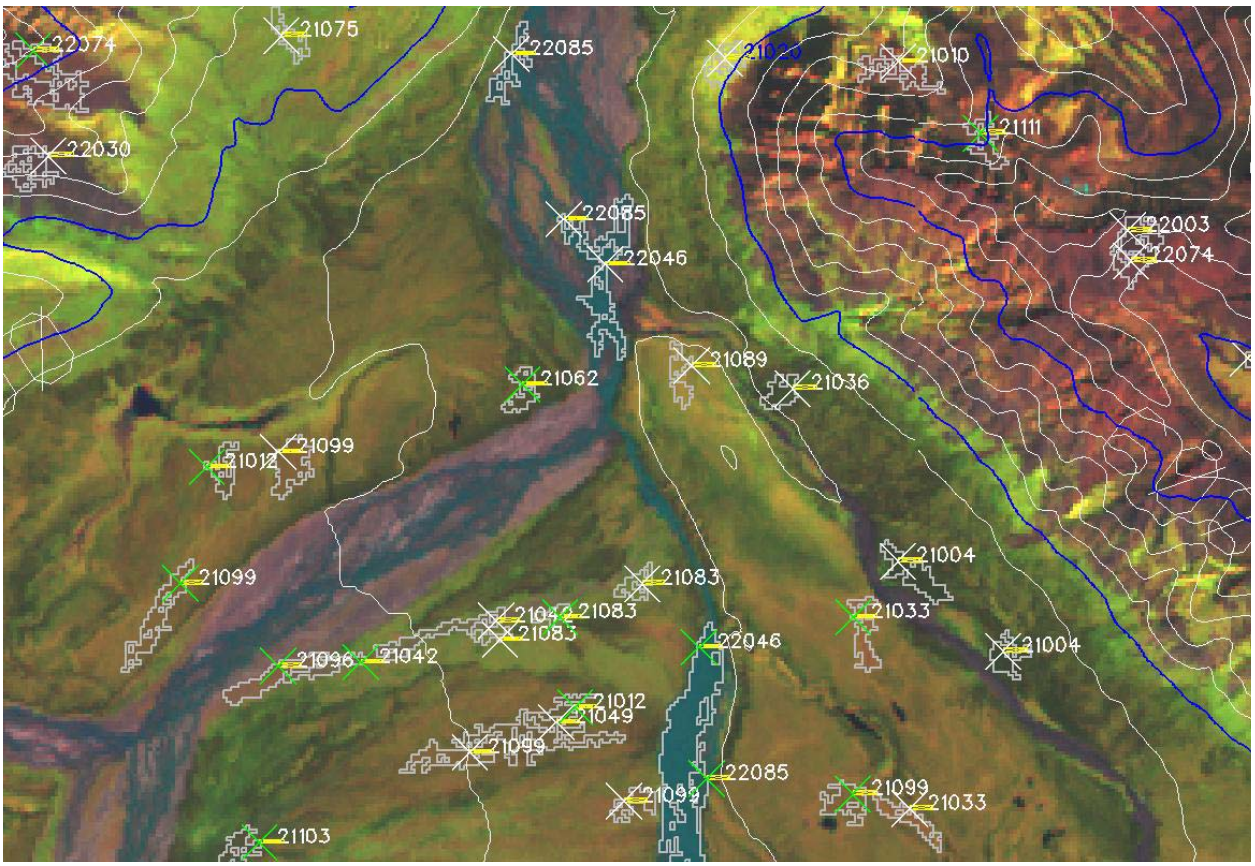

Figure 8: Field Map with Candidate Training Sites

Field Sampling Restrictions

Aerial sampling from a helicopter was used to maximize the number and diversity of sampled aerial training sites. This approach would yield the land cover components as viewed from above ("bird's-eye view") and enabled rapid (and safer) on-demand access to target training areas. However, constraints to sampling efforts existed due to fuel supply and availability, aircraft range, crew-ferrying time, no-flight zones, and weather conditions. Only two areas were designated as "no-fly" areas; these areas were the McCarthy Creek watershed just to the east

of McCarthy and the Chitisone River/Chitisone Pass vicinity. All other portions of the park were deemed accessible, with the only limitation being to avoid collecting aerial data close to private inholdings/homesites or wildlife. High priority was given to identifying and targeting training sites in areas of image overlap, as these sites could be used for training in all overlapping scenes. Large groups of candidate training site areas incorporating as many ecosections and ISODATA classes as possible were identified for sampling.

Aware of these constraints, and at the request of the AKRO, efforts were made to maximize field data collection efficiency by reducing travel time between training collection sites and the number of collection sites required to develop comprehensive supervised classification training data sets. Thus, potential training sites were organized as groups of sites, as much as possible, to minimize distance traveled between sample areas, while at the same time facilitate access by both ground and helicopter crews and adequately sample the geographic diversity of the Wrangell-St. Elias Project Area. Sample areas that fulfilled the sampling constraints, as well as the apparent project training data needs were identified. These proposed sample areas are shown in Figure 9.

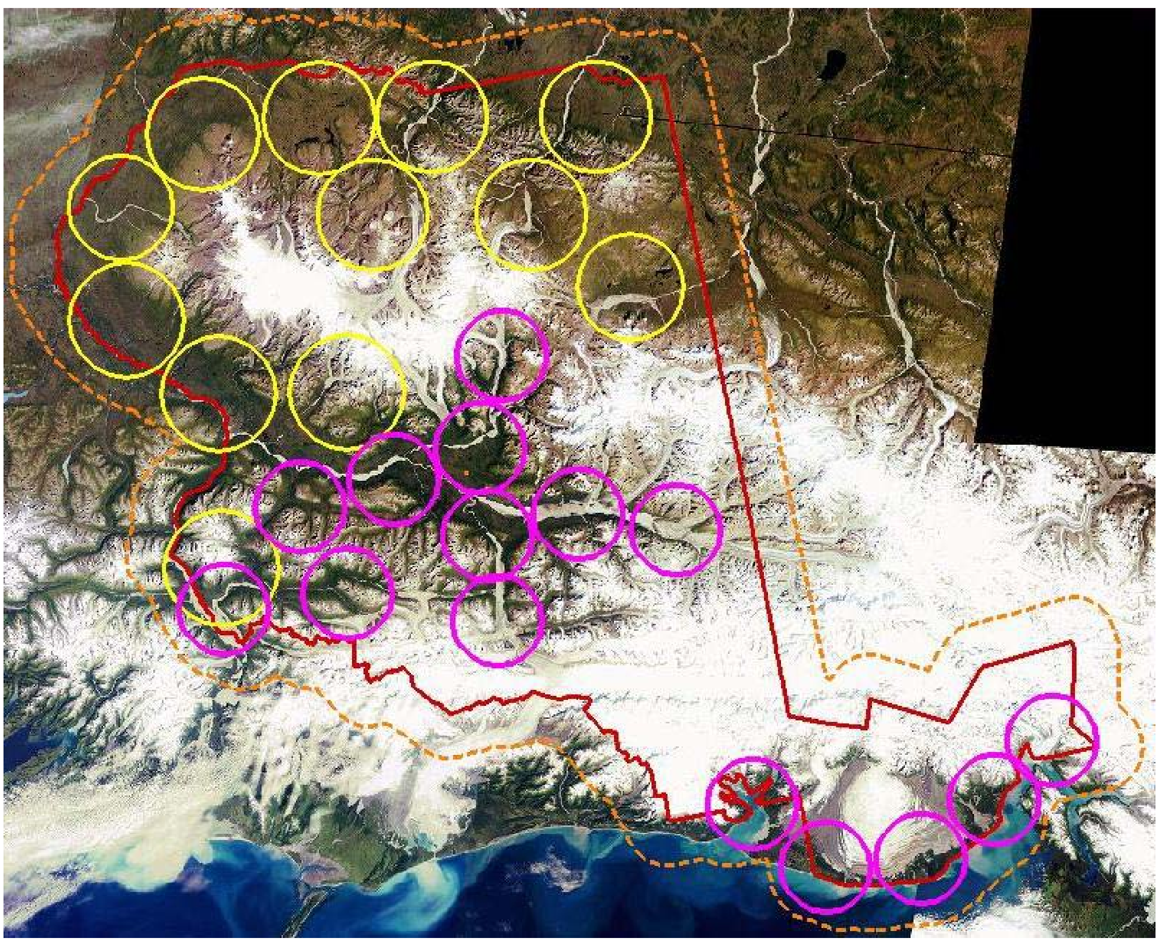

Figure 9: Sampling Areas-of-Interest in WRST

The magenta circles represent initial areas of interest identified for the 2004 field season and the yellow circles represent areas of interest for the 2005 field season. As is evident by the placement of the circles of interest, low priority was placed on sampling areas dominated by snow, ice, and glaciers.

Field Training Site Data Collection

Field data or "ground truth" information is one of the critical components of a land cover mapping effort like this project. The field data provide the land cover or "bird's-eye view" descriptions that will both guide the classification efforts as well as describe the resulting land cover features in the final classification map. Accurate and detailed field data are essential for the successful completion of such an effort. Any misinformation collected during this stage and later applied during classification efforts will be embedded in the final map. Care was taken during initial aerial survey sessions to use methods that would result in as consistent-as-possible vegetation cover estimates, recognizing the significance of the relative abundance of different types (genus) of plants but attempting to identify individual species whenever possible. Particular care was taken to properly identify differences between white and black spruce trees. As this was an aerial survey and not a ground survey, notes were taken whenever the botanist believed his/her species call might be suspect.

Field Data Collection Goals

Image classification training data sets must encompass the complete range of significant land cover characteristics present in the project area. To this end, **GRS** worked with AKRO staff and ABR botanical and ecological experts to identify a matrix of the land cover characteristics and conditions thought to exist in the project area. This matrix represented the variety of land cover characteristics, including species/cover components and vegetation density classes. The land cover class matrix was composed of a combination of the target (known) land cover classification system, as well as other recognized (potential) land cover types that might also be found within the project area. This land cover type matrix formed the basis of the land cover classification system that would be applied during the mapping project. This matrix also formed the basis for field data collection efforts, as classes that would ultimately be recognized and mapped would require training site locations associated with the many different land cover attribute descriptions ("ground truth").

The range of possible land cover types must be adequately sampled within the subject imagery to develop suitable classification training sets that will yield accurate and reliable image classification pixel maps. The basic matrix/listing of land cover types used to guide field data collection efforts is listed in Table 6. At each field data collection site information would be developed that would describe the cover characteristics of the site. This information amounted to a "bird's-eye view" from above of the land cover components that summed to a total of 100 percent cover. A field form was developed by AKRO, **GRS**, and ABR staff to record this information. A copy of one of these field forms is shown in Appendix A. The cover characteristics recorded at each site amount to a "bird's-eye view" of the site, such that the site would be described by species specific (if possible) land cover/vegetation characteristics that would sum to 100% cover. Additional cover (understory or overtopped) would also be noted as part of the information. In additional any specific characteristics regarding moisture regime and environment would also be recorded. Lastly, a land cover type would be assigned based on the botanist's interpretation of the cover composition of the site relative to the land cover classification rules being used in this project.

The vegetation/land cover classification system used for WRST was a modification of the Alaska vegetation classification developed by Viereck (Viereck et al 1992), and was designed by ABR vegetation experts in conjunction with AKRO. The system defined cover classes in terms of vegetation communities named after dominant species existing in principal layers.

The vegetation/land cover classification system evolved during the project as land cover data were processed and evaluated. The complete final set of cover types associated with this mapping project is included in the Results Section of this report in Table 24. A snippet of the C code used in **GRS** software to estimate the cover type class is listed in Appendix B. Schematic descriptions of project cover and density classes can be reviewed in the diagram in Appendices C and D.

Field Data Collection Operations

The collection of field data was a joint effort by personnel from AKRO, **GRS**, and ABR. All field data efforts were coordinated by AKRO personnel and guided by the project data collection needs, as identified by **GRS**, ABR, and AKRO. **GRS** was responsible for the development of daily aerial field survey data collection plans that included the selection of potential candidate field training sites and the information necessary to locate these locations. ABR was responsible for the ecological ground-sampling data collection efforts and the characterization (ecological description) of the different land cover types present in the WRST Project Area. This included the development of detailed land cover descriptions for the field training sites visited during aerial surveys. The AKRO was responsible for planning and coordinating all field data collection logistics over the three-year field data collection effort.

Field data collection efforts were planned to occur during July of 2004 and 2005. Data collection efforts were initiated on July 2, 2004 from Yakutat, AK, located near the southeastern extreme of the Park. A total of 5 days of field data collection surveys were undertaken from this coastal location. Field data collection efforts then shifted to the interior of WRST at May Creek located approximately 3 miles to the southeast of McCarthy, AK. For 8 days from July 16th through July 23rd, aerial survey data was collected south of the Wrangell Mountains. These 13 days comprised the 2004 field data collection effort. Starting on July 9th, 2005 field data collection efforts shifted to the northern side of the Wrangell Mountains where they were based out of Chisana, AK. Four days of field data collection efforts were undertaken from this location before crews relocated in Gakona, AK where field data collection efforts focused on the northwesterly portions of WRST for five days from July 13th through the 17th. Efforts then shifted back to the southern side of the Wrangell Mountains where field data collection efforts were initiated out of Kenney Lakes, AK. A total of 23.5 days of field data collection efforts were completed during 2004-2005. Upon an initial evaluation of the 2004-2005 data collection efforts and consultation with ABR and **GRS**, the AKRO Project Manager decided to schedule one last field data collection effort during July of 2006. This effort was designed to fill in any gaps or data thought to be missing from the 2004-2005 field data collection efforts.

Table 6:

WRST Original Land Cover Types
Sitka Spruce:Closed
Sitka Spruce:Open
Sitka Spruce:Wdlnd
Black Spruce Stunted:Wdlnd
Black Spruce:Closed
Black Spruce:Open
Black Spruce:Wdlnd
Spruce Mix:Closed
Spruce Mix:Open
Spruce Mix:Wdlnd
White Spruce:Closed
White Spruce:Open
White Spruce:Wdlnd
Mixed deciduous-conifer:Closed
Mixed deciduous-conifer:Open
Mixed deciduous-conifer:Wdlnd
Aspen:Closed
Aspen:Open
Aspen:Wdlnd
Balsam Poplar:Closed
Balsam Poplar:Open
Balsam Poplar:Wdlnd
Paper Birch:Closed
Paper Birch:Open
Paper Birch:Wdlnd
Mixed deciduous:Closed
Mixed deciduous:Open
Mixed deciduous:Wdlnd
Tall shrub:Closed:Alder
Tall shrub:Closed:Mix
Tall shrub:Closed:Willow
Tall shrub:Open:Alder
Tall shrub:Open:Mix
Tall shrub:Open:Willow
Low shrub:Closed:Mix
Low shrub:Closed:Willow
Low shrub:Open:Alder
Low shrub:Open:Mix
Low shrub:Open:Willow
Dwarf Shrub
Aquatic Forb
Carex
Forb
Graminoid
Lichen
Moss
Sparse Vegetation
Snow/Glacier
Barren
Water

An additional week of field data collection efforts were scheduled for July of 2006. These efforts lasted from July 7th through the 12th and were based out of Nabesna, AK in the northern portion of the WRST for the first 3 days before returning down to Kenney Lakes, AK in the more central portion of WRST for the final three days. On July 12th survey data was collected on the ground as we had exhausted the helicopter flight time during the first 5 days of our field efforts. Only one area designated for sampling was not able to be sampled during these efforts. The logistics and time requirements to get to Icy Bay in the southeastern portion of WRST made it impractical to sample this area during the project.

Table 7 summarizes project field data collection efforts and the number of aerial survey sites visited and described during these efforts. In total, aerial survey data were collected on **29 days** during the three different aerial data collection efforts. During those days, **104.3 hours** of flight time or approximately **3.6 hours/day** of actual time were logged surveying aerial sites. Much of the remaining helicopter time was spent transporting ground data collection crews to and from the field, moving equipment, and refueling the helicopter.

GRS staff maintained a WRST project database on a **GRS** laptop computer system that was used in the field to develop, revise, and administer aerial survey data collection efforts throughout the Wrangell-St. Elias National Park & Preserve. This system contained all WRST project data and imagery, as well as GIS and Image Processing software. **GRS** used this system to develop and revise daily aerial survey plans and schedules, query and review candidate training site locations to develop alternative plans, download and store GPS data and digital photography, and monitor data collection progress relative to project land cover sampling needs.

Date(YYMMDD)	Frequency
40702	28
40703	24
40704	31
40705	32
40706	13
40716	28
40717	22
40718	18
40719	22
40720	29
40721	34
40722	24
40723	38
50709	16
50710	33
50711	28
50712	31
50713	7
50714	20
50715	17
50716	39
50717	30
50718	28
50719	20
60707	16
60708	31
60709	16
60710	31
60711	25
60712	8
Grand Total	**739**

Table 7: Aerial Sites by Date

Aerial Survey Logistics

The basis of the aerial data collection efforts was the daily flight plan. **GRS** generated a daily flight plan consisting of a list of specific aerial training sites. Each site was selected based on an evaluation of data needs relative to up-to-date data collection efforts and a site specific evaluation of potentially available sites in the particular portion of WRST to be sampled that day. Particular emphasis was placed on locating candidate sites that were situated in overlapping areas of cloud free imagery in multiple images. These sites were consistently mapped as homogeneous areas in multiple images, a further indication that these sites were spectrally homogeneous and would make good image training sites. Planning efforts of this manner were implemented to fulfill data collection needs as-best-as-possible. Each flight plan guided the aerial survey data collection efforts using the Bell or R44 helicopters. This plan, as a tabular report, was printed on the aerial sampling form and included the sampling area number (a regional number assigned to different areas of the project area), candidate training site *iso*_class number, positional coordinates (lat/longs), aspect, slope, and elevation of the sample site locations. This report was generated using the GIS by performing a formatted query of the candidate sites selected and sequenced for sampling for any particular day.

Field maps, imagery, and aerial photos were reviewed and sampling sequences were developed to minimize travel time. Field maps were annotated with additional information as a navigational aid to help locate the selected areas. A tentative sampling sequence was delineated on appropriate field maps indicating selected flight paths, and used as a flight plan for the aerial survey efforts. Coordinates were loaded into the Garmin Map 76S GPS units and used as a navigational tool to quickly and accurately locate the targeted candidate sites. Figure 10 shows a portion of one of these annotated field maps.

As the plans were implemented and sites were visited, **GRS** assigned a unique training site identification number (*trsite_id*) to each aerial survey site. This *trsite_id* was generating by concatenating the date with a sequential visit numbers for each location. For example, the *trsite_id* "071108" would designate the 8th area visited on July 11th. If the same date was used in multiple years, the different years' sets of *trsite_id* values were offset by 50 to retain sets of unique numbers. Actual field locations, based coordinate locations based on the GPS receivers, were collected to "mark" surveyed training area locations from the air. Digital pictures and video representative of the aerial sites was also collected.

GRS made efforts to adhere and exceed daily aerial survey schedules. However, fuel capacity, time limits, and other constraints did not always allow for complete sampling of the scheduled areas or sites. Opportunistic sampling was implemented whenever feasible in order to supplement scheduled sampling efforts, so long as such efforts were not excessive such that they would prevent the primary schedule from being implemented. Opportunistic sampling was implemented in two ways. The first way entailed locating alternative *iso_class* training areas printed on field maps that were spectrally equivalent to and nearby scheduled areas (i.e., same *iso_class* code) that could not be sampled. The second type of opportunistic sampling involved spotting and sampling apparently promising areas while en route to other locations. These areas were not necessarily plotted on the field maps and may not have had assigned *iso_class* codes. However, they were visually estimated to be large enough and appeared homogeneous enough to qualify as valid sampling sites. These sites also tended to be land cover types known to be 'rare' or missing in the land cover matrix, such as wet herbaceous or aquatic types.

The aerial survey crew consisted of the helicopter pilot, a **GRS** image processing specialist and a botanical specialist. The botanical specialist was either an ABR employee or the AKRO Project Manager. The **GRS** specialist's responsibilities included navigating to and locating scheduled candidate training sites using coordinates listed in the daily flight plan printed on the sample schedule form and on the field maps. As the helicopter approached a target location, the **GRS** specialist used field maps to confirm arrival at the target site. Once arrival at a target sample site was visually confirmed and its extent described to the entire aerial survey crew, the pilot would begin to slowly circle the target site while the botanist proceeded with the ecological characterization of the land cover present within the training site. Meanwhile, the **GRS** specialist photographed and videotaped the site, recorded coordinate locations of the site using the GPS unit, and recorded pertinent comments. Once the ABR botanist and **GRS** specialist declared completion of their tasks, the **GRS** specialist provided navigational information and the pilot began flying to the next training site. If the botanist had questions regarding what he/she was viewing from the helicopter, the pilot would set down in the sample area, if possible, enabling the botanist to get out and actually see the vegetation and collect plant samples. This was not a common experience due to time and fuel limitations and happened at no more than 10% of the aerial survey sites.

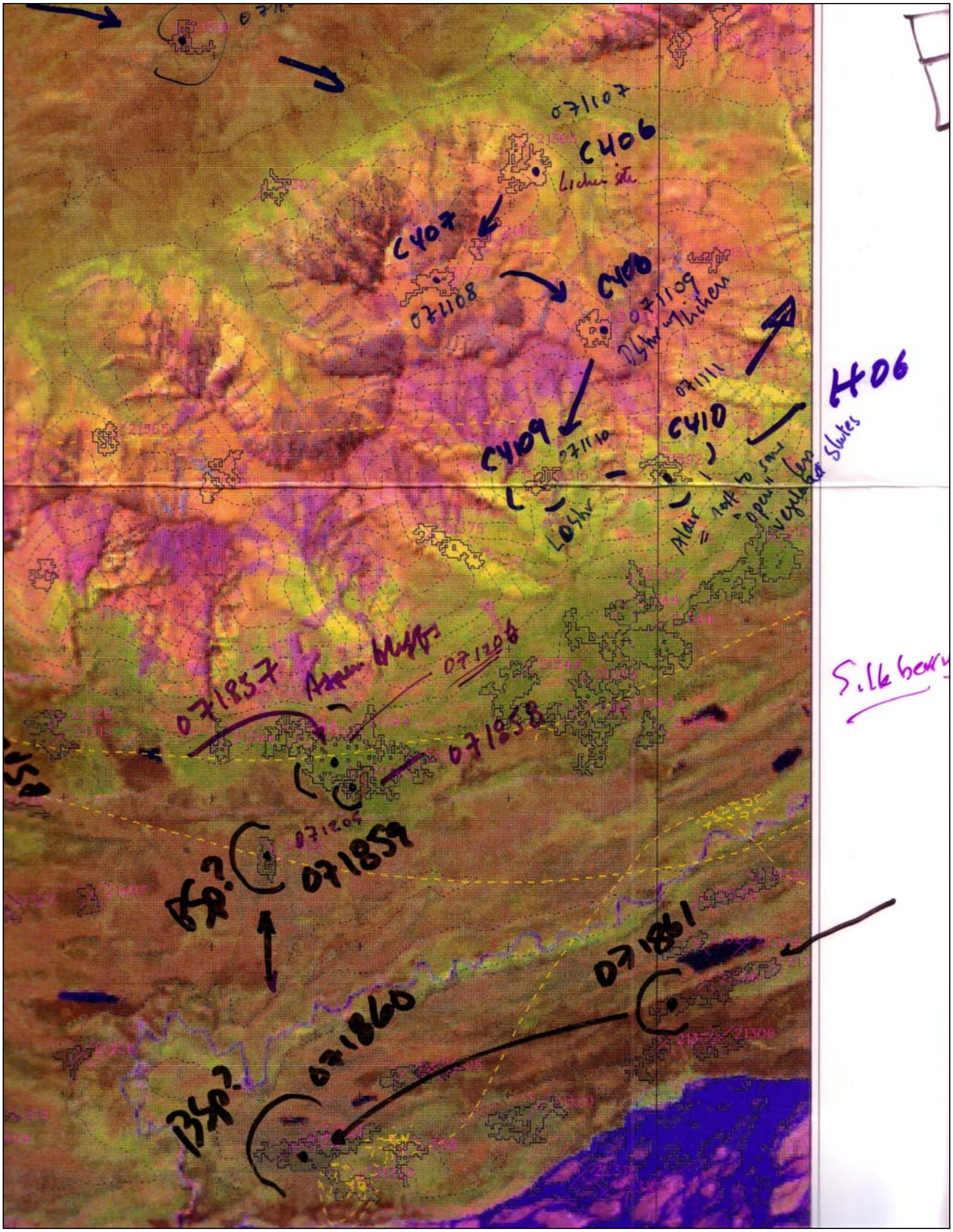

Figure 10: Annotated WRST Field Map (portion)

Each day following completion of aerial survey site data, the data were processed and the number of sites that had been sampled were tallied in the database, thereby enabling tracking of the frequency of samples by iso_class and land cover type. This information was used to identify types still lacking samples, as opposed to common types with many samples. Subsequent data collection efforts were adjusted daily in an effort to completely cover/fill the land cover type matrix. In addition, remaining unsampled types were identified and reprioritized so that they could be sampled as opportunistic training sites, if the aerial survey crew found suitable sites of these known unsampled types.

Aerial Survey Results

An average sampling day consisted of approximately four hours for actual training area aerial surveying. A total of 739 training sites were described by the aerial survey crew. An average of 25 sites were surveyed from the air per sampling day. At the end of each sampling day, the **GRS** specialist imported coordinate values for sampled training sites into the project database and maps. Each sampled site field-recorded position was converted into a point feature attributed with its unique training site ID. This ID was later used to relate each point to its respective land cover description data. All recorded digital imagery was also saved to disk. These efforts resulted in plotted flight paths, where each aerial site was a waypoint on the flight path. Locations were reviewed relative to the candidate site locations and the imagery, and any inconsistencies relative to the candidate site locations were identified. If the candidate site was 'missed' during the sampling it was not recorded as a sampled iso_class.

As data collection efforts progressed, field data were reviewed on a daily basis to assess the variability and number of land cover classes visited to-date. These reviews enabled GRS personnel to reprioritize efforts and guide subsequent data collection efforts to include classes that appeared under-represented in the current sample set. A summary of the number of sites surveyed from the air by the original land cover types listed in Table 6 is shown in Table 8. These data collection sites and classes were distributed over the entire project extent visited, spanning all nine LandSAT images.

Cover data for surveyed sites were imported into the project database tables and made available for database query and report tools used in the subsequent resolution of class confusion, assessment of training class performance, and characterization of each site's land cover attributes. SQL queries were performed to check for invalid data, such as sites for which the total "bird's-eye view" cover did not equal 100 percent. SQL statements were also used to generate the modified Viereck land cover types, to check for incorrect or inconsistent field calls. Data inconsistencies were identified and corrected. Data were summarized using ***GRS_covmatrixsum*** to develop a calculated cover type (*calc_class*) using the modified Viereck rules and estimates of cover by individual specie, as well as groups of species, and were loaded into the relational database tables as attributes of each site. In addition, the predominant cover component and percent cover were also loaded into the database tables.

Supplemental Data Sources

In addition to the aerial survey data, additional data sources were also used during this project. The field data that was collected over a total of 29 days amounts to approximately 3 days per image or sampling about 600,000 acres per day. While efforts had been made to assure sufficient distribution of sampling throughout the range of types and images, 29 days were not enough time to develop the fully comprehensive sample necessary to map the entire WRST. Supplemental data would be necessary to increase the sample size for underrepresented images and types.

In addition, **GRS** found as the project progressed that more floristic components, such as *Dryas sp*, *Betula sp*, *Betula-Salix* mixes, and *Cassiope* could be spectrally distinguished and mapped, if such sites could be included in the training data sets. Additional data sources were used in an effort to supplement the existing aerial data set that had been developed. While none of these supplemental sites had been prequalified to see if they were spectrally homogeneous, they did have vegetation characteristics that were of interest to the project.

The additional sources included ABR ground survey site data, NPS FirePro (FP) plot data, Ducks Unlimited (DU) aerial survey data, and **GRS** photo-interpreted/occular estimates. ABR ground data was used to generate estimates for a few sites that were lacking from the vegetation land cover matrix, such as Low:Open:Silverberry. In addition, a few ABR sites were used to represent land cover types present in the matrix, but missing from a particular scene. The same rationale was used when adding FP site data to the training data set. The DU data set had been collected during the summer of 2005 for a mapping project performed for Tetlin National Wildlife Refuge. This data set was of value as it contained many black spruce and wet herbaceous sites out on the Tetlin flat north of WRST that were thought-to-be representative of similar areas in that northeasterly area of WRST that **GRS** had only been able to sample for one day. Lastly, **GRS** added some sites using photo-interpreted or ocular estimated techniques to represent areas that could be estimated with a high degree of reliability. Many of these sites were in areas that **GRS** had visited or observed during sampling efforts, but had not actively collected data at the site during the aerial survey. The types added in this manner were typically non-vegetated land cover types such as snow, barren, water, glacier, and so forth which had been relatively low priority sample types relative to vegetation types. Some areas, with vegetation, were represented by data from other sites where the two sites were thought to be comparable in composition.

Table 8: Sample by Type

WRST Original Land Cover Types	Sample Count
Sitka Spruce:Closed	4
Sitka Spruce:Open	5
Sitka Spruce:Wdlnd	2
Black Spruce Stunted:Wdlnd	1
Black Spruce:Closed	1
Black Spruce:Open	18
Black Spruce:Wdlnd	15
Spruce Mix:Closed	0
Spruce Mix:Open	10
Spruce Mix:Wdlnd	4
White Spruce:Closed	8
White Spruce:Open	59
White Spruce:Wdlnd	38
Mixed deciduous-conifer:Closed	11
Mixed deciduous-conifer:Open	42
Mixed deciduous-conifer:Wdlnd	13
Aspen:Closed	9
Aspen:Open	6
Aspen:Wdlnd	1
Balsam Poplar:Closed	7
Balsam Poplar:Open	17
Balsam Poplar:Wdlnd	6
Paper Birch:Closed	4
Paper Birch:Open	1
Paper Birch:Wdlnd	2
Mixed deciduous:Closed	5
Mixed deciduous:Open	14
Mixed deciduous:Wdlnd	9
Tall shrub:Closed:Alder	34
Tall shrub:Closed:Mix	12
Tall shrub:Closed:Willow	18
Tall shrub:Open:Alder	12
Tall shrub:Open:Mix	10
Tall shrub:Open:Willow	7
Low shrub:Closed:Mix	12
Low shrub:Closed:Willow	1
Low shrub:Open:Alder	1
Low shrub:Open:Mix	69
Low shrub:Open:Willow	26
Dwarf Shrub	70
Aquatic Forb	3
Carex	26
Forb	51
Graminoid	4
Lichen	7
Moss	5
Sparse Vegetation	21
Snow/Glacier	0
Barren	28
Water	9

Land cover data for all four of these additional sources were processed to develop the 100% "bird's-eye view" land cover descriptions. These data were also loaded into the relational database tables and processed to develop information comparable to the information developed from the aerial survey sites. Data inconsistencies were identified by **GRS** and corrected by AKRO, ABR, and DU as best as possible to develop usable training data. Summary data were generated and loaded into the database. Locations were input into the GIS database and all sites were spatially referenced to the project database, in the event that they might be used as supplemental training sites.

Image Classification Training Set Development

GRS uses both supervised and unsupervised classification techniques to develop land cover pixel classification maps. Both these methods are dependent on training sets that characterize each individual image. Training set development is a critical component of a classification effort. "Ground truth" or land cover attribute data must be properly correlated to spectral data to develop accurate and detailed land cover map data. If the attribute descriptions are not properly associated with the spectral data, then the resulting land cover map will be an inaccurate representation of the project area. Care must be exercised to properly train the spectral data with the "ground truth."

The goal of this phase of the project is to build image training data sets that most accurately reflect the land cover types present in the project area, while at the same time minimizing confusion and uncertainty within the training data. Training areas should reflect the areas described during data collection efforts and have small statistical variation within the spectral data of each training site. Training areas of this sort tend to minimize overlap of spectral statistics and confusion between training data. Proper spatial registration and sufficient size are requirements of statistically reliable training data. As training sites are developed they are reviewed to determine their validity. Reviews include evaluations of confusion and fidelity/self-classification. Valid sites are used in classification efforts and invalid sites are withdrawn and discarded from the classification effort. A key component in **GRS**' supervised methodology is that an individual training class is developed for each field survey site, rather than for groups of sites that are thought to represent the range of a training class. This different approach tends to keep spectral statistical ranges small relative to the spectral statistics for classes formed from groups of similar sites and results in reduced statistical overlap and confusion of data for sites of different land cover characteristics.

Supervised Training Set Development Strategy

The first sites used to develop image training data were the aerial sites that were surveyed during **GRS**'s field data collection effort. These were the sites that were selected for sampling based on their spectral homogeneity and size. Several obvious land cover classes such as water, snow/ice, and barren were developed from training areas selected with the aid of aerial photography and satellite imagery. Where possible, the same obvious land cover training sites were used in each image in the areas of image overlap, to minimize the number of training sites needed to classify the imagery.

After review of the resulting frequency of sites by class (Table 8), certain land cover types, as well as certain portions of the project area were still lacking representative training sites. For these missing or under-represented areas, additional sites were added using data from the alternative sources of training site information. Training sites were first added from those areas

visited by ABR crews, as these sites were comprised of data most compatible with the aerial sites in terms of the data collection time period and descriptive information. Unfortunately, many of these potential sites were in areas that were simply too small (less than 15 pixels in size) to use as an image training site. DU sites were added to represent the northeastern portion of WRST in the Tetlin National Wildlife Refuge north of the Nutzotin Mountains. Additional sites, if still needed, were then added from the FP survey sites. Lastly, after review of all these additional sites, supplemental sites were added from photo-interpreted and ocular-estimated areas to finalize the classification training data sets.

Supervised Training Site Development Techniques

Training areas were developed in training sets that would be applied to the specific images during classification efforts. Nine training sets were initially developed, one for each original image – 6118, 63678, 6378, 6418, 6467a, 6467s, 6567, 65678, and 6767. Sets of training areas were developed image by image attempting to sample the same areas within overlapping images. Training areas within each training set were created individually using region growing techniques, a neighborhood seeding method that used a 5x5 pixel initial seed window surrounding a point interactively selected on the image to grow a spectrally homogeneous area around the seed location. Location of the initial point in each area was determined by the approximate location of the surveyed site, as indicated by GPS data collected to represent the survey site coverage overlaid on the imagery. Training area pixel inclusion was determined specific to each scene using a statistical threshold of 2 standard deviations from the grown region area mean spectral data. The maximum search area extent was limited to a 41x41 pixel area. These parameters were the basic parameters applied while developing training sites at all training site locations. However, if a sufficiently representative area could not be grown using these exact parameters, then the standards were modified (relaxed or tightened) as follows:

Option 1: Initial seeding points were moved slightly, but were still quite close to the location of the training site point, so that the resulting sample area represented the surveyed area. If this approach did not produce a sufficiently large enough training area, then option 2 was applied. Option 1 was the most desirable, since it would still keep training area spectral statistics as tight as possible, thereby reducing potential confusion during classification.

Option 2: If the resulting area was too small, the seed area would be enlarged to an initial 7x7-pixel window. If this approach did not produce a satisfactory training area, then variants in size were applied, such as a 5x7 window or a 7x5 window. Window size was increased up to 9x9 in an attempt to generate a representative training area. If the resulting area was too large, then a smaller initial seeding area of 3x3 was selected. 3x5 and 5x3 seeding areas would also be used in an attempt to generate a representative area. If neither of these two approaches worked then Option 3 was applied.

Option 3: The seed area would be set back to an initial 5x5-pixel window. If the generated area was too small then the pixel inclusion parameters would be relaxed to a threshold of 2.25 standard deviations. If the generated area was too large, then the pixel inclusion parameters would be decreased to a threshold of 1.75 standard deviations. The seed area window would then be increased or decreased in size, depending on the size of the generated training area relative to the survey site. If this approach did not produce a satisfactory training area, then option 4 was applied.

Option 4: The seed area would be set back to an initial 5x5-pixel window. If the generated area was too small then the pixel inclusion parameters would be relaxed to a threshold of 2.5 standard deviations. If the generated area was too large, then the pixel inclusion parameters

would be decreased to a threshold of 1.5 standard deviations. The seed area window would then be increased or decreased in size, depending on the size of the generated training area relative to the survey site. Varying the seed area size and pixel inclusion threshold in this manner usually generated areas of sufficient size. If a representative area still had not been obtained Option 5 was applied.

Option 5: Identify the training area by drawing a polygon around the pixels of interest.

While the ideal candidate site area size was originally set at 60 pixels, a minimum of 15 pixels was used in an effort to develop spectral training statistics. Sites this small most commonly occurred when training sites were developed using opportunistic or supplemental sites that were not pre-qualified as part of the candidate training site selection process. These smaller training areas were included in the initial classification in order to discard as few training sites as possible. The problem with such small areas is the potential for higher spectral data standard deviations (relative to larger sites) due to the smaller number of pixels that can sometimes overwhelm the classification process.

<u>Supervised Training Set Development</u>

Each of the aerial survey sites visited during the WRST field sampling efforts was included in at least one of the nine initial image classification training sets developed for this project. As land cover characteristics for these sites were evaluated and tabulated, missing or underrepresented types were then added from the supplemental data sources to the training data sets. The following sources of additional training site data were reviewed and used when possible.

The first supplemental source of training site data were those sites visited by the ABR ground crews during the same 2004-2006 field seasons. Although the cover for these sites was verified on the ground, there was no assurance that every site would exhibit the necessary spectral homogeneity and extent required for a training site. In some cases, it was possible to verify suitability for inclusion of these sites as training classes from review of digital photographs taken by the ABR ground crew. A total of **16** ABR ground data collection sites were reviewed and added to the supervised training sets.

The second supplemental source of training site data were those areas surveyed by Ducks Unlimited crews during their Tetlin National Wildlife Mapping Project of 2005. The DU database was comprised of 405 sites, of which **398** were considered as potential training sites after being reviewed and verified for positional accuracy by **GRS** personnel. Data were collected during June and July of 2005 using very similar aerial survey cover estimation techniques at sample sites based upon **GRS**'s sample site selection methodology.

The third supplemental source for training site data were those areas visited by FP ground crews over the past 25 years, mostly back in the 1980's and 1990's. The FP database for WRST was comprised of nearly 2,300 sites, of which **152** were considered as potential training sites after being verified for positional accuracy by **GRS** personnel. An inherent assumption in using these data was that the characteristics of the sites had not changed significantly since the areas were surveyed. A few sites that appeared out-of-date or inconsistent with image interpretation were discarded. Land cover data often did not total to 100% cover or were overly generalized without a species designation, but these cover values were reviewed and adjusted by AKRO and **GRS** staff to develop corrected "bird's-eye view" land cover summaries for each site to be used in the training data sets. Original FP field sheets and photography were reviewed during these efforts.

Finally, a fourth supplemental source for training site data were those additional sites developed by **GRS**, to represent obvious types and remaining areas not represented in the classification. Most of these additional sites were added in gaps that remained in the classification maps after initial classification efforts. After growing training polygons in these remaining unclassified areas, a combination of aerial photo-interpretation and comparison of statistical similarity with existing classes were used to define preliminary cover type descriptions for these supplemental classes. In most cases these unclassified areas were obvious types like water, barren, and glacier/snow types that were easily identified from aerial photography. Some of these areas represented herbaceous or sparse vegetation and were estimated using data from what were interpreted to be comparable sites in other image training sets. A total of **65** supplemental sites were developed during this project.

Supervised Training Site Review and Evaluation

The appropriateness of the training data was determined in two ways. One way involved a review of classification confusion reports that described confusion between training signatures within each training data set. The second involved a review of classification fidelity to determine if classified pixels within training sites yield the same land cover data descriptions (attributes) as the field survey data descriptions. If these evaluations yielded results indicating problem situations or data inconsistencies regarding a site, then the specific site was reevaluated and the problem identified. Types of problems most readily identified in this manner were the improper location of the training site location (build spectral signature in the wrong area), excessively high spectral variances of a class relative to other classes, or spectral confusion between dissimilar land cover types. If the problem could not be resolved by either correction of the training data or masking to separate the application of the spectral data, the site would eventually be withheld or discarded from the training data set.

Unfortunately, both of these evaluations are only useful in the determination of whether or not the training data that have been developed provide results that are consistent with other training data. Neither of these measures necessarily indicates whether or not the training data are an accurate representation of what the true land cover conditions are. For instance, if the vegetation in a specific site is incorrectly identified, or assigned incorrect cover estimates, these data will not necessarily be identified as incorrect or inconsistent unless there are other similar, slightly overlapping training sites that indicate an inconsistency amongst the land cover data. Therefore, sites that are totally non-overlapping will tend to have high pixel fidelity, but could still be wrong, if the underlying “ground truth” are incorrect. Therefore, data lacking confusion and exhibiting high self-classification may still be wrong. Large training data sets with multiple sample sites are desirable as they may help confirm the ‘goodness’ of the data.

Class Confusion Evaluation

Training classes were evaluated for confusion in terms of their Jeffries-Matusita (J-M) distance, which is a reliable indicator of class separability (Swain and Davis 1978). A maximum J-M distance of 2.0 between two classes means that they are perfectly distinguishable from each other. A minimum J-M distance of 0.0 indicates that two classes are, as far as the classifier is concerned, spectrally undistinguishable from each other. In general, the probability of error in distinguishing two classes drops as their J-M distance increases. At a J-M distance of 1.4, this probability is approximately 1%. Figure 11 shows the relationship of the J-M distance to the upper and lower limits of the probability of error.

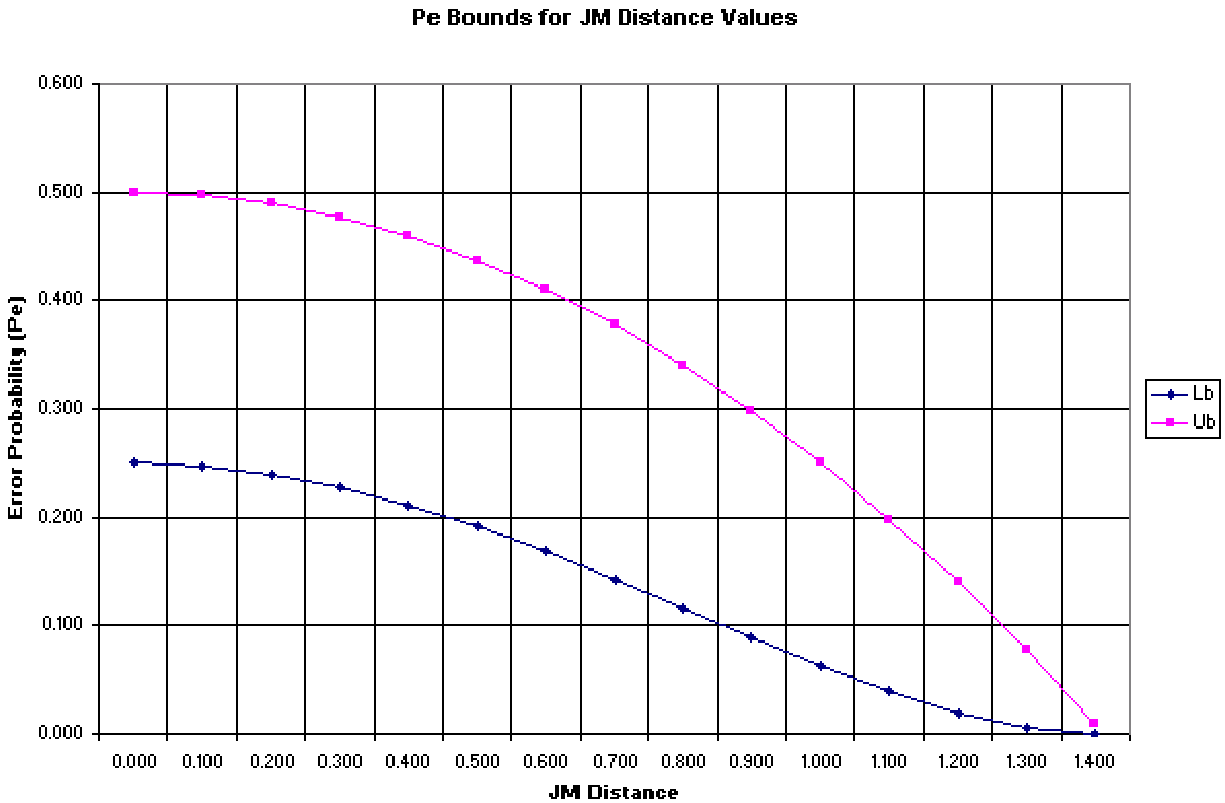

Figure 11: Probability of Error and J-M Distance

The Confusion Report used to evaluate training class confusion is generated for all training sites used in all of the training sets. The target minimum J-M distance value for inclusion in the Confusion report was set at a 1.4 threshold. Training sites related by J-M distance values below this threshold were reviewed and evaluated.

Sample portions of the Confusion Report are shown in Table 9. The data in this report are organized by training site and the training sites are listed in order of the calc_class (the generated type call based on the cover thresholds and definitions). For each site, all potentially confused training sites are listed in order of the magnitude of the J-M distance, along with the land cover characteristics of these sites. The training set in which the confusion exists is also listed for each confused site. The training set name is based on a combination of the characteristics of the training set that distinguish it from other training sets, such as the image name and the type of the training set. In this case, the type of the training sets evaluated was the supervised (Sup) training sets.

The confusion data were reviewed to identify potential sources of confusion. Review involved identification of nonconforming sites and was not based on any quantitative data limits, as there is tremendous potential overlap of somewhat similar land cover characteristics that have different land cover types. In general, those sites that were nonconforming are those that were not expected to be confused when one considered their descriptive data. Confusion between sites of similar or equal land cover types or cover characteristics was considered as agreement of the different sites and acceptable.

Bad Confusion:

Trsite_id:	70518		2	2000	HrC	Graminoid	0	0	15	0	70	0	15	108	1	38

Training Set	Confused trsite_id	J-M Dist	Eco-Type	Iso Class	Cover Type	Calculated Class	Tree Cover	Pct Conifer	Shrub Cover	Dsh Cover	Forb Cover	Bar. Cover	Oth Cover	Aspect	Slope	Elev
6118Sup	70532	1.072	2	2000	PSi	Sitka Spruce:Closed	70	90	10	0	0	15	5	131	1	393

Good/Acceptable Confusion:

Trsite_id:	70220		7	7000	TSA	Tall shrub:Closed:Alder	0	0	80	0	20	0	0	239	40	1457

Training Set	Confused trsite_id	J-M Dist	Eco-Type	Iso Class	Cover Type	Calculated Class	Tree Cover	Pct Conifer	Shr Cover	Dsh Cover	Forb Cover	Bar. Cover	Oth Cover	Aspect	Slope	Elev
6118Sup	70527	1.114	7	7000	TSh	Tall shrub:Closed:Mix	5	0	85	0	5	5	0	149	28	1519
6118Sup	70529	1.246	7	7000	TSA	Tall shrub:Closed:Alder	15	33	80	0	5	0	0	279	19	1215
6118Sup	70510	1.398	7	7000	TSA	Tall shrub:Closed:Alder	0	0	90	0	10	0	0	211	23	774

Trsite_id:	71669		12	0	PGl	White Spruce:Open	36	97	4	0	0	0	60	315	0	2469

Training Set	Confused trsite_id	J-M Dist	Eco-Type	Iso Class	Cover Type	Calculated Class	Tree Cover	Pct Conifer	Shr Cover	Dsh Cover	Forb Cover	Bar. Cover	Oth Cover	Aspect	Slope	Elev
65678Sup	71672	0.845	12	0	PGl	White Spruce:Closed	60	100	10	0	10	0	20	167	12	2594
65678Sup	71903	0.893	3	0	PGl	White Spruce:Open	35	100	31	15	1	0	18	159	1	1496
6467aSup	71672	1.050	12	0	PGl	White Spruce:Closed	60	100	10	0	10	0	20	167	12	2594
6567Sup	72113	1.070	3	3000	PGl	White Spruce:Open	42	83	15	0	5	0	38	66	3	931
65678Sup	72102	1.165	3	3000	PGl	White Spruce:Open	45	88	5	0	3	5	42	22	1	1497
6567Sup	71861	1.174	3	21306	PHw	Mixed decid-conifer:Open	57	61	10	10	5	0	18	172	1	1298
6567Sup	71672	1.212	12	0	PGl	White Spruce:Closed	60	100	10	0	10	0	20	167	12	2594
65678Sup	71163	1.234	5	21004	PGl	White Spruce:Closed	61	98	6	10	3	5	15	39	0	2157
6467aSup	70954	1.325	6	21036	PGl	White Spruce:Open	25	100	25	0	1	5	44	143	6	3471
65678Sup	71864	1.377	3	21306	PGU	White Spruce Cmplx:Closed	65	76	30	0	0	0	5	186	14	1449

Trsite_id:	71970		1	21327	PMa	Black Spruce:Open	30	100	30	30	0	0	10	205	2	1772

Training Set	Confused trsite_id	J-M Dist	Eco-Type	Iso Class	Cover Type	Calculated Class	Tree Cover	Pct Conifer	Shr Cover	Dsh Cover	Forb Cover	Bar. Cover	Oth Cover	Aspect	Slope	Elev
65678Sup	71855	0.756	3	21327	PMa	Black Spruce:Open	35	100	25	20	0	0	20	135	1	1560
65678Sup	71852	0.843	3	21399	PMa	Black Spruce:Wdlnd	22	100	15	35	10	0	18	169	2	1218
65678Sup	71901	0.956	3	3000	PMa	Black Spruce:Wdlnd	20	100	20	5	4	0	51	297	1	1526
65678Sup	71969	0.965	1	21399	UP	Spruce Mix:Open	40	100	15	30	0	0	15	185	4	1976
65678Sup	71853	1.121	3	21414	PMa	Black Spruce:Wdlnd	23	100	20	20	12	0	25	0	0	1801
65678Sup	71024	1.164	1	21399	PGl	White Spruce:Open	35	100	6	25	0	0	34	352	1	2416
65678Sup	71207	1.260	3	21327	PMa	Black Spruce:Wdlnd	20	100	26	10	4	5	35	38	4	1395
65678Sup	71758	1.268	1	21399	PMa	Black Spruce:Wdlnd	20	100	15	0	6	9	50	328	1	1848

Table 9: Confusion Report (selected examples)

This type of confusion was considered “good confusion,” as this sort of comparison confirms that the overlapping signatures are classifying pixels of somewhat similar land cover characteristics. Confusion of similar land cover types indicates that the supervised methodology is mapping “shades-of-gray.” The “good confusion” examples in Table 9 show how the confused training sites appear to be variants of each other, rather than dissimilar types; in this case, any one of these confused types would likely still be a suitable representative type for the confused pixel. On the other hand, confusion between sites of dissimilar or completely different land cover types or cover characteristics was considered unacceptable confusion. This confusion was “bad confusion,” as it indicates similar or overlapping spectral data for very dissimilar land cover type characteristics. The example of “bad confusion” in Table 9 indicates a Graminoid site with no tree cover was confused with a Sitka Spruce:Closed type with 70% tree cover. These confused sites are very different types and one type is not a suitable replacement of the other if they were misapplied during classification efforts.

The magnitude of the confusion, as indicated by the J-M distance, was also considered when evaluating confused training classes. J-M distance values near or above 1.3 were considered still viable for class separation, given a less than 10% chance of misclassification. In reality, class separation is still possible at lower J-M distances, but the probability of classification error is greater. In these cases, the nature of what classes were confused with each other became most important in evaluating the confusion. For the WRST Land Cover Mapping Project, if the confused classes were of fairly similar land cover characteristics, **GRS** accepted the overlap of the spectral training data, since the resulting class would likely still fall within a similar land cover type. However, if land cover values were sufficiently confused and the types were dissimilar like the Graminoid and Sitka Spruce:Closed sites in Table 9, then the confusion had to be resolved.

The first step in resolving the confusion was to recheck the location, shape, and size of the training areas involved, to be certain that the spectral training data had been collected in the appropriate locations. If the training polygons were correctly located and configured, then resolution required either removal of the badly confused class or segregation of the confused training classes into different training data sets that would be applied separately to the imagery during the classification process. The segregation of training data into sets that had “tree” data and “no tree” data is an example of how confusion between some of the moderate-to-high density spruce types and non-spruce types could be resolved.

After resolving as much training site confusion as was possible, a certain degree of confusion remained. The primary source of confusion in several different images occurred between Open White/Sitka Spruce sites and Wet Herbaceous classes. This confusion could not be resolved by means of training area editing as the spectral statistics for most of the confused classes were nearly identical to each other. In order to resolve these inconsistencies, masks were developed and used in conjunction with elevation/slope modeling to limit the distribution of the confused spruce and wet herbaceous types to different and appropriate portions of the project area. A secondary source of confusion occurred between a limited number of White and Black Spruce sites. While this confusion was quite limited (overall the confusion report indicated a fairly high degree of separability between White and Black Spruce sites), it resulted in a few Black Spruce types occurring in areas where Black Spruce was known not to occur. Lastly, the “shades-of-gray” confused sites sometimes might result in some shrub types with no trees being represented by shrub types with a very minor tree cover component of just a few percent cover. This type of confusion could lead to higher elevation shrub types containing tree cover where in reality they were above the “tree-line”. Masks and elevation/slope modeling were used to resolve as best as possible these two types of confusion.

Classification Fidelity Evaluation

A test of how the confusion affects the classification output may be determined by review of the classification fidelity data. All training classes were evaluated for classification fidelity. Each training site was evaluated to determine how well the individual training area was classified by comparing the characteristics of the classified pixels that formed each training class with the observed field characteristics of the training area. Fidelity is viewed in two ways. The first compares the number of pixels of the training area that were actually classed as that training class value. The second compares the land cover characteristics developed by summarizing the classified pixel attributes of the training site with the observed land cover characteristics of the site. Confusion of spectral signatures of different land cover types will result in infiltration of different cover attributes into the training areas polygon and a subsequent change in calculated land cover attributes for the training area of a confused type. Confusion of types with similar attributes will result in infiltration of similar characteristics and will not change the land cover attributes of the calculated training area.

The Fidelity Report (see Table 10) is used to evaluate classification fidelity. Formatted as a spreadsheet, this report shows fidelity data for different versions of the participating training sets, as applied to each scene (the training set names follow the same conventions as in the Confusion Report). Report data were developed by computing for each training area the stratified averages of the different classified pixels' land cover values based on a Maximum Likelihood supervised classification of these areas. Fidelity data included the scene ID, training site ID, percent pure (self-classification), area pixel count, calculated cover-type code, predominant cover component, and predominant component's cover, as well as a break-down of training area cover composition based on the classification of the training area pixels. These data were then compared to the "ground truth", a more generalized calculated field call based on the field data, and the field described cover components of each site (also included in the table) to evaluate the fidelity of each training class.

The following criteria were used to evaluate pixel fidelity for each training site:

- **Self-Match** -- the level of self-classification (percent pure) of an area – how many pixels of the training area were classified as that same class. The following percent self-classification limits were used to describe the degree of self-matching:

Degree of Match	Self-Classification Limits
Strong Match (**M**)	>= 75%
Near Match (**mm**)	>= 50% and < 75%
Slight match (**nn**)	>= 25% and < 50%
Not a match (**N**)	< 25%

- **Type-Match** -- the degree of matching land cover class and component cover attributes.
    - Sites that matched land cover classes of type, predominant species, and density for the land cover components were a Strong Match.
    - Sites that showed land cover class component values that differed from calculated ones by no more than approximately ten percent – these areas might not exactly match class values, but still matched land cover attributes and were also a Strong Match. These cases typically concerned comparison of values that are quite similar, but which may in fact span type or class thresholds or limits.

Source	trsite_id	Comments	Type-Match	Self-Match	Percent Pure	#pixels	Type	pr_comp	pr-comp cover	cover class	tree cover	veg cover	conf cover	hdwd cover	shrub cover	TSh cover	LSh cover	DSh cover	hrb cover	aqu cover	other cover	bar cover	water cover	undf cover
	71601																							
6378Sup	71601				27.5%	229	PGI	White Spruce	33.2	Open	43	41.5	86.6	13.4	30.1	9.1	21	1.7	9.7	0	14.7	0.7	0	0
6467sSup	71601				19.1%	89	PGI	White Spruce	26.2	Open	41.1	32.9	88	12	25.2	9.3	15.9	1.1	6.6	0	23.5	1.8	0.7	0
65678Sup	71601				48.2%	195	PGI	White Spruce	31.4	Open	43.4	36.1	91.7	8.3	29.5	11.8	17.7	0.7	6	0	19.1	1.3	0.1	0
6567Sup	71601				69.4%	85	PGI	White Spruce	43.2	Open	50.9	39.2	87.5	12.5	31.8	12.7	19.1	0.2	7.3	0	9.6	0.2	0	0
CalcTypeCall06	71601	OK			TR	1	PGI	White Spruce	50.0	Open	55.0	45.0	90.9	9.1	35.0	15.0	20.0	0.0	10.0	0.0	0.0	0.0		
TrainCalc'ed	**71601**	**White Spruce:Open**	**mm**	**nn**	**39.0%**	598	PGI	White Spruce	33	Open	44	38.2	88.6	11.4	29.4	10.5	18.9	1.1	7.7	0	16.7	1	0.1	0
TrainCall	71601				TR		PGI	White Spruce	50	Open	**55**	**40**	**90.9**	**9.1**	**35**	**15**	**20**	**0**	**5**	**0**	**5**	**0**	**0**	**0**
	71602										DIFF										DIFF			
6378Sup	71602				44.0%	75	PGI	White Spruce	31.7	Open	38	44.4	93.1	6.9	30.1	6.1	24	3	11.4	0	16.2	1.4	0	0
6467sSup	71602				6.6%	61	PGI	White Spruce	23.9	Open	37.5	30.4	86.6	13.4	23.1	9.6	13.5	0.8	6.5	0	30.2	1.9	0	0
65678Sup	71602				36.2%	47	PGI	White Spruce	29	Open	38.1	39.1	95.3	4.7	25.3	4.5	20.8	4	9.9	0	20.6	2.2	0	0
6567Sup	71602				50.0%	52	PGI	White Spruce	31.7	Open	41	41.1	84.1	15.9	24.6	5.3	19.2	2.7	13.8	0	16.9	1	0	0
CalcTypeCall06	71602	OK			TR	1	PGI	White Spruce	35.0	Open	35.0	63.0	100.0	0.0	30.0	0.0	30.0	0.0	33.0	0.0	0.0	2.0		
TrainCalc'ed	**71602**	**White Spruce:Open**	**mm**	**nn**	**34.0%**	235	PGI	White Spruce	29.1	Open	38.5	39	89.8	10.2	26.1	6.5	19.6	2.6	10.3	0	20.9	1.6	0	0
TrainCall	71602				TR		PGI	White Spruce	35	Open	**35**	**50**	**100**	**0**	**30**	**0**	**30**	**0**	**20**	**0**	**13**	**2**	**0**	**0**
	71603																DIFF							
6378Sup	71603				48.7%	189	PGI	White Spruce	35.1	Open	50.5	40.7	78.7	21.3	30.5	16.7	13.8	0.3	9.9	0	7.4	1.4	0	0
6467sSup	71603				27.9%	86	PGI	White Spruce	33.4	Open	44.9	38.7	89.4	10.6	29.5	13.2	16.3	3.9	5.3	0	14.6	1.6	0.1	0
65678Sup	71603				35.0%	183	PGI	White Spruce	38.1	Open	48.6	40.8	82.6	17.4	30.6	17.6	13	2.1	8.2	0	9.7	0.9	0	0
6567Sup	71603				85.7%	49	PGI	White Spruce	43.5	Open	49.3	45.7	88.2	11.8	38.4	23	15.4	0.3	7	0	4.9	0.1	0	0
CalcTypeCall06	71603	OK			TR	1	PGI	White Spruce	45.0	Open	50.0	50.0	90.0	10.0	40.0	25.0	15.0	0.0	10.0	0.0	0.0	0.0		
TrainCalc'ed	**71603**	**White Spruce:Open**	**M**	**nn**	**43.8%**	507	PGI	White Spruce	36.7	Open	48.8	40.9	82.7	17.3	31.2	17.1	14.1	1.5	8.2	0	9.2	1.1	0	0
TrainCall	71603				TR		PGI	White Spruce	45	Open	**50**	**47**	**90**	**10**	**40**	**25**	**15**	**0**	**7**	**0**	**3**	**0**	**0**	**0**
	71604																							
6378Sup	71604				87.2%	180	DSD	Dwarf shrb drg	68.8		4.9	73.5	53.6	46.4	4.5	0	4.5	68.8	0.2	0	2.3	19.4	0	0
6467sSup	71604				80.7%	384	DSD	Dwarf shrb drg	63.9		4.7	72.5	53.3	46.7	4.5	0.1	4.4	66.6	1.3	0	2.3	20.5	0	0
65678Sup	71604				77.0%	427	DSD	Dwarf shrb drg	62		4.7	67.9	50.2	49.8	4	0	3.9	62.6	1.4	0	2.2	25.2	0	0
6567Sup	71604				96.5%	227	DSD	Dwarf shrb drg	72.9		4.9	79.1	59.2	40.8	4.8	0	4.8	73.9	0.4	0	0.4	15.6	0	0
CalcTypeCall06	71604	OK			TR	1	DSh	Dwarf shrb mix	75.0		5.0	80.0	60.0	40.0	5.0	0.0	5.0	75.0	0.0	0.0	0.0	15.0		
TrainCalc'ed	**71604**	**Dwarf Shrub:Dryas**	**M**	**M**	**83.33%**	1218	DSD	Dwarf shrb drg	65.6		4.8	72.2	53.4	46.6	4.4	0	4.3	66.9	1	0	1.9	21.1	0	0
TrainCall	71604				TR		DSD	Dwarf shrb drg	75		**5**	**80**	**60**	**40**	**5**	**0**	**5**	**75**	**0**	**0**	**0**	**15**	**0**	**0**
	71605																							
6378Sup	71605				94.0%	348	SVg	Dwarf shrb mix	5.7		0.9	15.3	0	100	0.2	0	0.2	9.4	5.7	0	0	83.7	0	0
6467sSup	71605				86.5%	784	SVg	Dwarf shrb mix	5.3		0.9	14.1	0	100	0	0	0	8.8	5.3	0	0	85	0	0
65678Sup	71605				93.0%	142	SVg	Dwarf shrb mix	5.6		0.9	14.9	0	100	0	0	0	9.3	5.6	0	0	84.2	0	0
6567Sup	71605				95.5%	242	SVg	Dwarf shrb mix	5.8		1	15.5	0.4	99.6	0	0	0	9.7	5.8	0	0	83.5	0	0
CalcTypeCall06	71605	OK			TR	1	SVg	Dwarf shrb mix	6.0		1.0	16.0	0.0	100.0	0.0	0.0	0.0	10.0	6.0	0.0	0.0	83.0		
TrainCalc'ed	**71605**	**Sparse Vegetation**	**M**	**M**	**90.24%**	1516	SVg	Dwarf shrb mix	5.5		0.9	14.7	0.1	99.9	0.1	0	0.1	9.1	5.5	0	0	84.4	0	0
TrainCall	71605				TR		SVg	Dwarf shrb mix	6		**1**	**16**	**0**	**100**	**0**	**0**	**0**	**10**	**6**	**0**	**0**	**83**	**0**	**0**
	71606																							
6378Sup	71606				24.4%	45	UP	White Spruce	13.8	Open	34.3	44.4	84.8	15.2	30.7	11.1	19.6	2.2	11.5	0	21.2	0	0	0
6467sSup	71606				41.2%	51	UP	Black Spruce	15.3	Open	26.2	55.6	91.8	8.2	37	13.5	23.5	2.5	16.1	0	15.4	2.2	0.5	0
65678Sup	71606				53.5%	43	PMa	Black Spruce	24.3	Open	35.4	51.3	93.8	6.2	31.6	13.5	18.1	4	15.7	0	12.3	1	0	0
6567Sup	71606				73.1%	52	PMa	Black Spruce	22.9	Open	27.7	61.2	96.9	3.1	36.7	12.6	24.1	1.7	22.8	0	8.5	1.7	0.9	0
CalcTypeCall06	71606	OK			TR	1	PMa	Black Spruce	30.0	Open	30.0	70.0	100.0	0.0	40.0	15.0	25.0	0.0	30.0	0.0	0.0	0.0		
TrainCalc'ed	**71606**	**Black Spruce:Open**	**M**	**nn**	**48.7%**	191	PMa	Black Spruce	19	Open	30.6	53.5	91.7	8.3	34.2	12.7	21.5	2.5	16.7	0	14.2	1.3	0.4	0
TrainCall	71606	**confused w/71257**			TR		PMa	Black Spruce	30	Open	**30**	**65**	**100**	**0**	**40**	**15**	**25**	**0**	**25**	**0**	**5**	**0**	**0**	**0**
	71607																							
6378Sup	71607				98.1%	52	LSh	Low shrub mix	44.1	Open	0	94.7	0	100	59.9	0.1	59.8	0	34.8	0	5	0.3	0	0
6467sSup	71607				76.1%	67	LSh	Low shrub mix	34.3	Open	1.2	88.4	96.4	3.6	55	4.2	50.9	1.5	31.8	0	8.2	2.1	0.1	0
65678Sup	71607				45.3%	75	LSh	Low shrub mix	20.6	Open	8.4	78.7	92.1	7.9	41.6	1.5	40.1	7.7	29.4	0	9.2	3	0.7	0
6567Sup	71607				81.6%	49	LSh	Low shrub mix	36.7	Open	2.3	88.1	100	0	52.6	0.2	52.4	6.1	29.4	0	8.7	0.8	0	0
CalcTypeCall06	71607	OK			TR	1	LSh	Low shrub mix	45.0	Open	0.0	100.0	0.0	0.0	60.0	0.0	60.0	0.0	40.0	0.0	0.0	0.0		
TrainCalc'ed	**71607**	**Low shrub:Open:Mix**	**mm**	**mm**	**72.43%**	243	LSh	Low shrub mix	32.7	Open	3.4	86.7	93.4	6.6	51.4	1.7	49.8	4	31.2	0	7.9	1.7	0.2	0
TrainCall	71607				TR		LSh	Low shrub mix	45	Open	**0**	**95**	**0**	**0**	**60**	**0**	**60**	**0**	**35**	**0**	**5**	**0**	**0**	**0**
	71608																DIFF							
6378Sup	71608				100.0%	14	H2O	Water	95		0	5	0	0	0	0	0	0	5	0	0	0	95	0
6467sSup	71608				100.0%	8	H2O	Water	95		0	5	0	0	0	0	0	0	5	0	0	0	95	0
65678Sup	71608				85.7%	14	H2O	Water	95.7		0	4.3	0	0	0	0	0	0	4.3	0	0	0	95.7	0
6567Sup	71608				100.0%	9	H2O	Water	95		0	5	0	0	0	0	0	0	5	0	0	0	95	0
CalcTypeCall06	71608	OK			TR	1	H2O	Water	95.0		0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	95.0	0.0	0.0		
TrainCalc'ed	**71608**	**Water**	**M**	**M**	**95.6%**	45	H2O	Water	95.2		0	4.8	0	0	0	0	0	0	4.8	0	0	0	95.2	0

Table 10: Detail of Pixel Fidelity Report for WRST training classes

- Sites matched the general type values but contained land cover class component values that differed from calculated ones by no more than approximately twenty-five percent were considered a Near Match – these areas might not match class values in one category of land cover, but still matched the general land cover attributes.

- Sites that matched most of the general cover class attributes but contained individual attribute differences of more than 25% cover in at least one cover component were considered a Slight Match.

- Sites that did not match the general cover class attributes and contained individual attribute differences of more than 25% in at least one cover component were considered a Mis-Match.

Type match comparison often concerned comparison of values that are similar in most cases, but not all cases, sometimes resulting in one different categorical value because the field attributes and weighted averages spanned the threshold of a class decision rule value.

In summary, sites that met the first two type-match criteria for similarity (<=10 percent difference) of the major type characteristics (classes and /or values) were considered strong type matches (**M**). Sites showing class and attribute values that differed by more than 10 percent but less than 25 percent were considered as a Near Match (**mm**). Sites of mostly similar class attributes that differed by more than 25 percent were considered a Slight Match (**nn**). Sites were deemed a Mis-Match (**N**) and unacceptable for the classification process if most of the class attributes did not match and causes of the mismatch could not be resolved and eliminated. These mismatched sites typically confirmed confusion of the subject site with another site. This confusion was addressed by reviewing the aforementioned J-M Distance Confusion Report, assessing which sites participated in the confusion, and resolving or removing the truly confused ("bad") training sites from the same training set, thereby avoiding the inclusion of confused training data in the classification effort.

Matches were determined for each training set in which a training site participated. A separate line in the report describes the fidelity results of a training class within a training set. The degree of self-match was developed for each site by training set based on the percent self-classification. In addition, a degree of self-match was determined for the site as a whole, based on the average of the percent self-classification values by training set. The report also includes a description of the original training site field description (**TrainCall**), as well as the calculated summary and type data (**TrainCalc'ed**) to verify that the calculated data based the project classification logic and lookup tables agree with the field description. Table 11 shows final results of the evaluation of the Fidelity Report data, for both self matches and type matches for all the training sites involved in the project.

It is apparent in these data that a low "percent pure" self-match value did not necessarily mean poor fidelity of the class. While only **51.9** percent of the sites were classified as Strong Matches (**M**) based on self-classification, **81.8** percent of the sites were considered Strong Matches (**M**) by type characteristics. Another **33.8** percent of the sites were evaluated as Near Matches (**mm**) based on self-classification, whereas another **18.8** percent of the training areas were Near Matches based on the comparison of attributes. A total of 99.8 percent of the training areas were judged as a Near Match or better (**mm** or **M**) based on the comparison of the training area characteristics. Nearly all of the sites that did not exhibit purity as a self-match did in fact match by type characteristics. Sites confused with other sites of very similar land cover attributes show these lower "percent pure" values, but still yield very similar land cover characteristics resulting in a match. This situation indicates that the "good confusion" of training site data helps develop similar land cover characteristics, as opposed to different values.

Table 11: Fidelity Match by Self-Match and Type-Match

All Scenes	------------ Self-Match ---------				------------ Type Match --------			
	N	n	m	M	N	n	m	M
Type	< 25%	25-49%	50-74%	>= 75%	not	slight	near	Same
Sitka Spruce:Closed	1	1	3	5			2	8
Sitka Spruce:Open		3	3	2			4	4
Sitka Spruce:Wdlnd	1	1	1				2	1
Black Spruce Cmplx:Open				2				2
Black Spruce Cmplx:Wdlnd-Lichen		1					1	
Black Spruce Dead:Wdlnd				1				1
Black Spruce Stunted:Wdlnd				1				1
Black Spruce:Closed			1	4				5
Black Spruce:Open		8	9	5			1	21
Black Spruce:Open-Lichen			2	2				4
Black Spruce:Open-Tussock				1				1
Black Spruce:Wdlnd		3	13	1			5	12
Black Spruce:Wdlnd-Tussock				2				2
Spruce Mix Cmplx:Wdlnd				1				1
Spruce Mix:Open			6	3				9
Spruce Mix:Open-Tussock				1				1
Spruce Mix:Wdlnd		1	2				1	2
White Spruce Cmplx:Closed				1				1
White Spruce Cmplx:Open		2	3				3	2
White Spruce Cmplx:Wdlnd		2	2				2	2
White Spruce Dead:Open			1					1
White Spruce Dead:Wdlnd			3					3
White Spruce Dead:Wdlnd-Lichen			1					1
White Spruce:Closed		1	3	7			1	10
White Spruce:Open	2	11	28	16			9	48
White Spruce:Wdlnd		3	13	12			6	22
White Spruce:Wdlnd-Lichen			2	1				3
White Spruce:Wdlnd-Tussock				1				1
Mixed deciduous-conifer:Closed	1	3	5	4			3	10
Mixed deciduous-conifer:Open	6	13	24	5			14	34
Mixed deciduous-conifer:Open-Lichen				1				1
Mixed deciduous-conifer:Wdlnd	1	3		3			2	5
Aspen:Closed		5	5	3			5	8
Aspen:Open		2	3	1			3	3
Balsam Poplar:Closed		2	4	4			1	9
Balsam Poplar:Open		4	9	4			4	13
Cottonwood:Closed		1	2				1	2
Cottonwood:Open	1	2	7	1			1	10
Paper Birch:Closed		2	1	5			2	6
Paper Birch:Open			1					1
Mixed deciduous:Closed		1	1	2			2	2
Mixed deciduous:Open		2	1	1				4
Tree shrub:Closed:Alder			1				1	
Tree shrub:Closed:Willow		2	4	2			4	4
Tree shrub:Open:Willow				1				1

Table 11: Fidelity Match by Self-Match and Type-Match (continued)

All Scenes	------------ Self-Match ---------				------------ Type Match --------			
Type	N < 25%	n 25-49%	m 50-74%	M >= 75%	N not	n slight	m near	M Same
Tall shrub:Closed:Alder	1	9	24	22			9	47
Tall shrub:Closed:Mix	2	2	10	6		1	8	11
Tall shrub:Closed:Willow		3	6				7	2
Tall shrub:Open:Alder		3	7	7			2	15
Tall shrub:Open:Mix		3	9	7			4	15
Tall shrub:Open:Willow		1	5	4			4	6
Mixed shrub:Open:Alder				1				1
Mixed shrub:Open:Mix			2	3				5
Mixed shrub:Open:Mix-Lichen				2				2
Mixed shrub:Open:Mix-Tussock				2				2
Mixed shrub:Open:Willow		1						1
Low shrub:Closed:Birch			1	6			1	6
Low shrub:Closed:Ericaceous			1					1
Low shrub:Closed:Mix			1	4			2	3
Low shrub:Closed:Silverberry				2				2
Low shrub:Closed:Willow				3			1	2
Low shrub:Closed:Willow-Birch Mix			1					1
Low shrub:Open:Alder			1	1				2
Low shrub:Open:Birch		3	4	11			2	16
Low shrub:Open:Birch-Lichen		1					1	
Low shrub:Open:Birch-Tussock				1				1
Low shrub:Open:Ericaceous			2	5			2	5
Low shrub:Open:Ericaceous-Tussock			1					1
Low shrub:Open:Mix		1	7	9			4	13
Low shrub:Open:Mix-Tussock		1	1	4			1	5
Low shrub:Open:Silverberry				1				1
Low shrub:Open:Willow		5	12	13			11	19
Low shrub:Open:Willow-Birch Mix	1	5	15	10			9	22
Low shrub:Open:Willow-Birch Mix-Lichen				1				1
Low shrub:Open:Willow-Birch Mix-Tussock				2				2
Low shrub:Open:Willow-Lichen				1				1
Low shrub:Open:Willow-Tussock			1					1
Dwarf Shrub		3	16	13			9	23
Dwarf Shrub:Cassiope			1	3			1	3
Dwarf Shrub:Cassiope-Lichen				1				1
Dwarf Shrub:Dryas			1	11				12
Dwarf Shrub:Dryas-Lichen				2				2
Dwarf Shrub-Lichen		3	4	10			3	14
Dwarf Shrub-Sage Bluff				2				2
Dwarf Shrub-Tussock			1	1			1	1

Table 11: Fidelity Match by Self-Match and Type-Match (continued)

All Scenes **------------ Self-Match ---------** **------------ Type Match ---------**

Type	N < 25%	n 25-49%	m 50-74%	M >= 75%	N not	n slight	m near	M Same
Herbaceous			8	30			6	32
Elymus				1				1
EriVag-Tussock			1					1
Graminoid		3	12	40		1	14	40
Graminoid-Lichen			1	3			1	3
Graminoid-Tussock				2				2
Moist Sedge-Shrub Meadow		1	7	12			2	18
Moist Sedge-Shrub Meadow-Lichen			1	1				2
Moist Sedge-Shrub Meadow-Tussock			1	1				2
Aquatic Forb				9			1	8
Lichen			1	7				8
Moss			1	3				4
Sparse Vegetation			7	25			3	29
Sparse Vegetation-Sage Bluff				3				3
Barren/NonVeg			2	58				60
Barren-Sage Bluff				3				3
Barren-Wet				3				3
Snow/Glacier				1				1
Water			1	33				34
Water-Aquatic Forb				8				8
Water-Sparse Vegetation				4				4
Grand Total	17	127	341	524	0	2	189	818
Percent of Total	1.7%	12.6%	33.8%	51.9%	0.0%	0.2%	18.8%	81.1%

In earlier reports generated during the course of the project, truly confused sites showed mismatches by self-match and type-match. Such information was used to identify suspect classes, refine training areas, and resolve confusion. In the final report, only two sites were identified as Slight Matches (**nn**) by Type-Match, and only one of these sites still exhibited such significant confusion with dissimilar sites that its confusion could not be resolved, such that we removed this site from the classification training sets. While no accuracy assessment was performed on this data set, the resolution of class confusion in this manner, as determined from fidelity and J-M distance reports, builds confidence in these classification training data. A table summarizing the different type matches by Self-match and Type-match is shown in Table 12.

What was evident from these reports was confusion between certain wet herbaceous types and certain White Spruce:Open or Sitka Spruce:Closed types. This confusion was most easily seen in the Fidelity Report, as conifer tree cover would be present in the "calculated" Herbaceous types, whereas tree cover would diminish and herbaceous cover would increase in the confused conifer types. Both of these situations indicate that the training areas of the confused conifer types were being infiltrated by confused herbaceous types and visa versa. Resolution of this confusion could not be resolved in the training data sets. While there were only a few badly confused sites (less than 10), the confusion seriously impacted the mapping efforts. As a result, masks would be developed and applied during classification efforts to resolve these confused conifer and herbaceous classes.

	TypeMatch				
	M	Mm	nn	N	Grand Total
Self-Match					
M	507	17	0	0	524
Mm	254	86	1	0	341
Nn	53	74	0	0	127
N	4	12	1	0	17
Grand Total	818	189	2	0	1009

Table 12: Training Sites by Test and Type of Match

Supervised Training Set Development Results

The complete training data set used for this project was comprised of **1009** training sites. Of the original **739** aerial survey sites, **726** were found suitable for inclusion in the final training data sets. Three sites were not included in the spectral data set because they represented verification sites that involved revisiting a site surveyed in a prior year to confirm prior results or correct possible errors. Another two sites were subsequently rejected after arrival at the site and assignment of a trsite_id. Seven sites were too small and representative training areas could not be developed for these sites (these three sites were all opportunistically sampled and not in the candidate database). The remaining site was that one site determined to be unsuitable for inclusion in the final training data set because it was in an area that was spectrally too variable (trsite_id 72012). These aerial survey sites are identifiable in the final pixel map, as they have trsite_id values that range between 70201 and 72339 and a Source value of 'GRSAIR' in the database table.

A total of **16** of the ABR sites participated in final training sets. Classes of this type are identified by their ABR transect/point value (TTPP), which is between 2005 and 6710. The original ABR site id is listed other_id column of the trsites attribute data.

A total of **117** of the FirePro ground sites were added to the composite training data set. These sites are identified by trsite_id values that ranged from 10106 to 12173. The original FP site id is listed other_id column of the trsites attribute data.

A total of **81** of the Ducks Unlimited ground sites were added to the composite training data set to increase the representation of land cover types in the 6467a image that covered the portions of the Tetlin National Wildlife Refuge and WRST. These sites are identified by trsite_id values that ranged from 15001 to 15404. The original DU site id is listed other_id column of the trsites attribute data.

GRS added **65** additional sites to the final training data sets. 52 of these sites were in obvious classes of water (22), barren (29), and snow/glacier (1). The other 16 were in land cover classes representing vegetation types not included in any of the field data training sets for a particular image. 4 of these sites represented Sparse Vegetation types, 2 sites represented Forb types, 5 represented Graminoid types, 1 represented a Tall Shrub type, and 1 site represented an Aquatic Forb type. The supplemental sites all have trsite_id values that are within the same numeric range as the GRSAIR Sites (from 70201-72431), but may be distinguished from GRSAIR Sites based of the value of the Source attribute being set to 'GRSSUPP' in the trsites attribute table.

Of the **1009** training sites developed, many were used in the classification of more than one scene, as they were located in areas covered by overlapping imagery. **52** training sites were used in five different training sets, **226** training sites were used in four different training sets, **305** training sites were used in three different training sets, and **159** training sites were used in two different training sets. Only **267** training sites, approximately 26.2 percent of the 1009 training sites were used in only one training set.

A breakdown of the number of training sites by image and source is shown in Table 13. The total number of supervised training sites per image ranged from as few as 53 sites in image 6418 to as many as 591 sites in image 56578. The number of sites per image is a pretty accurate reflection of the amount of area each individual image contributed to the coverage of WRST, with the images with the higher number of sites covering the largest portions of the project area. In some cases the individual training sets covered such large areas that it was necessary to break the training sets

Table 13: Supervised Training Sites by Image and Source

Source / Image	GRS Aerial	ABR	FP	DU	GRS Supp	Total
6118	115	0	18	0	19	152
63678	131	7	6	0	13	157
6378	183	3	49	0	11	246
6418	41	0	8	0	4	53
6467a	230	6	7	80	11	334
6467s	435	7	8	0	29	479
6567	510	9	31	0	29	579
65678	521	7	32	0	31	591
6767	49	6	15	0	11	81
Total	2215	45	174	80	158	2671

into smaller subsets of the original training sets. A total of 15 different training sets were developed to classify the nine images. In these cases when an image training set was broken into subsets, it was done so that training data would not be applied over too great a distance from one area of the project area where the training data were collected to another portion of the project area that might possibly be an inappropriate misapplication of the training data. For example, a White Spruce type north of Nabesna should not be applied 85 miles to the south in the McCarthy Corridor, or 140 miles to the south near the mouth of the Bremner River; a Sitka Spruce type on the coast should not be applied inland 110 miles to the north near the Chitina River where Sitka Spruce does not grow. The training data for images 6567 and 65678 were split into subsets to represent three areas - the area north of the Wrangell Mountains, the area south of the Wrangell Mountains, and the area in the immediate vicinity of the Bremner River and Mountains. Training data in these areas were then applied to the appropriate portion of the image in which the training set's sites were located. Training sets for images 6378 and 6467s were also split, but into only two areas. 6378 was split to separate the area south of the Bagley Ice Field from the area north of the Bagley Ice Field, while the training set for 6467s was split to represent the areas north and south of the St. Elias Mountains. In this manner training data would not be applied hundreds of miles from where it had been observed. One situation concerned subset areas that not based on different geographic areas; image 6767 was processed in two parts, one that represented the cloud-free portion of the image, and the other that was covered by a very thin haze. In all, 16 classification areas were developed within the 9 original images. A listing of these classification areas (subsets) by image is shown in Table 14.

Table 14: Image Classification Subsets

Image	Subset	Designation	Description

6118			
63678			
6378	north	**n**	north of Bagley Ice Field
	south	**s**	south of Bagley Ice Field
6418			
6467a			cloud-free portion north of Wrangell-St.Elias Mountains
6467s	north	**n**	north of Wrangell-St.Elias Mountains
	south	**s**	south of Wrangell-St.Elias Mountains
6567	north	**n**	Copper Center - north of Wrangell Mountains
	south	**s**	Sanford River - south of Wrangell Mountains excepting Bremner Vicinity
	Bremner	**b**	Bremner Vicinity
65678	north	**n**	Copper Center - north of Wrangell Mountains
	south	**s**	Sanford River - south of Wrangell Mountains excepting Bremner Vicinity
	Bremner	**b**	Bremner Vicinity
6767	clear		
	haze	**h**	hazy portion of image in project area

Unsupervised Training Set Development

The same basic unsupervised training data sets used to develop candidate site locations were also used to perform ISODATA classifications of the imagery that would be used to supplement supervised classification data and fill in remaining gaps and voids in the supervised pixel maps. Most of these unsupervised training sets were the same training sets created during the initial image pre-processing classification efforts during the development of the candidate training site locations. A few of these unsupervised training sets were refined for use in the development of ISODATA classification maps. The principal difference between these final ISODATA training data sets involved in this reprocessing effort concerned the development of training sets with respect to the NDVI masks as opposed to original processing accomplished with respect to the ecotype section boundaries. The NDVI masks used to distinguish vegetated from non-vegetated areas during initial stratification efforts formed the basis for stratification for all ISODATA classification efforts. Unsupervised training sets were developed to represent the vegetated and non-vegetated classes. In addition, classes were developed specific to cloud-free imagery; as classes were reviewed and checked, any cloud or cloud shadow classes that were identified and the affected areas were added to the appropriate cloud mask to eliminate the affected area(s) from subsequent processing.

Vegetation/Land Cover Classification

As the project progressed and training site information were summarized, reviewed, and processed in terms of confusion and fidelity AKRO, ABR, and **GRS** met on four different occasions from 2005 - 2007 to review in-progress mapping results and findings. Field observations as well as ABR field site data and information from other ground locations were reviewed relative to the mapping effort in an effort to identify errors and inconsistencies. One of the major results of this effort was the modification and refinement of the land cover vegetation classification system that would be used to categorically describe the different classes contained in the WRST Land Cover data set. Integral to any discussions was the nomenclature used to describe different land cover classes or types found on the ground and in the data set. The land cover vegetation classification system in place at the

beginning of the project was the Viereck classification system, the same system used when **GRS** mapped Katmai National Park and Preserve (2003). It was "slightly-modified" to reflect some very minor modifications that could result in the misnaming or misclassification of a site into a potentially incorrect name/type (for example, the Sparse Vegetation class was modified so that sites with more than 30% vegetative cover, but too little cover to categorize the site as a tree, tall or low shrub, dwarf shrub, or herbaceous type were not mistakenly labeled as Barren; in a similar vein, all alder shrub forms were considered as Tall Shrub cover, regardless of actual height).

Over the course of the project several modifications and enhancements were made to the vegetation/land cover classification system (rules), each designed to handle certain issues identified during the mapping project. These modifications concerned the development of "new" vegetation types, as well as the modification of several cover component thresholds and mixtures. In most cases the modifications and enhancements to the classification system were made in an attempt to meet the intent of the Viereck Classification System when a type's cover components were slightly different than the requirements necessary to assign a particular class. Rather than follow a very strict interpretation of the Viereck Classification System rules and thresholds and assign classes that appeared inappropriate or inaccurate, the rules were modified to better represent these "different" types. It is important to note these deviations from what would be considered the traditional Viereck Classification System nomenclature so that the user of this land cover data set understands these differences and correctly interprets the mapped types. Modifications to the Viereck Classification System thresholds and nomenclature used during this mapping effort are discussed below.

<u>Modified Types and Designations</u>

Hardwood Woodland Cover Density Class

The **Woodland** cover density designation for all deciduous hardwood types and Mixed Deciduous-Conifer types dominated by hardwoods was dropped from the classification. This change allowed the type name to be developed based on the cover of the predominant lifeform and species present in the type, rather than the very scattered hardwood component. As a result there are no Aspen:Woodland, Balsam Poplar:Woodland, Cottonwood:Woodland, Paper Birch:Woodland, or Mixed deciduous:Woodland types in the WRST Land Cover data set. These types are now represented by type names based on the non-hardwood cover components present in each type. In addition, most of the Mixed deciduous-conifer:Woodland types also were typed to different non-hardwood types, except those Mixed deciduous-conifer:Woodland types that had a sufficient amount of conifer cover to have been the basis for a conifer:Woodland designation without the hardwood composition. For example, a Mixed deciduous-conifer:Woodland type comprised of 10% hardwood cover and 5% conifer cover would have received a new type name based on the non-tree cover present in this type. However, a Mixed deciduous-conifer:Woodland type comprised of 10% conifer cover and 5% hardwood cover would remain a Mixed deciduous-conifer:Woodland type, as the 10% conifer cover would comprise a Conifer:Woodland type by itself.

Tree Shrub Class

The Tree Shrub class involves training sites that were dominated by either *Salix scouleriana* or *Alnus tenuifolia* where these shrubs were found growing as very tall tree-like shrubs. These tall shrubs were often at least 10-15 meters in height and the types classified using these very tall shrub sites were often somewhat confused and intermixed with other deciduous hardwood type pixels rather than Tall Shrub type pixels. The Tree Shrub class was developed so that these very tall tree-like types may be differentiated from the more traditional tall shrubs that are closer to 1.5-4.5 meters in height. The same cover density levels for the Tall Shrub class were applied to the Tree Shrub classes.

Mixed Shrub Type Class

The Mixed Shrub class indicates types in which neither the tall shrub cover or low shrub cover met the minimum 25% cover threshold to call the type either a Tall or Low Shrub type, but the combination of the tall and low shrub cover is the dominant lifeform present and the sum of the shrub cover exceeds the minimum 25% shrub cover threshold. If the combined cover is of a dominant genus (*salix* or *alnus*) or alliance (*salix-betula*), then that floristic component is also included in the type name. By definition, there should only be "Open" Mixed Shrub types, since if there is enough combined tall and low shrub cover to exceed the 75% cover threshold for a Closed density class then either tall or low shrub cover should have been sufficient to result in either a Low Shrub:Open or Tall Shrub:Open class. However, a "Sparse" shrub density class designation was added to identify one particular situation; the Sparse designation indicates that the sum of the tall and low shrub cover are greater than the dwarf shrub cover, but the sum is less than the 25% shrub cover threshold until the dwarf shrub cover is added to the tall and low shrub cover. Sparse therefore indicates that the tall, low, and dwarf Shrub cover sum to more than 25% cover and that the tall and low shrub cover are predominant relative to the dwarf shrub cover. A mixture of this nature in which the sum of the tall, low, and dwarf shrub cover exceed the 25% minimum cover threshold and the dwarf shrub cover is the predominant cover would be classified as a Dwarf Shrub type.

Dwarf Shrub Class

The definition of the Dwarf Shrub class was expanded to include situations when the dominant shrub component was comprised of dwarf shrubs and the sum of the dwarf shrub, tall shrub, and low shrub cover exceeded the minimum requirement of 25% shrub cover.

Moist Sedge Shrub Meadow Type Class

The Moist Sedge Shrub Meadow type was developed to represent certain combinations of shrubs (predominantly dwarf shrub) and *Carex* species that occurred with regularity, but were not being named consistently. This designation indicates types in which the sum of the shrub cover (tall, low, and dwarf) is at least 25% cover; the dwarf shrub component is the dominant shrub cover component and is not more than 35% cover; and the *Carex* (graminoid) cover component is at least 10% cover.

Herbaceous Type Class

The Herbaceous type cover thresholds were modified slightly from the typical Viereck minimum threshold of 25% herbaceous cover to include an additional requirement of a minimum total vegetation cover of at least 30%. In addition, herbaceous cover did not include cover of lichens or moss, and types for each of these forms of plant life were based solely on the cover of these lifeforms meeting their appropriate minimum levels of 25% cover.

Aquatic Forb Class

The Aquatic Forb class was used to differentiate aquatic forb cover from other herbaceous cover. The dominant species in all of the Aquatic Forb types that were mapped was *Nuphar sp*.(pond lily), but this class also included plants such as, *Menyanthes sp*.(buckbean), and *Potamogeton sp*. (pondweed), and *Potentilla palustris* (marsh cinquefoil). The Aquatic Forb class was assigned when the cover of aquatic forbs was the dominant plant form. In this classification effort the aquatic forb component always comprised at least 50% cover.

Water Class Definition and Designations

The Water class was assigned when the water cover component comprised at least 50% cover of a type. Additional designations were added to the Water class to differentiate combinations of water and vegetation cover. If vegetation, including aquatic cover, comprised at least 15% cover in addition to the minimum 50% water cover component the –Sparse Vegetation designation was added to the Water class name. In cases when the cover of vegetation was between 30 and 50% cover, and the dominant lifeform of vegetation was aquatic forbs the –Aquatic Forb designation was added to the Water class name.

Unknown Classes

Six different unknown classes are represented in the WRST Land Cover Map. These six classes include a generic Unknown class assigned to all unclassified pixels, an Unknown ClSh class assigned to mapped clouds and their shadows, and four Unknown terrain shadow classes (TSb, TSs, TSv, and TSu) assigned to pixels modeled to represent locations where the imagery was dominated by terrain shadow and the mapped results were though to be unreliable. The four variations of the Unknown Terrain Shadow classes all represent different estimates of what generic land cover type may exist in those particular locations, where Unknown TSb represents areas of terrain shadow thought to be barren, Unknown TSs represents areas of terrain shadow thought to be snow or ice, Unknown TSv represents areas of terrain shadow thought to be vegetation, and Unknown TSu represents areas of terrain shadow that are of an unknown type.

Conifer Cover Status/Mortality Designations

Due to the presence of significant amounts of dead White Spruce cover due to Spruce Bark Beetle mortality, the status of the conifer cover is included in the conifer type name. This type name situation is already handled in Viereck as 'Stunted' spruce types are distinguished from normal spruce types with separate type names. In this case dead and mixed dead-and-alive designations will be reflected in the classification system. If at least two-thirds of the tree cover of a conifer type is described as dead, the adjective "Dead" is added to the name of the type. If the type is a mix of live and dead cover with neither live or dead comprising a dominant component (at least 66.67%), then the adjective "Cmplx" is added to the name of the type indicating it is a mixture of live and dead cover. If the dominant conifer cover is alive no change is made to the existing Viereck type name. For example, the White Spruce Dead:Open type indicates a type with between 25 and 59.9% tree cover dominated by White Spruce of which at least 66.67% of that cover is dead; the White Spruce Cmplx:Woodland type indicates a type with between 10 and 24.9% tree cover dominated by White Spruce of which at least 33.33% of that cover is alive and 33.33% of the cover is dead.

Lichen Designation

The –Lichen designation was appended to any land cover type that was estimated to contain at least 10% cover of lichens unless the type was a Lichen type.

Sage Bluff Designation

The –Sage Bluff designation was appended to any class that originated in an area that was determined to be representative of a Sage Bluff. Based on the vegetation cover estimated for these areas during field data collection efforts, these areas could be Dwarf Shrub, Sparse Vegetation, or Barren types. The assignment of this designation was a qualitative decision based on a comparison of the geophysical characteristics of the individual field sites relative to areas commonly referred to as Sage Bluffs that were primarily located in the Copper, Sanford, and Chitina River drainages.

Tussock Designations

The –Tussock designation was appended to any land cover type that was estimated to contain at least 15% cover of *Eriophorum vaginatum*.

Wet Designation

The –Wet designation was appended to Barren classes when there was a water component of at least 5% cover in the type. The class was often used to describe what appeared to be Barren areas that were also found in areas that were associated with components of water in an attempt to differentiate Barren types in wet surroundings from other Barren types. Most common applications of this designation are in wet damp gravel beds that may include very shallow water, edges of glaciers with very wet damp gravel/soil and standing water, as well as areas of wet damp gravel till on the top surface of glaciers.

Image Classification Mask Development

Area Masks

An area mask that represented the applicable area to be classified was developed for each image. For those images that had image training subsets, an area mask was developed that represented the applicable area for the image training subset. Area masks were not mutually exclusive and small areas of overlap were created along the boundaries of subset areas to provide a smooth transition of classified types in these areas. Each of these masks would be applied during classification efforts to limit the application of the training data sets to the appropriate portion(s) of the imagery.

Cloud Masks

A cloud mask was developed for each image to represent portions of the imagery affected by clouds, haze, contrails, smoke, and any associated shadows. Any image defects, such as missing or offset band data that precluded use of a portion of the imagery was also included in these masks.

Confusion (Winter Image) Masks

Masks were developed to resolve confusion found between the several confused wet herbaceous and coniferous forest classes. Integral to this effort was finding some type of data or information that could be used to discriminate between the confused classes. After discussions with the AKRO Project Manager, AKRO and **GRS** agreed to develop masks based upon winter imagery of the project area. Masks would be developed that would estimate where the confused wet herbaceous types and the coniferous were most likely to occur, as well as not occur.

Three images of March 2002 winter imagery that covered the entire WSRT Project Area were provided to **GRS** by AKRO in the Fall of 2006. Key to selecting this imagery was the fact that there had been sufficient snowfall to cover the ground, but enough time had passed since the last snowfall so that flat areas were covered by snow, but the trees in forested areas had relatively little snow covering the tree foliage. The brightness of Band 1 in the winter imagery would be used to estimate presence and absence of the confused characteristics, as this band was quite sensitive to snow, being brighter in areas with snow and darker in areas with little or no snow. Areas with very bright snow cover (high Band 1 values) would be indicative of areas without tree cover in which wet herbaceous cover types could exist (under the snow), whereas areas with less bright or no snow

cover (mid to low Band 1 values) would be indicative of areas without the wet herbaceous cover types in which areas with tree cover would typically exist. In addition, slope and elevation would also be included in the masking process knowing that the wet herbaceous areas existed in relatively flat areas and that tree cover would never be found above the tree-line. Development of masks suitable to resolve the type confusion would involve estimation of thresholds or limits in the Band 1 digital data that would accurately reflect where these different types could occur, as well as any slope and elevation limits that would help with this process.

GRS undertook an evaluation of the training site locations and information (site type and species components) relative to the Band 1 (B1) data, elevations, and slope values to estimate thresholds that could be used in masks that could be applied to limit the application of the confused sites specifically to areas that were thought highly probable areas where these different types would actually exist. These values were developed through an evaluation of all of the training site location information relative to the winter imagery along with slope and elevation information (based on the USGS DEM data). Initial efforts focused on developing mutually exclusive ranges of B1 data that represented a simple 2x2 matrix as shown in Figure 15.

Site Characteristics	Slope	
Band 1 Data	**Flat**	**Sloped**
Bright (high) Values	Wet Herbaceous Types and No Tree Types	No Wet Herbaceous Types and No Tree Types
Dim (low) Values	Tree Types and No Wet Herbaceous Types	Tree Types and No Wet Herbaceous Types

Figure 15: Projected Winter Mask Categories

While slope and elevation thresholds were found that approximated the limits of the occurrence of the wet herbaceous and tree types, finding valid B1 data thresholds was not at all an easy and straightforward process. Rather, there were many instances of wet herbaceous types occurring in areas of B1 data that were not bright, as well as tree types or types having tree cover components occurring in areas that were fairly bright. In some cases wet areas were frozen and ice appeared somewhat darker than the flat brighter areas that were snow covered. In other cases the B1 data was saturated (B1=255) for areas that obviously had land cover types with tree cover components. And then there were areas of small young trees that could appear very bright if they were completely covered by snow.

In addition, there were several other trends that were noted regarding where types occurred relative to the slope, elevation, and B1 values. For example, water and Closed tree stands typically occurred in the darkest B1 data whereas Dwarf Shrub and Herbaceous types typically occurred in the brighter B1 data. It was apparent that these masks might also satisfy another purpose. Developing and using the masks in such a manner would not only resolve confusion, but could also prevent the misapplication of certain training data into portions of the imagery into which it did not belong (e.g. prevent water types from being applied in dark areas on steep north facing slopes) if the proper logic could be incorporated into such a mask. Further evaluation of the data revealed that the tree types that occupied the same mid-range (fairly bright) of B1 data as the wet herbaceous types were not the confused tree types, but rather the Woodland and Open tree types with less than approximately 30 percent tree cover. The confused tree types were typically comprised of higher tree cover and were found in the darker range of B1 data.

This finding resulted in the development of a third range of B1 values that represented a region of B1 data in which types with sparse to moderate (≤ 30% cover) tree cover might be found as well as some of the wet herbaceous types. This third range was fairly bright relative to the darker B1 data, but not quite as bright as the brightest B1 data. In addition, in order to differentiate very steep areas potentially impacted by terrain shadowing, the incidence angle information developed for each image would be integrated into the mask by using a threshold of 70 degrees to indicate extremely steep shaded areas of the imagery (this is the same maximum incidence angle threshold used during illumination correction processing of the imagery). By incorporating the third range of B1 data, treatment of saturated B1 data, incidence angle information, and an elevation threshold above which tree types and any types with tree cover would not occur, the winter mask development process had become much more complex, but it now served multiple purposes in addition to the resolution of confusion. The end result was development of nine distinct winter mask categories or classes which are shown in Figure 16.

Site Characteristics	**For Elevation < 5000 feet**		
Band 1 Data	**Slope** Flat (≤ 5°)	**Slope** Sloped (> 5°) and Incidence Angle ≤ 70	**Slope** Sloped (> 5°) and Incidence Angle > 70
"Brightest" Values (>220 && ≤ 254)	**H5** Wet Herbaceous Types and Sparsest Tree Cover	**O5** No Wet Herbaceous Types Sparsest Tree Cover	**HI** No Wet Herbaceous Types No Dense Tree Types No Water
"Brighter" Values (moderately bright) (>172 && ≤ 220 >	**H6** Sparse Tree Cover and Woodland Tree Types and Wet Herbaceous Types	**T11** Sparse Tree Cover Woodland Tree Types No Wet Herbaceous Types	**HI** No Wet Herbaceous Types No Dense Tree Types No Water
"Darker" Values (≤ 172)	**T10** All Tree Types No Wet Herbaceous Types	**T10** All Tree Types and No Wet Herbaceous Types	**HI** No Wet Herbaceous Types No Dense Tree Types No Water
Undefined (255)	**H5** (See above)	**O9** No Wet Herbaceous Types No Dense Tree Types	**HI** No Wet Herbaceous Types No Dense Tree Types No Water
	For Elevation >= 5000 feet		
	Slope Flat (≤ 5°)	**Slope** Sloped (> 5°) and Incidence Angle ≤ 70	**Slope** Sloped (> 5°) and Incidence Angle > 70
All Values (>0 && ≤ 255)	**EF** No Aquatic Forb Cover No Tree Cover	**EF** No Aquatic Forb Cover No Tree Cover	**EI** No Aquatic Forb Cover No Tree Cover No Water

Figure 16: Mask Classes for Winter Image 6469

Unfortunately, the application of the winter mask classes dramatically increased classification efforts, as separate classifications would have to be performed for each of the nine winter mask classes in each image or image subset. This involved not only nine separate classifications for each image or image area subset, but also the partitioning of each spectral training set to exclude training sites that should not be applied into the different winter mask classes. For this reason, the winter mask classes were only applied to images or subset areas of images in which confusion was found. Winter mask classes were developed and applied for images and image subsets for 6118, 6378, 6467a, 6467s, 6567, and 65678; winter mask classes were not applied for images 63678, 6418, and 6767, which coincidentally all had the lowest number of training sites and all contributed relatively small area to the overall coverage of the WRST Project Area.

The B1 thresholds noted in Figure 16 that were used to differentiate the "Brightest" portion of the winter image B1 data from the "Brighter" and "Darker" are the actual values (220 and 172) that were developed for winter image 6469. Corresponding thresholds for winter image 6218 were 246 and 176 and for image 6667 were 246 and 210. The slope threshold used during mask development was 5 degrees and the elevation threshold was set at 5000 feet. These elevation and slope thresholds were slightly higher than observed values to provide for sampling variability and allow the limited types to be applied at elevations that were slightly higher than sites with observed tree cover and on slopes that were not necessarily flat, due to inaccuracies in the USGS DEM data.

Masks were developed based on each winter image, the associated DEM data, and the B1 data thresholds and then overlaid relative to the corrected imagery and incidence angle data to assign pixels to one of the nine mask classes shown in Figure 16 and develop masks specific to the individual images used in this classification effort.

Image Classification

GRS applied a hybrid classification methodology that uses both supervised and unsupervised techniques. Multiple classification maps (class maps) are developed using both supervised and unsupervised training sets with different statistical thresholds of 90 and 99%.

<u>Supervised Classification</u>

Supervised classifications efforts were carried out for all participating 16 images and subset areas using bands 1, 2, 3, 4, 5, and 7 and the maximum-likelihood classifier. Nine different classification maps were developed for each image or image subset area using the supervised training sets, statistical thresholds, and the winter image mask classes. Each of these nine non-overlapping class maps were merged into one class map to produce a comprehensive supervised class map for each statistical threshold for each image or subset area. A total of 12 images and subset areas were processed in this manner resulting in a total of 216 different class maps that were merged to form 24 comprehensive class maps. The remaining 4 images and subset areas (63678, 6418, 6767, and 6767h) were classified in their entirety at each statistical threshold resulting in an additional 8 comprehensive class maps. A total of 32 comprehensive supervised class maps (16 image and subset areas each at 2 statistical thresholds) were produced.

All raw classification grids were standardized to a common set of training class values by means of class lookup tables that matched each raw-grid value to its particular class id through each class' unique *gridval* value. This was achieved using custom **GRS** grid reclassification processing software. *gridval*s less than 25000 represented types generated using the 90% threshold, whereas *gridval*s between 26000 and 50000 represented types generated using the 99% threshold.

Unsupervised Classification

Unsupervised classification maps were generated using bands 1, 2, 3, 4, 5, and 7. The ISODATA clustering method was used to develop the unsupervised training data sets on an image-by-image basis. These training sets were developed based on NDVI masks (vegetated versus unvegetated areas) and were applied using the maximum-likelihood classifier with the same statistical thresholds as were used during supervised classification efforts. No other masking was used during the unsupervised classifications resulting in classes that were not limited by elevation, ecotype section, subset area, or slope. In cases where the unsupervised training data for a particular image contained spectral statistical data with a Singular Covariance Matrix, these sites were withheld from the maximum-likelihood classification and a minimum-distance classifier was also applied to this image at thresholds (distances) of 2 and 3 standard deviations to generate class maps that included these extremely homogeneous classes. This situation occurred in images 6118, 63678, 6378, 6467a, 6567, and 65678. A total of 36 unsupervised class maps were developed using the maximum-likelihood classifier and another 24 class maps were developed using the minimum distance classifier. These class maps were merged together on an image by image basis to form a comprehensive unsupervised class maps for each of the nine images at the two statistical thresholds. Class maps were merged by statistical threshold (90% = 2SDs and 99%=3SDs); maximum-likelihood pixel data were given priority over the minimum-distance results and the NDVI vegetated area training set results were given priority over the NDVI unvegetated area training set results during the merging of the class maps. The original 60 class maps were merged into 18 comprehensive unsupervised class maps (9 images each at 2 statistical thresholds).

An additional set of unsupervised classification training sets and pixel maps were created for each image. These supplementary unsupervised map data were used to represent the major classes present in the unclassified portions of the 18 previously developed comprehensive unsupervised maps. These data sets were developed (one for each image) using the maximum-likelihood classifier at a 99% threshold.

All unsupervised classes were represented in the class maps by a standardized value (*gridval*) unique to each training class as applied in each image. *gridval*s between 51000 than 55999 represented types generated using the 90% threshold, whereas *gridval*s between 56000 and 61990 represented types generated using the 99% threshold. Each unsupervised class was displayed visually and reviewed to confirm the appropriateness of its application. Suspicious and questionable types were identified for subsequent modeling and modification.

Land Cover Database Development

Pixel Class Map Merging

The resulting 50 different supervised and unsupervised pixel class maps were systematically merged to form one comprehensive (composite) land cover pixel classification map. Pixels for this composite map were assembled or included from the supervised and unsupervised classifications by overlaying them in a hierarchical order based on the specific image or subset area, the training set, and the statistical threshold of the classification. As each subsequent pixel classification map was overlaid on the composite map, pixel values were transferred into the composite map when the pixel value filled a VOID location in the composite map. In this way, merged map data never replaced data as it was merged into the composite map, but instead contributed new data in this map.

Data from what were considered primary images and subset areas were merged into the composite map before data from secondary images and subset areas were processed. Images were assigned priorities based on the relative value of images based on the sensor (ETM+ or TM5), coverage,

acquisition date, and the completeness of the land cover types represented by the image training sets. Image cloud masks and subset area masks were applied to limit the data merging to only include the appropriate pixel data within any image or subset area. Six different types of merging logic were applied during this process that ranged from simply adding pixel data into the composite map to limiting the merging of pixel values to areas of cloud cover within another image but not within the extent of a third image (for example, merge the data from image subset 65678n into cloud cover areas of 6567n but not that portion of 6567n that is covered by 6467a). Supervised classification data of the highest reliability (90% threshold) was merged first to form the basis of the composite map. Classification data from progressively lower levels of statistical confidence were then added to this initial map, gradually filling in VOIDs in the prior version of the map, until the final pixel map has been developed. After the supervised data were merged, the unsupervised data were added, using similar logic to add the most reliable data first and then the data of lower reliability. The end result, after 146 overlay processes was one comprehensive land cover pixel classification map based on all the different classification efforts that covers the entire WSRT project area. Table 15 lists the basic hierarchy of merge priorities used to develop the composite land cover map. Figure 17 depicts the merging strategy from Step 1 (top left) to Step 146 (bottom right).

Classifier (1)	Reliability / Threshold (2)	Image / Subset Area (3)	Merge Strategy	Description
Supervised	**90%**	**6467a**	**M**	Merge Grid1 into Composite Map
	99%	**6567n**		
		6567b	**MF**	Merge Grid1 into Composite Map AND NOT Clear Areas of Grid2
Unsupervised	**90%**	**6567s**		
	99%	**6418**	**F**	Merge Grid1 into Clouded Area of Grid2
		6767		
		6118	**FN**	Merge Grid1 into Clouded Area of Grid2 NOT in Area of Grid3
		6378s		
		65678s	**FW**	Merge Grid1 into Area of Grid 2
		65678n		
		65678b	**FWN**	Merge Grid1 into Area of Grid 2 NOT in Area of Grid3
		6378n		
		6467sn		
		6467ss		
		6767h		
		63678		

Table 15: Class map Merge Priorities

Land cover attribute descriptions were developed for each pixel class in the composite land cover map, based on the "ground truth" data used to estimate the attributes of each training class. Unsupervised class attributes were developed by relating each unsupervised class to supervised classes that occupied the same locations, reviewing these data for satisfactory data content, and then calculating land cover attributes based on the specific related supervised pixel classes and their relative frequencies. Land cover components of the "ground truth" information were included in the database tables.

Another map product developed during this process was a separate grid that identifies the classification source of each pixel merged into the composite map, in terms of the origin of its assignment. This source value represents the different classification characteristics of each pixel that was merged into the composite map. This pixel source information is quite useful as it identifies the image or subset area, the type and statistical threshold of the classifier, and the merging strategy used to assign the land cover class to every pixel in the map. The definition of the pixel source value is shown in Table 16.

ClassMap Merge Order and Function

Sml90	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**				
Scene	6467a	6567n	6567b	6567s	6418	6767	6118	6378s	65678s	65678n	65678b	6378n	6467sn	6467ss	6467ss	6767h				
Function	M	MF	M	M	MF	MF	M	MF	F	FN	F	MF	FN	F	FN	MF				
Fill within	n/a	6467a	n/a	n/a	6567(b)	6567	n/a	6118	6567(s)	6567(n)	6567(b)	6567(s)	6467a	6567(s)	6378(n)	6567				
not										6467a			6567		6567					
Sml99	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**				
Scene	6467a	6567n	6567b	6567s	6418	6767	6118	6378s	65678s	65678n	65678b	6378n	6467sn	6467ss	6467ss	6767h				
Function	M	MF	M	M	MF	MF	M	MF	F	FN	F	MF	FN	F	FN	MF				
Fill within	n/a	6467a	n/a	n/a	6567(b)	6567	n/a	6118	6567(s)	6567(n)	6567(b)	6567(s)	6467a	6567(s)	6378(n)	6567				
not										6467a			6567		6567					
SmlFill90	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**										
Scene	6567n	65678s	65678n	65678b	6418	6378s	6378n	6467sn	6467ss	6467ss										
Function	FW	FW	FWN	FW	FW	FW	FW	FWN	FW	FWN										
Fill within	6467a	6567s	6567(n)	6567(b)	6567(b)	6118	6567(s)	6467a	6567(s)	6378(n)										
not			6467a					6567		6567										
threshold	90	90	90	90	90	90	90	90	90	90										
SmlFill99	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**
Scene	6567n	65678s	65678n	65678b	6418	6378s	6378n	6467sn	6467ss	6467ss	65678n	6467sn	6467ss	65678n	6467sn	6467ss	63678	63678	63678	63678
Function	FW	FW	FWN	FW	FW	FW	FW	FWN	FW	FWN	FW	FW	FW	FW	FW	FW	F	F	F	F
Fill within	6467a	6567(s)	6567(n)	6567(b)	6567(b)	6118	6567(s)	6467a	6567(s)	6378(n)	6567(n)	6467a	6378(n)	6567(n)	6467a	6378(n)	6467a	6378(n)	6467a	6378(n)
not			6467a					6567		6567										
threshold	99	99	99	99	99	99	99	99	99	99	90	90	90	99	99	99	90	90	99	99
Iso90	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**				
Scene	6467a	6567n	6567b	6567s	6418	6767	6767h	6118	6378s	65678s	65678n	65678b	6378n	6467sn	6467ss	6467ss				
Function	M	MF	M	M	MF	MF	MF	M	MF	F	FN	F	MF	FN	F	FN				
Fill within	n/a	6467a	n/a	n/a	6567b	6567	6567	n/a	6118	6567s	6567n	6567b	6567s	6467a	6567s	6378n				
not											6467a			6567		6567				
Iso99	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**				
Scene	6467a	6567n	6567b	6567s	6418	6767	6767h	6118	6378s	65678s	65678n	65678b	6378n	6467sn	6467ss	6467ss				
Function	M	MF	M	M	MF	MF	MF	M	MF	F	FN	F	MF	FN	F	FN				
Fill within	n/a	6467a	n/a	n/a	6567b	6567	6567	n/a	6118	6567s	6567n	6567b	6567s	6467a	6567s	6378n				
not											6467a			6567		6567				
IsoFill90	**95**	**96**	**97**	**98**	**99**	**100**	**101**	**102**	**103**	**104**										
Scene	6567n	65678s	65678n	65678b	6418	6378s	6378n	6467sn	6467ss	6467ss										
Function	FW	FW	FWN	FW	FW	FW	FW	FWN	FW	FWN										
Fill within	6467a	6567s	6567(n)	6567(b)	6567(b)	6118	6567(s)	6467a	6567(s)	6378(n)										
not			6467a					6567		6567										
threshold	90	90	90	90	90	90	90	90	90	90										
IsoFill99	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**	**122**	**123**	**124**
Scene	6567n	65678s	65678n	65678b	6418	6378s	6378n	6467sn	6467ss	6467ss	65678n	6467sn	6467ss	65678n	6467sn	6467ss	63678	63678	63678	63678
Function	FW	FW	FWN	FW	FW	FW	FW	FWN	FW	FWN	FW	FW	FW	FW	FW	FW	F	F	F	F
Fill within	6467a	6567(s)	6567(n)	6567(b)	6567(b)	6118	6567(s)	6467a	6567(s)	6378(n)	6567(n)	6467a	6378(n)	6567(n)	6467a	6378(n)	6467a	6378(n)	6467a	6378(n)
not			6467a					6567		6567										
threshold	99	99	99	99	99	99	99	99	99	99	90	90	90	99	99	99	90	90	99	99
Isor99	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**	**136**	**137**	**138**	**139**	**140**				
Scene	6467a	6567n	6567s	6418	6767	6767h	6118	6378s	65678s	65678n	6378n	6467sn	6467ss	6467ss	63678	6567n				
Function	M	MF	M	MF	MF	MF	M	MF	F	FN	MF	FN	F	FN	FN	F				
Fill within	n/a	6467a	n/a	6567b	6567	6567	n/a	6118	6567s	6567n	6567s	6467a	6567s	6378n	6378n	65678				
not										6467a		6567		6567	6567					
Exceptions:	**Fill hole in using Bremner**				**Fill holes in 6567**					**Fill holes in cloud mask**										
sml99all	141				**Iso icr**	142	143	144		**Iso icc**	145	146								
Scene	65678b				Scene	65678b	6767	6767h		Scene	65678n	6567n								
Function	FWN				Function	FWN	F	F		Function	F	F								
Fill within	65678(s)				Fill within	65678(s)	65678(s)	65678(s)		Fill within	6567n	65678								
not	6567				not	6567				not										
threshold	99				threshold	99	99	99		threshold	99	99								

Figure 17: Class map Merge Sequence and Specifications

- **Image Value** – the scene value is the 4th and 5th (leftmost) characters (**XX**——) of the pixel source value. The value represents the origin of the pixel value in terms of the training set/image or subset area:

Value	Image/Subset Area	Source Value (XX——)
1	6118	1 ___
2	63678	2 ___
3	6378s	3 ___
4	6378n	4 ___
5	6418	5 ___
6	6467a	6 ___
7	6467ss	7 ___
8	6467sn	8 ___
9	6567s	9 ___
10	6567n	10 ___
11	6567b	11 ___
12	65678s	12 ___
13	65678n	13 ___
14	65678b	14 ___
15	6767	15 ___
16	6767h	16 ___

- **Classification/threshold** – the type and threshold of the classification are represented by the 3rd digit from the right (—**X**—) of the pixel source value. The order in which classifications of different thresholds were mosaiced was:

Order/Value	Classification	Source Value (—X—)
1	supervised – 90% threshold	—**1**—
2	supervised – 99% threshold	—**2**—
3	unsupervised – 90% threshold	—**3**—
4	unsupervised – 99% threshold	—**4**—

- **Merge/Fill Function** – the merge/fill function used to populate the pixel location is represented by the 2nd digit from the right (——**X**–) of the pixel source value. The order in which classifications of different thresholds were mosaiced was:

Value/Order	Function	Source Value (——X–)
1	Merge	——**1**–
2	Merge/Fill	——**2**–
3	Fill	——**3**–
4	Fill Not	——**4**–
5	Fill Within	——**5**–
6	Fill Within Not	——**6**–

- **Modeling Application** – the modeling application used to model the pixel location is represented by the 1st digit from the right (———**X**) of the pixel source value. The values representing the different modeling applications are:

Value	Modeling Application	Source Value (———X)
1	PMA and PGI Extent	———**1**
2	Tree Terrain Shadow	———**2**
3	**Models 1 and 2**	———**3**
4	Terrain Shadow and Other Modeling	———**4**
8	Isolated Unclassified	**8**
9	Bodies of Water/Clouds	**9**

As these modifications were of a relatively minor nature compared to the overall classification efforts they were handled through post-classification modeling of the composite land cover map.

Modeling of Black Spruce and White Spruce Types and Cover

Issues 1 and 2 regarding tree cover and composition were handled as one modeling effort. A mask was developed to indicate portions of the project area in which Black Spruce did not occur. This "No Black Spruce" mask identified the White River drainage, the upper reaches of the Chisana River near Chisana, the Chitina River drainage east of Goat Creek, and areas south of the Hanagita Valley and Lower Tana River drainage as areas in which Black Spruce should not be mapped. In all other portions of the WRST Project Area, Black Spruce was limited to a maximum elevation of 3200 feet. White Spruce was limited to a maximum elevation of 5000 feet throughout the project area.

Input data for the modeling effort were the land cover pixel map, the DEM grid, and the "No Black Spruce" mask. The following changes were made during this grid modeling effort to create a modified version of the composite land cover map:

1. A pixel of a Black Spruce (PMa) type or having PMa cover found in an area defined as "No Black Spruce" was changed to a new unique type and all associated type and cover information were changed from PMa to White Spruce (PGl).

2. A pixel of a Black Spruce (PMa) type or having PMa cover found at an elevation above 3200 feet elevation was changed to a new unique type and all associated type and cover information were changed from PMa to PGl.

3. A pixel of a PGl type or having PGl cover found at an elevation above 5000 feet elevation was changed to a new unique type and all associated cover information was changed from PGl to an unknown shrub code.

A total of **577,381** pixels were altered during this modeling effort. More than half of these modeled pixels were in image 6467a, in particular in the White River drainage, where White Spruce stands of a somewhat stunted nature were found that were very similar in morphology and composition to Black Spruce stands occurring elsewhere in the image.

Modeling of Tree Types in Areas of Terrain Shadow

Issue 3 involved the influence of terrain shadows on the land cover pixel map. In this case there were portions of the classification map in areas of steep slope of a northwesterly to northeasterly aspect that were incorrectly classified as a coniferous forest type when in fact the areas were likely barren or covered with snow and ice. After an evaluation of the occurrence of the tree class type data relative to slope and aspect, modeling rules were developed to modify the tree class data in areas of terrain shadow to an Unknown Terrain Shadow class. Different slope and aspect thresholds were tested and map results compared. It was apparent that different thresholds generated different results, which in most cases corrected the erroneously mapped tree type data, but at the same time would also change some correctly mapped tree type pixel data to be incorrectly mapped as Terrain Shadow. Slope and aspect thresholds were selected that appeared to generate results that were slightly conservative in their application, in order to minimize altering correctly mapped tree type pixels at the expense of modeling the incorrectly typed tree class pixels to terrain shadow pixels.

Input data for this modeling effort included the pixel map output by the prior modeling process and the WRST slope and aspect grids. Tree type classes that were on slopes greater than or equal to 30 degrees located on aspects of between 270° (NW) to 60° (NWN) were modified to the Unknown Terrain Shadow Barren (TSb) class during this modeling effort and a modified version of the composite land cover map was created.

A total of **237,882** pixels were altered during this modeling effort.

Modeling of Other Suspect Types

Issues 4, 5, 6, and 7 all involved types that exhibited signs of confusion among unsupervised classes that were used to add pixel class estimates to the composite map. Most all of these issues involved Water or wet classes of one sort or another. Issue 4 concerned Water classes that were applied in areas of terrain shadow. These situations were typically areas of north or northwesterly aspect on steeper slopes. These Water pixels were very likely the result of very dark (low digital value) pixels in areas of very low illumination that are most appropriately described as terrain shadows. After all the bands were normalized for differential illumination, these very dark pixels were still very dark. Unfortunately, very dark pixels tend to be confused with Water type pixels, as areas of water have virtually no reflectance. These dark pixels were subsequently classified in error as Water pixels, when they should be labeled as Terrain Shadow pixels.

Post processing or modeling was applied to the final pixel classification map, in an effort to identify, and reclass as Terrain Shadow as many of these misclassified Water pixels as possible. This modeling effort entailed identifying suspect Water locations in the final map and altering their values to indicate Terrain Shadow types as opposed to Water types. Areas of Water on steep northwesterly to northeasterly aspects were identified and type specific rules were established to convert these troublesome Water type pixels into Terrain Shadow pixels. Unfortunately, further investigation revealed that some valid Water pixels were now misclassified as Terrain Shadow. Some of these misclassified pixels resulted along the edges of lakes where the slope map may have been slightly misaligned with the satellite imagery, resulting in areas of high slope along the edges of large bodies of water that overlap Water pixels. This misalignment of the slope and Water data caused some valid pixels to be changed to Terrain Shadow pixels. Other misclassified pixels occurred where the USGS DEM indicated sloped surfaces in areas of water which should in fact have been flat (in the slope map). Whereas further modeling refinements and pixel aggregation into polygons were not in the scope of this mapping effort, these misclassified Water data remained in the Terrain Shadow class in the final map.

Some of the other classes that were most confused represented wet gravelly areas and silty water, water and terrain shadow, barren areas and terrain shadow, and darker snow/ice areas and wet gravelly areas. These unsupervised types were identified during the review of all of the unsupervised type classes. Frequency distributions with respect to slope, aspect, and elevation were generated for these suspect type classes. Resolution of each of these types involved review of the frequency distribution data relative to the visual display of the suspect class and the development of criteria including elevation, slope, and aspect that could be used to modify and correct these suspect classes where they appeared to be incorrectly applied. For example, unsupervised classes 51005 and 56005 which are Barren/Nonveg types occurring both in barren areas and in areas that should be water were changed to a value representing a Water class where they occurred at elevations below 40 feet. Another example involved limiting the **–Sage Bluff** designation to elevations below 2250 feet and removing the designation at higher elevations.

Input data for this modeling effort included the pixel map output by the prior modeling process and the WRST DEM, slope, and aspect grids. Elevation, slope, and/or aspect criteria for 341 suspect classes were applied to generate a modified version of the composite land cover map. A total of **1,040,181** pixels were altered during this modeling effort.

Bodies of Water

Several large bodies of water and lakes were identified in which the prior terrain shadow modeling process converted water pixels into terrain shadow pixels. These problems resulted due to inaccuracies in the slope grid created from the USGS DEM data. Pixels were converted to Terrain Shadow pixels because the slope data indicated the effected portions of the lakes and bodies of water have slopes that were greater than 5 degrees. Other bodies of silty water were identified that were interspersed with Barren pixels. In this case the confusion within unsupervised classes could not be completely resolved through prior modeling efforts. These mapping problems were resolved by creating a grid that represented the extent of these bodies of water and replacing the incorrectly mapped areas with the Water type grid values. A total of **257,445** were modeled during this effort.

Isolated Unknown Pixels

The last modeling effort concerned the modification of isolated Unclassified or Terrain Shadow pixels. In situations when an Unclassified or Terrain Shadow pixel was completely surrounded by pixels of the same major cover class (conifer, hardwood, tall shrub, and so forth) the singleton pixel was converted to the predominant class of the surrounding pixels. This process was not applied to any Unclassified or Terrain Shadow pixels that were connected diagonally or to any isolated pixels next to more than one major class of land cover. A total of **52,558** pixels of an Unknown value were modeled during this effort.

Attribute Development

The WRST land cover type database consists of two database tables. These two tables contain all the information that describes each class of the final pixel classification map. The main table is the value attribute table or .VAT table. The VALUE item (the column that contains the actual numeric pixel values) represents the grid values (*gridval*) of the grid data. This table contains all the land cover class summary information such as the trsite_id and calc_class, as well as percent cover of trees, conifer and hardwood cover composition, and percent cover of all other general land cover components including, tall shrub, low shrub, dwarf shrub, herbaceous, aquatic forbs, other, barren, and water. These cover components comprise the “bird’s-eye view” description of each land cover type. Each table record also contains information regarding image participation, hydric regime, and

modifier. The second table (*gridval_cover.dat*) contains the individual species records (species, species code, cover, strata, and so forth) for each supervised training site used in the classification. This table, when related to the .VAT table using the trsite_id columns of the .VAT table and *gridval_cover.dat* tables associates individual cover characteristics with the land cover type data. A sample listing of a database record is shown in Table 17. Listings and definitions of the attributes of the *wrst_lcover.vat* and the *gridval_cover.dat* tables are included in Appendix E.

VALUE(**gridval**)	=	1031
COUNT	=	36095
TRSITE_ID	=	71863
ELEVATION_FT	=	2989
SLOPE_DEGREES	=	2
ASPECT	=	264
X_COORDINATE	=	540070.57
Y_COORDINATE	=	1437532.69
LATITUDE	=	62:31:23.444077
LATITUDE	=	-143:26:11.398721
PHOTO_ID	=	71863.JPG
SOURCE_CLASS	=	SUPML90
SOURCE_DATA	=	GRSAIR
SCENE_IND	=	000011110
OTHER_ID	=	n/a
SPEC_CLASS	=	Black Spruce:Wdlnd
GRIDCLVAL	=	1
MAJOR_CLASS	=	Conifer
REGIME	=	mesic
MODIFIER	=	upland
REMAP_VAR	=	0
TYPE	=	PMa
CALC_CLASS	=	Black Spruce:Wdlnd
PREDOMINANT_COMP	=	Black Spruce
PR_COMP_COVER	=	8.0
COVER_CLASS	=	Wdlnd
TREE_COVER	=	10.0
OTHER_VEG_COVER	=	67.0
CONF_COVER	=	10.0
HDWD_COVER	=	0.0
PCT_CONF	=	100.0
PCT_HDWD	=	0.0
SHR_COVER	=	55.0
TSH_COVER	=	0.0
LSH_COVER	=	55.0
DSH_COVER	=	0.0
HRB_COVER	=	12.0
OTH_COVER	=	13.0
AQU_COVER	=	0.0
BAR_COVER	=	10.0
H2O_COVER	=	0.0
UNDF_COVER	=	0.0
ALNUS_COVER	=	0.0
SALIX_COVER	=	10.0
GRAM_COVER	=	0.0

Table 17:Sample Land Cover Type Attribute Listing

The land cover characteristics or attributes in the final pixel classification map database, as represented in the *wrst_lcover.vat* table, are derived from two sources – supervised classification data and unsupervised classification data. The first source of information is the entire set of land cover information (field observations) associated with each training site used to form a training class in the supervised training sets. Throughout this entire classification effort a link has been retained that associates the original training site description with the *gridval* of the final pixel map. This link is used to relate or join the land cover attributes of the description with the mapped pixel elements. Using this link information based on the aerial survey data, FirePro data, ABR ground data, and supplemental data were associated with the proper grid values in the final map.

The second source of data describes the unsupervised pixel classes used to supplement the supervised classification data. All the unsupervised data were developed and applied without knowledge of any land cover characteristics. In order to estimate the land cover characteristics of unsupervised classes, the *ISODATA* classes developed in unsupervised classifications were related to supervised classes of the merged 90% threshold maximum-likelihood classification using cross tabulation reports of the appropriate grids (the cross tabulation report describes a pixel-by-pixel overlay of the supervised and unsupervised pixel maps). Unsupervised map data were related to supervised map data that reflected the same images and subset areas used during the supervised classification (e.g. unsupervised 6567 classification map data were related separately to the supervised 6567n, 6567s, and 6567b map data). Each cross tabulation report described the frequency of each supervised class pixel value (*gridval*) that comprised each unsupervised class of that map, as shown in the

Table 18: UnsupXSup CrossTab Results

Class,gridval,frequency
…
51037,0,3540
51037,2090,3649
51037,2091,1113
51037,2092,18
51037,2093,33
51037,3017,769
51037,3022,475
51037,3023,157
51037,3024,153
51037,3027,8
51037,3028,3602
51037,12035,346
51037,17063,28
…

sample data in Table 18. In this example, unsupervised class 51037 corresponds to 12 supervised *gridval*s. 4 *gridval*s indicate Open conifer types (2xxx), 6 *gridval*s indicate Closed conifer types (3xxx), and the other two *gridval*s indicate an Open Low shrub type (12xxx) and an Herbaceous type (17xxx). The listing includes the number of pixels of each overlapping class. *gridval* 2090 contributes 3649 pixels to class 51037, *gridval* 2091 contributes 1113, *gridval* 2092 contributes 18, *gridval* 2093 contributes 33, *gridval* 3017 contributes 769, and so forth. Land cover attributes were then estimated by processing these gridval/frequency data by isoclass with ***GRS_covmatrixsum***. This process developed estimates of land cover attributes of each unsupervised class by calculating the average weighted values of all the different class attributes of the supervised pixels that correspond to that unsupervised class weighting each contributing class by the number of pixels of that class. The cover summary for iso_class 51037, which indicates this class represents a Black Spruce:Open type, is shown in Table 19. Using this approach, an unsupervised class' characteristics are based solely on the attributes of all the supervised class attributes that occupy the same pixel locations in the supervised pixel map. An unsupervised class comprised solely of one supervised class would be assigned the attributes of that class, as the weighted average would be the same as the supervised class values.

Table 19: ***GRS_covmatrixsum*** Cover Summary

```
Transect Cover Percent Density Summary for Top Layer:
Site/Polygon Id: 51037
Number of Pixels: 13754
Size(Dbh) not Designated for this Class

 Dbh Size Class:            > 4.95"  > 8.95"  >12.95"    Tree  Non-Tree   Total
                 <= 4.95" <= 8.95" <=12.95"             Cover    Cover    Cover
Species

Black Spruce        51.2      0.0      0.0      0.0     51.2              51.2
BlSpruce-Dead        1.8      0.0      0.0      0.0      1.8               1.8
Tall shrub sal                                                    7.1      7.1
Low shrub sal                                                     0.2      0.2
Low shrub bet                                                     1.4      1.4
Low shrub eri                                                     0.2      0.2
Dwarf shrb eri                                                   16.1     16.1
Dwarf shrb mix                                                    2.1      2.1
Sedge/rush                                                        1.5      1.5
Forb                                                              1.1      1.1
Moss                                                             10.0     10.0
Lichen                                                            4.3      4.3
Litter                                                            2.9      2.9

Totals              53.0      0.0      0.0      0.0     53.0     47.0    100.0
```

GRS_covmatrixsum rejected unsupervised classes lacking sufficient correlation to supervised classes during processing of these data. Sufficient correlation was set at a minimum threshold of 25 percent correspondence of the unsupervised class. Land cover attributes were estimated in this manner for the classes in each unsupervised classification map that was used in the development of the final pixel classification map. The attributes (weighted averages) were output in the same table structure as that shown in Table 17 for each of the ISODATA classes that were included in the land cover map. All classes lacking sufficient correlation were reviewed individually to verify and estimate land cover components.

As was previously mentioned, the land cover components estimated at each supervised training site were also included in a database table called *gridval_cover.dat*. These table records may be joined to the land cover attributes table using the trsite_id columns as the key field. These data were not generated for unsupervised classes. A sample listing of a record from this table is shown in Table 20.

```
Record 1:
  TRSITE_ID        =          71863
  SOURCE           =         AIR_95
  SPECIES          =      Picea Mar
  SPCODENUM        =             43
  SPCODE           =         PICMAR
  COVER            =            8.0
  STRATA           =              C
  COMMENT          =
  GRIDVAL          =           1031

Record 2:

  TRSITE_ID        =          70210
  SOURCE           =            AIR_95
  SPECIES          =     Betula nan
  SPCODENUM        =            132
  SPCODE           =         BETNAN
  COVER            =           30.0
  STRATA           =              L
  COMMENT          =
  GRIDVAL          =           1031
```

Table 20: Sample Cover Data Attribute (*gridval_cover.dat*)

Results

The results of this land cover mapping project are contained in the modeled composite land cover classification pixel map and the associated attribute tables that describe the land cover characteristics of each pixel type. A total of 92,167,997 pixels or approximately 18.5 million acres are represented by 10,062 different pixel classes in the final WRST Land Cover Map. Final land cover map frequency of pixels by image/subset area is shown in Table 21. A summary of pixels by image/subset area and classification type and threshold is shown in Table 22.

Table 21: Area Summary by Image/Subset Area

Image / Subset Area	Source	Number of Pixels	Acreage	Pct of Total	Number of Pixels By Image	Acreage	Pct of Total
6118	1xxx	8,740,161	1,754,242	9.48%	**8,740,161**	**1,754,242**	**9.48%**
63678	2xxx	1,194,048	239,658	1.30%	**1,194,048**	**239,658**	**1.30%**
6378s	3xxx	12,901,975	2,589,562	14.00%			
6378n	4xxx	7,370,829	1,479,403	8.00%	**20,272,804**	**4,068,966**	**22.00%**
6418	5xxx	1,172,823	235,398	1.27%	**1,172,823**	**235,398**	**1.27%**
6467a	6xxx	12,878,039	2,584,758	13.97%	**12,878,039**	**2,584,758**	**13.97%**
6467ss	7xxx	4,622,580	927,801	5.02%			
6467sn	8xxx	2,302,258	462,087	2.50%	**6,924,838**	**1,389,888**	**7.51%**
6567s	9xxx	16,673,295	3,346,506	18.09%			
6567n	10xxx	7,260,309	1,457,221	7.88%			
6567b	11xxx	6,063,945	1,217,098	6.58%	**29,997,549**	**6,020,824**	**32.55%**
65678s	12xxx	3,381,688	678,740	3.67%			
65678n	13xxx	5,253,918	1,054,517	5.70%			
65678b	14xxx	394,141	79,108	0.43%	**9,029,747**	**1,812,365**	**9.80%**
6767	15xxx	765,025	153,549	0.83%			
6767h	16xxx	859,562	172,523	0.93%	**1,624,587**	**326,072**	**1.76%**
Modeled	xxx	333,401	66,917	0.36%	**333,401**	**66,917**	**0.36%**
Grand Total		**92,167,997**	**18,499,089**	**100.00%**	**92,167,997**	**18,499,089**	**100.00%**

Table 22: Number of Pixels by Image/Subset Area and Classification Type and Threshold

Image / Subset Area	SUPML - 90%	SUPML - 99%	UNSUP - 90%	UNSUP - 99%	Modeled	Total	Pct of Total
6118	787,578	461,800	6,396,957	1,093,826		8,740,161	9.48%
63678	754,545	299,029	123,933	16,541		1,194,048	1.30%
6378s	1,614,352	1,003,250	8,391,876	1,892,497		12,901,975	14.00%
6378n	1,614,038	951,689	4,603,041	202,061		7,370,829	8.00%
6418	149,931	86,155	887,602	49,135		1,172,823	1.27%
6467a	6,766,726	3,628,908	2,307,888	174,517		12,878,039	13.97%
6467ss	1,791,917	972,805	1,742,830	115,028		4,622,580	5.02%
6467sn	1,525,844	579,026	187,147	10,241		2,302,256	2.50%
6567s	9,182,412	4,011,681	3,276,764	202,438		16,673,295	18.09%
6567n	3,197,018	2,113,931	1,856,217	93,143		7,260,309	7.88%
6567b	2,003,259	1,010,903	2,919,220	130,563		6,063,945	6.58%
65678s	2,336,503	839,653	195,632	9,900		3,381,688	3.67%
65678n	3,179,707	1,473,397	536,063	64,751		5,253,918	5.70%
65678b	227,475	146,353	11,012	9,301		394,141	0.43%
6767	327,009	211,420	178,773	47,823		765,025	0.83%
6767h	175,752	192,470	441,311	50,029		859,562	0.93%
Modeled					333,401	333,401	0.36%
Grand Total	**35,634,066**	**17,982,470**	**34,056,266**	**4,161,794**	**333,401**	**92,167,997**	**100.00%**
Pct of Total	**38.66%**	**19.51%**	**36.95%**	**4.52%**	**0.36%**	**100.00%**	
Pct by Classifier		**58.17%**		**41.47%**			

During previous projects supervised classification techniques have typically resulted in the classification of approximately 90-95% of the mapped area, while unsupervised techniques have typically account the remaining 5-10% of the classification, depending on how thoroughly the training data represent the variety of land cover characteristics found in the project area.

In this project, due to the large expanses of snow, ice, glaciers, water, and barren mountains that were not represented by supervised training sites, the percent of the project area mapped using supervised techniques accounted for only 58.2 % of the mapped area.

A summary of pixels and area by major land cover type and data origin (classification method and threshold) is shown in Table 23. This table shows the distribution of area by major type. 54.3% of WRST Project Area was classified as one of the non-vegetated classes and 45.7% as one of the vegetated land cover classes. On this basis of these data, the supervised classification techniques accounted for mapping 93.7% of the WRST Project Area as one of the vegetated land cover types. Table 24 shows similar information for the specific land cover types that were mapped.

Table 23: Pixel Frequency and Area (Acreage) By Major Class and Classification

Pixel Frequency by Major Type and Classification							
Major Class	**SUP90**	**SUP99**	**ISO90**	**ISO99**	**TSH/UNCL**	**Grand Total**	**Pct of Area**
Conifer	8,997,572	3,479,085	573,873	127,686		13,178,216	14.3%
ConHwd Mix	1,793,795	675,862	124,521	38,940		2,633,118	2.9%
Hardwood	1,146,625	480,265	32,127	12,891		1,671,908	1.8%
Tall Shrub	3,443,512	1,275,765	186,269	75,743		4,981,289	5.4%
Low Shrub	5,014,654	2,270,707	299,216	81,264		7,665,841	8.3%
Dwarf Shrub	2,412,900	1,365,725	135,546	27,924		3,942,095	4.3%
Herbaceous	1,717,158	1,094,687	198,665	60,515		3,071,025	3.3%
Sparse	2,566,745	1,643,392	640,476	97,582		4,948,195	5.4%
Barren	7,993,141	5,300,193	30,019,370	2,468,495		45,781,199	49.7%
Water	383,696	226,910	343,125	2,958,667		3,912,398	4.2%
Unknown			3,277	1,614	377,822	382,809	0.4%
Grand Total	35,469,798	17,812,591	32,556,465	5,951,321	377,822	92,167,997	100.0%
Pct of Area	38.5%	19.3%	35.3%	6.5%	0.4%	100.0%	
						Unvegetated=	54.3%

Acreage by Major Type and Classification							
Major Class	**SUP90**	**SUP99**	**ISO90**	**ISO99**	**TSH/UNCL**	**Grand Total**	**Pct of Area**
Conifer	1,805,912	698,291	115,183	25,628		2,645,013	14.3%
ConHwd Mix	360,034	135,653	24,993	7,816		528,496	2.9%
Hardwood	230,140	96,394	6,448	2,587		335,570	1.8%
Tall Shrub	691,151	256,060	37,386	15,202		999,799	5.4%
Low Shrub	1,006,496	455,756	60,056	16,311		1,538,619	8.3%
Dwarf Shrub	484,296	274,116	27,206	5,605		791,222	4.3%
Herbaceous	344,652	219,716	39,874	12,146		616,388	3.3%
Sparse	515,174	329,847	128,551	19,586		993,157	5.4%
Barren	1,604,311	1,063,807	6,025,218	495,454		9,188,790	49.7%
Water	77,012	45,543	68,869	593,837		785,261	4.2%
Unknown			658	324	75,833	76,834	0.4%
Grand Total	7,119,179	3,575,183	6,534,441	1,194,496	75,833	18,499,131	100.0%
Pct of Area	38.5%	19.3%	35.3%	6.5%	0.4%	100.0%	

Table 24: Area (Acreage) By Land Cover Class and Classification

Land Cover Type (calc_class)	SUP90	SUP99	Pct SUP	ISO90	ISO99	Pct ISO	TSH UNCL	Total	Pct of Total
Sitka Spruce:Closed	8,118	2,812	0.1%	159	61	0.0%		11,150	0.1%
Sitka Spruce:Open	14,439	7,231	0.1%	3,000	4,303	0.0%		28,974	0.2%
Sitka Spruce:Wdlnd	8,151	2,775	0.1%			0.0%		10,927	0.1%
Black Spruce Cmplx:Open	494	201	0.0%			0.0%		695	0.0%
Black Spruce Cmplx:Wdlnd-Lichen	701	279	0.0%			0.0%		980	0.0%
Black Spruce Stunted:Wdlnd	4,716	3,463	0.0%			0.0%		8,179	0.0%
Black Spruce:Closed	21,384	10,139	0.2%			0.0%		31,522	0.2%
Black Spruce:Open	191,209	74,036	1.4%	5,871	1,420	0.0%		272,537	1.5%
Black Spruce:Open-Lichen	32,007	10,278	0.2%			0.0%		42,284	0.2%
Black Spruce:Open-Tussock	7,792	4,016	0.1%			0.0%		11,809	0.1%
Black Spruce:Wdlnd	164,710	55,088	1.2%	10,994	2,028	0.1%		232,820	1.3%
Black Spruce:Wdlnd-Tussock	29,054	11,568	0.2%	530	120	0.0%		41,272	0.2%
Spruce Mix Cmplx:Wdlnd	2,105	1,531	0.0%	36	16	0.0%		3,689	0.0%
Spruce Mix:Open	86,940	41,072	0.7%	16,712	2,960	0.1%		147,685	0.8%
Spruce Mix:Open-Tussock	10,187	6,178	0.1%			0.0%		16,365	0.1%
Spruce Mix:Wdlnd	36,939	13,698	0.3%	19,825	2,820	0.1%		73,283	0.4%
Spruce Mix:Wdlnd-Tussock			0.0%	11	8	0.0%		19	0.0%
White Spruce Cmplx:Closed	4,148	1,668	0.0%			0.0%		5,816	0.0%
White Spruce Cmplx:Open	95,385	20,896	0.6%	4	7	0.0%		116,293	0.6%
White Spruce Cmplx:Wdlnd	51,156	14,261	0.4%	266	105	0.0%		65,789	0.4%
White Spruce Cmplx:Wdlnd-Lichen	373	118	0.0%			0.0%		490	0.0%
White Spruce Dead:Open	1,267	183	0.0%			0.0%		1,450	0.0%
White Spruce Dead:Wdlnd	15,268	8,057	0.1%			0.0%		23,325	0.1%
White Spruce Dead:Wdlnd-Lichen	2,735	845	0.0%			0.0%		3,580	0.0%
White Spruce Stunted:Wdlnd	180	217	0.0%			0.0%		397	0.0%
White Spruce:Closed	52,731	16,887	0.4%	5	4	0.0%		69,628	0.4%
White Spruce:Open	561,470	212,032	4.2%	27,976	6,383	0.2%		807,860	4.4%
White Spruce:Open-Lichen	3,752	2,239	0.0%			0.0%		5,991	0.0%
White Spruce:Open-Tussock	2,889	1,518	0.0%			0.0%		4,407	0.0%
White Spruce:Wdlnd	336,630	151,440	2.6%	29,791	5,394	0.2%		523,256	2.8%
White Spruce:Wdlnd-Lichen	50,589	18,316	0.4%			0.0%		68,905	0.4%
White Spruce:Wdlnd-Tussock	8,392	5,246	0.1%			0.0%		13,638	0.1%
Total Conifer	**1,805,912**	**698,291**	**13.5%**	**115,183**	**25,628**	**0.8%**		**2,645,013**	**14.3%**
Mixed deciduous-conifer:Closed	56,803	26,665	0.5%	555	154	0.0%		84,177	0.5%
Mixed deciduous-conifer:Open	279,588	99,422	2.0%	20,052	6,267	0.1%		405,329	2.2%
Mixed deciduous-conifer:Open-Lichen	1,267	594	0.0%			0.0%		1,861	0.0%
Mixed deciduous-conifer:Wdlnd	22,377	8,973	0.2%	4,386	1,394	0.0%		37,129	0.2%
Total Mixed deciduous-conifer	**360,034**	**135,653**	**2.7%**	**24,993**	**7,816**	**0.2%**		**528,496**	**2.9%**
Aspen:Closed	34,126	15,208	0.3%	100	42	0.0%		49,476	0.3%
Aspen:Open	22,683	8,156	0.2%	834	458	0.0%		32,131	0.2%
Balsam Poplar:Closed	18,475	11,717	0.2%	615	118	0.0%		30,926	0.2%
Balsam Poplar:Open	74,794	31,555	0.6%	250	162	0.0%		106,761	0.6%
Cottonwood:Closed	6,322	979	0.0%			0.0%		7,301	0.0%
Cottonwood:Open	16,379	3,702	0.1%	2,176	704	0.0%		22,961	0.1%
Paper Birch:Closed	37,824	15,749	0.3%	288	94	0.0%		53,955	0.3%
Paper Birch:Open	1,584	602	0.0%	181	71	0.0%		2,438	0.0%
Mixed deciduous:Closed	11,812	6,444	0.1%	1,112	350	0.0%		19,717	0.1%
Mixed deciduous:Open	6,142	2,282	0.0%	893	588	0.0%		9,905	0.1%
Total Mixed deciduous	**230,140**	**96,394**	**1.8%**	**6,448**	**2,587**	**0.0%**		**335,570**	**1.8%**

Table 24: Area (Acreage) By Land Cover Class and Classification (continued)

Land Cover Type (calc_class)	SUP90	SUP99	Pct SUP	ISO90	ISO99	Pct ISO	TSH UNCL	Total	Pct of Total
Tree shrub:Closed:Alder	5,976	2,199	0.0%			0.0%		8,175	0.0%
Tree shrub:Closed:Willow	35,069	10,363	0.2%	143	51	0.0%		45,625	0.2%
Tree shrub:Open:Alder			0.0%	111	62	0.0%		173	0.0%
Tree shrub:Open:Willow	6,973	2,264	0.0%	85	59	0.0%		9,381	0.1%
Tall shrub:Closed:Alder	273,847	93,271	2.0%	3,023	1,122	0.0%		371,263	2.0%
Tall shrub:Closed:Mix	77,575	24,289	0.6%	568	168	0.0%		102,600	0.6%
Tall shrub:Closed:Willow	77,828	26,285	0.6%			0.0%		104,113	0.6%
Tall shrub:Open:Alder	95,449	50,243	0.8%	20,313	8,172	0.2%		174,177	0.9%
Tall shrub:Open:Mix	67,180	23,862	0.5%	10,919	5,217	0.1%		107,178	0.6%
Tall shrub:Open:Willow	51,254	23,285	0.4%	2,223	352	0.0%		77,115	0.4%
Total Tall shrub	**691,151**	**256,060**	**5.1%**	**37,386**	**15,202**	**0.3%**		**999,799**	**5.4%**
Mixed shrub:Open:Alder	4,003	5,738	0.1%	5,435	1,538	0.0%		16,713	0.1%
Mixed shrub:Open:Mix	14,376	11,330	0.1%	6,705	3,033	0.1%		35,443	0.2%
Mixed shrub:Open:Mix-Lichen	7,203	3,950	0.1%			0.0%		11,153	0.1%
Mixed shrub:Open:Mix-Tussock	3,751	2,759	0.0%			0.0%		6,510	0.0%
Mixed shrub:Open:Willow	10,875	4,023	0.1%			0.0%		14,898	0.1%
Mixed shrub:Open:Willow-Lichen			0.0%	6	7	0.0%		13	0.0%
Mixed shrub:Sparse:Alder			0.0%	451	91	0.0%		542	0.0%
Mixed shrub:Sparse:Mix			0.0%	7,336	1,780	0.0%		9,115	0.0%
Mixed shrub:Sparse:Mix-Lichen			0.0%	1,494	420	0.0%		1,914	0.0%
Low shrub:Closed:Alder			0.0%	974	190	0.0%		1,164	0.0%
Low shrub:Closed:Birch	62,773	35,759	0.5%			0.0%		98,532	0.5%
Low shrub:Closed:Ericaceous	1,084	326	0.0%			0.0%		1,409	0.0%
Low shrub:Closed:Mix	41,120	19,147	0.3%	60	17	0.0%		60,345	0.3%
Low shrub:Closed:Willow	4,113	2,384	0.0%			0.0%		6,497	0.0%
Low shrub:Closed:Willow-Birch Mix	22,117	9,696	0.2%			0.0%		31,813	0.2%
Low shrub:Open:Alder	6,161	3,743	0.1%	922	265	0.0%		11,092	0.1%
Low shrub:Open:Birch	128,113	64,085	1.0%	4,670	898	0.0%		197,766	1.1%
Low shrub:Open:Birch-Lichen	1,012	6,511	0.0%			0.0%		7,523	0.0%
Low shrub:Open:Birch-Tussock	4,900	2,403	0.0%			0.0%		7,303	0.0%
Low shrub:Open:Ericaceous	11,011	4,556	0.1%	965	382	0.0%		16,915	0.1%
Low shrub:Open:Ericaceous-Tussock	13,453	4,187	0.1%			0.0%		17,641	0.1%
Low shrub:Open:Mix	166,633	71,679	1.3%	6,560	2,032	0.0%		246,903	1.3%
Low shrub:Open:Mix-Tussock	68,988	34,028	0.6%	554	218	0.0%		103,788	0.6%
Low shrub:Open:Silverberry	1,284	833	0.0%			0.0%		2,117	0.0%
Low shrub:Open:Willow	123,625	49,034	0.9%	7,350	1,220	0.0%		181,229	1.0%
Low shrub:Open:Willow-Birch Mix	287,479	106,553	2.1%	16,574	4,221	0.1%		414,828	2.2%
Low shrub:Open:Willow-Birch Mix-Lichen	5,889	1,860	0.0%			0.0%		7,749	0.0%
Low shrub:Open:Willow-Birch Mix-Tussock	8,605	4,618	0.1%			0.0%		13,222	0.1%
Low shrub:Open:Willow-Lichen	3,582	4,873	0.0%			0.0%		8,455	0.0%
Low shrub:Open:Willow-Tussock	4,348	1,678	0.0%			0.0%		6,027	0.0%
Total Low-Mixed shrub	**1,006,496**	**455,756**	**7.9%**	**60,056**	**16,311**	**0.4%**		**1,538,619**	**8.3%**
Dwarf Shrub	232,310	136,356	2.0%	17,662	4,015	0.1%		390,342	2.1%
Dwarf Shrub:Cassiope	34,355	20,512	0.3%	293	22	0.0%		55,182	0.3%
Dwarf Shrub:Cassiope-Lichen	5,760	4,786	0.1%			0.0%		10,545	0.1%
Dwarf Shrub:Dryas	56,872	42,370	0.5%	7,016	860	0.0%		107,118	0.6%
Dwarf Shrub:Dryas-Lichen	7,617	8,258	0.1%			0.0%		15,875	0.1%
Dwarf Shrub:Ericaceous			0.0%	206	55	0.0%		261	0.0%
Dwarf Shrub-Lichen	133,757	54,196	1.0%	2,029	653	0.0%		190,635	1.0%
Dwarf Shrub-Sage Bluff	1,974	2,228	0.0%			0.0%		4,202	0.0%
Dwarf Shrub-Tussock	11,652	5,411	0.1%			0.0%		17,063	0.1%
Total Low-Mixed shrub	**484,296**	**274,116**	**4.1%**	**27,206**	**5,605**	**0.2%**		**791,222**	**4.3%**

Table 24: Area (Acreage) By Land Cover Class and Classification (continued)

Land Cover Type (calc_class)	SUP90	SUP99	Pct SUP	ISO90	ISO99	Pct ISO	TSH UNCL	Total	Pct of Total
Herbaceous	58,018	39,942	0.5%	8,456	5,532	0.1%		111,948	0.6%
Elymus	285	326	0.0%	848	119	0.0%		1,578	0.0%
EriVag-Tussock	8,828	3,694	0.1%			0.0%		12,522	0.1%
Graminoid	109,253	68,079	1.0%	3,013	950	0.0%		181,296	1.0%
Graminoid-Lichen	3,963	3,763	0.0%			0.0%		7,726	0.0%
Graminoid-Tussock	3,079	1,747	0.0%			0.0%		4,825	0.0%
Moist Sedge-Shrub Meadow	93,034	51,108	0.8%	19,166	4,332	0.1%		167,640	0.9%
Moist Sedge-Shrub Meadow-Lichen	13,745	7,051	0.1%	1,116	272	0.0%		22,184	0.1%
Moist Sedge-Shrub Meadow-Tussock	5,555	2,436	0.0%			0.0%		7,991	0.0%
Aquatic Forb	653	611	0.0%		36	0.0%		1,299	0.0%
Water-Aquatic Forb	1,698	1,452	0.0%			0.0%		3,150	0.0%
Lichen	28,759	25,358	0.3%	5,002	590	0.0%		59,709	0.3%
Moss	17,782	14,151	0.2%	2,273	315	0.0%		34,521	0.2%
Total Herbaceous and Non-Vascular	**344,652**	**219,716**	**3.1%**	**39,874**	**12,146**	**0.3%**		**616,388**	**3.3%**
Sparse Vegetation	512,962	326,559	4.5%	123,774	18,618	0.8%		981,913	5.3%
Sparse Vegetation-Lichen			0.0%	2,239	160	0.0%		2,399	0.0%
Sparse Vegetation-Sage Bluff	1,626	1,342	0.0%			0.0%		2,968	0.0%
Water-Sparse Vegetation	586	1,946	0.0%	2,538	807	0.0%		5,877	0.0%
Total Sparse Vegetation	**515,174**	**329,847**	**4.6%**	**128,551**	**19,586**	**0.8%**		**993,157**	**5.3%**
Barren/NonVeg	1,508,752	990,972	13.5%	1,226,148	131,646	7.3%		**3,857,519**	**20.9%**
Barren-Sage Bluff	445	336	0.0%			0.0%		781	0.0%
Barren-Wet	80,180	57,488	0.7%	41,476	5,195	0.3%		184,339	1.0%
Snow/Glacier	14,946	15,019	0.2%	4,757,594	358,614	27.7%		**5,146,172**	**27.8%**
Total Barren	**1,604,323**	**1,063,816**	**14.4%**	**6,025,217**	**495,455**	**35.2%**		**9,188,811**	**49.7%**
Water	77,000	45,534	0.7%	68,869	593,837	3.6%		785,240	4.2%
Total Water	**77,000**	**45,534**	**0.7%**	**68,869**	**593,837**	**3.6%**		**785,240**	**4.2%**
Unknown ClSh			0.0%			0.0%	528	528	0.0%
Unknown TSb			0.0%			0.0%	18,972	18,972	0.1%
Unknown TSs			0.0%			0.0%	708	708	0.0%
Unknown TSu			0.0%			0.0%	2,162	2,162	0.0%
Unknown TSv			0.0%			0.0%	48,768	48,768	0.3%
Unknown			0.0%	658	324	0.0%	4,696	5,678	0.0%
Total Unknown	**0**	**0**	**0.0%**	**658**	**324**	**0.0%**	**75,834**	**76,816**	**0.4%**
Grand Total	**7,119,178**	**3,575,183**	**57.8%**	**6,534,440**	**1,194,496**	**41.8%**	**75,834**	**18,499,131**	**100.0%**

Tables 23 and 24 represent the "calculated" land cover type (*calc_class*) by their source, in terms of the classification method and threshold. The four sources represent the two thresholds (90% and 99%) of supervised and unsupervised classifications. These values indicate the source of the different land cover type data, which can be interpreted to indicate different levels of confidence in the pixel data. For instance, pixels derived from the 90% threshold classification efforts were classified with tighter statistics than pixels derived from the 99% threshold classification efforts and would be expected to be a more accurate or reliable assignment of pixel classes than those pixels derived from classification efforts with looser statistics. This holds true for both the supervised and unsupervised classifications.

These tables indicate that approximately two-thirds (13,653,613 acres) of the project area was mapped at the lower statistical threshold of 90% while the remaining area (4,769,679 acres) was mapped at the higher threshold of 99%. The lower threshold indicates higher classification reliability as these are pixels that were classified using a tighter statistical threshold. The 99% threshold represents less stringent statistical limits and allows more pixels (area) to be mapped. A total of 5,678 acres (0.03%) of the project area were unclassified and were not mapped during classification efforts, while 70,615 acres (0.38%) were modeled to one of the Terrain Shadow classes during post-classification modeling efforts.

Land Cover Type Area Distribution and Source

Table 25 represents the distribution of pixels and area by the **123** “calculated” land cover classes (*calc_class*) used during this mapping project. These are the classes that were assigned when the land cover distributions were processed using the various land cover component thresholds and rules that comprised the vegetation classification system.

Table 25: Area by Land Cover

calc_class	Pixel Frequency	Acreage	Percent of Total	Type Total Percent
Sitka Spruce:Closed	55,551	11,150	0.1%	
Sitka Spruce:Open	144,355	28,974	0.2%	
Sitka Spruce:Wdlnd	54,439	10,927	0.1%	
Black Spruce Cmplx:Open	3,461	695	0.0%	
Black Spruce Cmplx:Wdlnd-Lichen	4,883	980	0.0%	
Black Spruce Stunted:Wdlnd	40,749	8,179	0.0%	
Black Spruce:Closed	157,053	31,522	0.2%	
Black Spruce:Open	1,357,859	272,537	1.5%	
Black Spruce:Open-Lichen	210,673	42,284	0.2%	
Black Spruce:Open-Tussock	58,835	11,809	0.1%	
Black Spruce:Wdlnd	1,159,975	232,820	1.3%	
Black Spruce:Wdlnd-Tussock	205,630	41,272	0.2%	
Spruce Mix Cmplx:Wdlnd	18,378	3,689	0.0%	
Spruce Mix:Open	735,808	147,685	0.8%	
Spruce Mix:Open-Tussock	81,536	16,365	0.1%	
Spruce Mix:Wdlnd	365,115	73,283	0.4%	
Spruce Mix:Wdlnd-Tussock	94	19	0.0%	
White Spruce Cmplx:Closed	28,977	5,816	0.0%	
White Spruce Cmplx:Open	579,404	116,293	0.6%	
White Spruce Cmplx:Wdlnd	327,778	65,789	0.4%	
White Spruce Cmplx:Wdlnd-Lichen	2,443	490	0.0%	
White Spruce Dead:Open	7,226	1,450	0.0%	
White Spruce Dead:Wdlnd	116,210	23,325	0.1%	
White Spruce Dead:Wdlnd-Lichen	17,837	3,580	0.0%	
White Spruce Stunted:Wdlnd	1,980	397	0.0%	
White Spruce:Closed	346,905	69,628	0.4%	
White Spruce:Open	4,024,991	807,860	4.4%	
White Spruce:Open-Lichen	29,849	5,991	0.0%	
White Spruce:Open-Tussock	21,958	4,407	0.0%	
White Spruce:Wdlnd	2,607,011	523,256	2.8%	
White Spruce:Wdlnd-Lichen	343,306	68,905	0.4%	
White Spruce:Wdlnd-Tussock	67,947	13,638	0.1%	
Total Conifer	**13,178,216**	**2,645,013**		**14.3%**

Table 25: Area by Land Cover (continued)

calc_class	Pixel Frequency	Acreage	Percent of Total	Type Total Percent
Mixed deciduous-conifer:Closed	419,394	84,177	0.5%	
Mixed deciduous-conifer:Open	2,019,465	405,329	2.2%	
Mixed deciduous-conifer:Open-Lichen	9,270	1,861	0.0%	
Mixed deciduous-conifer:Wdlnd	184,989	37,129	0.2%	
Total deciduous-conifer	**2,633,118**	**528,496**		**2.9%**
Aspen:Closed	246,504	49,476	0.3%	
Aspen:Open	160,086	32,131	0.2%	
Balsam Poplar:Closed	154,076	30,925	0.2%	
Balsam Poplar:Open	531,909	106,760	0.6%	
Cottonwood:Closed	36,375	7,301	0.0%	
Cottonwood:Open	114,397	22,961	0.1%	
Paper Birch:Closed	268,813	53,954	0.3%	
Paper Birch:Open	12,147	2,438	0.0%	
Mixed deciduous:Closed	98,236	19,717	0.1%	
Mixed deciduous:Open	49,350	9,905	0.1%	
Total deciduous	**1,671,893**	**335,567**		**1.8%**
Tree shrub:Closed:Alder	40,729	8,175	0.0%	
Tree shrub:Closed:Willow	227,317	45,625	0.2%	
Tree shrub:Open:Alder	863	173	0.0%	
Tree shrub:Open:Willow	46,740	9,381	0.1%	
Tall shrub:Closed:Alder	1,849,737	371,263	2.0%	
Tall shrub:Closed:Mix	511,184	102,600	0.6%	
Tall shrub:Closed:Willow	518,720	104,113	0.6%	
Tall shrub:Open:Alder	867,799	174,177	0.9%	
Tall shrub:Open:Mix	533,992	107,178	0.6%	
Tall shrub:Open:Willow	384,208	77,115	0.4%	
Total Tall/Tree Shrub	**4,981,289**	**999,799**		**5.4%**
Mixed shrub:Open:Alder	83,270	16,713	0.1%	
Mixed shrub:Open:Mix	176,587	35,443	0.2%	
Mixed shrub:Open:Mix-Lichen	55,567	11,153	0.1%	
Mixed shrub:Open:Mix-Tussock	32,434	6,510	0.0%	
Mixed shrub:Open:Willow	74,228	14,898	0.1%	
Mixed shrub:Open:Willow-Lichen	65	13	0.0%	
Mixed shrub:Sparse:Alder	2,701	542	0.0%	
Mixed shrub:Sparse:Mix	45,416	9,115	0.0%	
Mixed shrub:Sparse:Mix-Lichen	9,535	1,914	0.0%	
Low shrub:Closed:Alder	5,801	1,164	0.0%	
Low shrub:Closed:Birch	490,915	98,532	0.5%	
Low shrub:Closed:Ericaceous	7,022	1,409	0.0%	
Low shrub:Closed:Mix	300,656	60,345	0.3%	
Low shrub:Closed:Willow	32,370	6,497	0.0%	
Low shrub:Closed:Willow-Birch Mix	158,501	31,813	0.2%	
Low shrub:Open:Alder	55,264	11,092	0.1%	
Low shrub:Open:Birch	985,325	197,766	1.1%	
Low shrub:Open:Birch-Lichen	37,483	7,523	0.0%	
Low shrub:Open:Birch-Tussock	36,385	7,303	0.0%	
Low shrub:Open:Ericaceous	84,273	16,915	0.1%	
Low shrub:Open:Ericaceous-Tussock	87,891	17,641	0.1%	
Low shrub:Open:Mix	1,230,140	246,903	1.3%	
Low shrub:Open:Mix-Tussock	517,101	103,788	0.6%	
Low shrub:Open:Silverberry	10,547	2,117	0.0%	
Low shrub:Open:Willow	902,936	181,229	1.0%	
Low shrub:Open:Willow-Birch Mix	2,066,791	414,828	2.2%	
Low shrub:Open:Willow-Birch Mix-Licher	38,608	7,749	0.0%	
Low shrub:Open:Willow-Birch Mix-Tusso	65,878	13,222	0.1%	
Low shrub:Open:Willow-Lichen	42,124	8,455	0.0%	
Low shrub:Open:Willow-Tussock	30,027	6,027	0.0%	
Total Low/Mixed Shrub	**7,665,841**	**7,665,841**		**8.3%**

Table 25: Area by Land Cover (continued)

calc_class	Pixel Frequency	Acreage	Percent of Total	Type Total Percent
Dwarf Shrub	1,944,795	390,342	2.1%	
Dwarf Shrub:Cassiope	274,932	55,182	0.3%	
Dwarf Shrub:Cassiope-Lichen	52,539	10,545	0.1%	
Dwarf Shrub:Dryas	533,691	107,118	0.6%	
Dwarf Shrub:Dryas-Lichen	79,093	15,875	0.1%	
Dwarf Shrub:Ericaceous	1,300	261	0.0%	
Dwarf Shrub-Lichen	949,796	190,635	1.0%	
Dwarf Shrub-Sage Bluff	20,937	4,202	0.0%	
Dwarf Shrub-Tussock	85,012	17,063	0.1%	
Total Dwarf Shrub	**3,942,095**	**791,222**		**4.3%**
Herbaceous	557,756	111,948	0.6%	
Elymus	3,298	662	0.0%	
EriVag-Tussock	62,386	12,522	0.1%	
Graminoid	907,834	182,212	1.0%	
Graminoid-Lichen	38,494	7,726	0.0%	
Graminoid-Tussock	24,041	4,825	0.0%	
Moist Sedge-Shrub Meadow	835,233	167,640	0.9%	
Moist Sedge-Shrub Meadow-Lichen	110,525	22,184	0.1%	
Moist Sedge-Shrub Meadow-Tussock	39,811	7,991	0.0%	
Aquatic Forb	6,472	1,299	0.0%	
Water-Aquatic Forb	15,695	3,150	0.0%	
Lichen	297,485	59,709	0.3%	
Moss	171,995	34,521	0.2%	
Total Herbaceous	**3,071,025**	**616,388**		**3.3%**
Sparse Vegetation	4,892,174	981,913	5.3%	
Sparse Vegetation-Lichen	11,952	2,399	0.0%	
Sparse Vegetation-Sage Bluff	14,786	2,968	0.0%	
Water-Sparse Vegetation	29,283	5,877	0.0%	
Total Sparse Vegetation	**4,948,195**	**993,157**		**5.4%**
Barren/NonVeg	19,219,269	3,857,519	20.9%	
Barren-Sage Bluff	3,893	781	0.0%	
Barren-Wet	918,428	184,339	1.0%	
Snow/Glacier	25,639,711	5,146,172	27.8%	
Total Barren	**45,781,301**	**9,188,811**		**49.7%**
Water	3,912,291	785,240	4.2%	
Total Water	**3,912,291**	**785,240**		**4.2%**
Unknown ClSh	2,629	528	0.0%	
Unknown TSb	94,525	18,972	0.1%	
Unknown TSs	3,526	708	0.0%	
Unknown TSu	10,772	2,162	0.0%	
Unknown TSv	242,977	48,768	0.3%	
Unknown	28,289	5,678	0.0%	
Total Unknown	**382,718**	**76,816**		**0.4%**
Grand Total	**92,167,997**	**18,499,131**		**100.0%**

Table 26 represents the distribution of pixels and area by the major land cover classes that were derived by collapsing the 123 “calculated” land cover classes in Table 25 into twenty-five (25) land cover classes that tend to reflect more generalized classes of lifeform and density.

Table 26: Area and Frequency by Lifeform and Density

Generalized Lifeform:Density	Pixel Frequency	Acreage	Percent of Total
Spruce:Woodland	5,333,775	1,070,547	5.8%
Spruce:Open	7,255,955	1,456,350	7.9%
Spruce:Closed	588,486	118,116	0.6%
Deciduous-conifer:Woodland	184,989	37,129	0.2%
Deciduous-conifer:Open	2,028,735	407,189	2.2%
Deciduous-conifer:Closed	419,394	84,177	0.5%
Deciduous:Woodland	-	-	0.0%
Deciduous:Open	867,892	174,195	0.9%
Deciduous:Closed	804,016	161,375	0.9%
Tall Shrub:Open	1,833,602	368,024	2.0%
Tall Shrub:Closed	3,147,687	631,775	3.4%
Mixed Shrub:Sparse	57,652	11,571	0.1%
Mixed Shrub:Open	422,151	84,730	0.5%
Low Shrub:Open	6,190,773	1,242,556	6.7%
Low Shrub:Closed	995,265	199,761	1.1%
Dwarf Shrub	3,942,095	791,222	4.3%
Herbaceous - Forb	2,579,378	517,710	2.8%
Moss	171,995	34,521	0.2%
Lichen	297,485	59,709	0.3%
Aquatic Forb	22,167	4,449	0.0%
Sparse Vegetation	4,948,195	993,157	5.4%
Barren	20,141,590	4,042,639	21.9%
Snow/Ice	25,639,711	5,146,172	27.8%
Water	3,912,291	785,240	4.2%
Unknown	382,718	76,816	0.4%
Totals	**92,167,997**	**18,499,131**	**100.0%**

Tables 25 and 26 show that a little more than one quarter (27.8%) of the project area was mapped as Snow/glacier and another one-fifth (21.9%) was mapped as Barren. Forest types comprised 19% of the project area with coniferous forest accounting for 14.3% of the project area. Low, Mixed, and Tall Shrub types accounted for 8.3%, 0.6%, and 5.4%, while Dwarf Shrub types comprised 4.3% of the land cover map. Herbaceous and Sparse Vegetation accounted for only 3.3% and 5.4% of the project area, while Water types comprised 4.2% of the area. Only 0.4% of the area was mapped as unknown with nearly all of that area being pixels modeled to one of the Terrain Shadow classes.

Table 27 identifies the classification source of pixels for each of the 123 land cover classes. The primary pixel source for each land cover type, in terms of the percentage of that type, is indicated in **boldface** type. In most cases, the supervised classifications were the source of the vegetated types, whereas the unsupervised classifications were often the source of the unvegetated types.

Table 27: Land Cover Type Pixel Frequency and Percent by Source

Calc_class	Pixels SUP90	Pixels SUP99	Pixels ISO90	Pixels ISO99	Grand Total	Pct SUP90	Pct SUP99	Pct ISO90	Pct ISO99
Sitka Spruce:Closed	40,444	14,011	794	302	55,551	**72.8%**	25.2%	1.4%	0.5%
Sitka Spruce:Open	71,940	36,028	14,948	21,439	144,355	**49.8%**	25.0%	10.4%	14.9%
Sitka Spruce:Wdlnd	40,612	13,827	0	0	54,439	**74.6%**	25.4%	0.0%	0.0%
Black Spruce Cmplx:Open	2,461	1,000	0	0	3,461	**71.1%**	28.9%	0.0%	0.0%
Black Spruce Cmplx:Wdlnd-Lichen	3,493	1,390	0	0	4,883	**71.5%**	28.5%	0.0%	0.0%
Black Spruce Stunted:Wdlnd	23,496	17,253	0	0	40,749	**57.7%**	42.3%	0.0%	0.0%
Black Spruce:Closed	106,539	50,514	0	0	157,053	**67.8%**	32.2%	0.0%	0.0%
Black Spruce:Open	952,660	368,870	29,253	7,076	1,357,859	**70.2%**	27.2%	2.2%	0.5%
Black Spruce:Open-Lichen	159,467	51,206	0	0	210,673	**75.7%**	24.3%	0.0%	0.0%
Black Spruce:Open-Tussock	38,824	20,011	0	0	58,835	**66.0%**	34.0%	0.0%	0.0%
Black Spruce:Wdlnd	820,631	274,464	54,777	10,103	1,159,975	**70.7%**	23.7%	4.7%	0.9%
Black Spruce:Wdlnd-Tussock	144,753	57,637	2,642	598	205,630	**70.4%**	28.0%	1.3%	0.3%
Spruce Mix Cmplx:Wdlnd	10,490	7,629	180	79	18,378	**57.1%**	41.5%	1.0%	0.4%
Spruce Mix:Open	433,161	204,635	83,265	14,747	735,808	**58.9%**	27.8%	11.3%	2.0%
Spruce Mix:Open-Tussock	50,756	30,780	0	0	81,536	**62.2%**	37.8%	0.0%	0.0%
Spruce Mix:Wdlnd	184,043	68,248	98,773	14,051	365,115	**50.4%**	18.7%	27.1%	3.8%
Spruce Mix:Wdlnd-Tussock	0	0	55	39	94	0.0%	0.0%	**58.5%**	41.5%
White Spruce Cmplx:Closed	20,665	8,312	0	0	28,977	**71.3%**	28.7%	0.0%	0.0%
White Spruce Cmplx:Open	475,238	104,111	22	33	579,404	**82.0%**	18.0%	0.0%	0.0%
White Spruce Cmplx:Wdlnd	254,874	71,052	1,327	525	327,778	**77.8%**	21.7%	0.4%	0.2%
White Spruce Cmplx:Wdlnd-Lichen	1,857	586	0	0	2,443	**76.0%**	24.0%	0.0%	0.0%
White Spruce Dead:Open	6,312	914	0	0	7,226	**87.4%**	12.6%	0.0%	0.0%
White Spruce Dead:Wdlnd	76,069	40,141	0	0	116,210	**65.5%**	34.5%	0.0%	0.0%
White Spruce Dead:Wdlnd-Lichen	13,629	4,208	0	0	17,837	**76.4%**	23.6%	0.0%	0.0%
White Spruce Stunted:Wdlnd	899	1,081	0	0	1,980	**45.4%**	54.6%	0.0%	0.0%
White Spruce:Closed	262,723	84,138	26	18	346,905	**75.7%**	24.3%	0.0%	0.0%
White Spruce:Open	2,797,403	1,056,406	139,382	31,800	4,024,991	**69.5%**	26.2%	3.5%	0.8%
White Spruce:Open-Lichen	18,692	11,157	0	0	29,849	**62.6%**	37.4%	0.0%	0.0%
White Spruce:Open-Tussock	14,396	7,562	0	0	21,958	**65.6%**	34.4%	0.0%	0.0%
White Spruce:Wdlnd	1,677,186	754,520	148,429	26,876	2,607,011	**64.3%**	28.9%	5.7%	1.0%
White Spruce:Wdlnd-Lichen	252,048	91,258	0	0	343,306	**73.4%**	26.6%	0.0%	0.0%
White Spruce:Wdlnd-Tussock	41,811	26,136	0	0	67,947	**61.5%**	38.5%	0.0%	0.0%

Table 27: Land Cover Type Pixel Frequency and Percent by Source (continued)

Calc_class	Pixels SUP90	Pixels SUP99	Pixels ISO90	Pixels ISO99	Grand Total	Pct SUP90	Pct SUP99	Pct ISO90	Pct ISO99
Mixed deciduous-conifer:Closed	283,008	132,851	2,766	769	419,394	**67.5%**	31.7%	0.7%	0.2%
Mixed deciduous-conifer:Open	1,392,987	495,349	99,904	31,225	2,019,465	**69.0%**	24.5%	4.9%	1.5%
Mixed deciduous-conifer:Open-Lichen	6,312	2,958	0	0	9,270	**68.1%**	31.9%	0.0%	0.0%
Mixed deciduous-conifer:Wdlnd	111,488	44,704	21,851	6,946	184,989	**60.3%**	24.2%	11.8%	3.8%
Aspen:Closed	170,025	75,771	497	211	246,504	**69.0%**	30.7%	0.2%	0.1%
Aspen:Open	113,011	40,637	4,155	2,283	160,086	**70.6%**	25.4%	2.6%	1.4%
Balsam Poplar:Closed	92,044	58,379	3,066	587	154,076	**59.7%**	37.9%	2.0%	0.4%
Balsam Poplar:Open	372,644	157,216	1,244	805	531,909	**70.1%**	29.6%	0.2%	0.2%
Cottonwood:Closed	31,496	4,879	0	0	36,375	**86.6%**	13.4%	0.0%	0.0%
Cottonwood:Open	81,604	18,442	10,842	3,509	114,397	**71.3%**	16.1%	9.5%	3.1%
Paper Birch:Closed	188,444	78,465	1,436	468	268,813	**70.1%**	29.2%	0.5%	0.2%
Paper Birch:Open	7,894	2,998	901	354	12,147	**65.0%**	24.7%	7.4%	2.9%
Mixed deciduous:Closed	58,850	32,105	5,538	1,743	98,236	**59.9%**	32.7%	5.6%	1.8%
Mixed deciduous:Open	30,600	11,371	4,448	2,931	49,350	**62.0%**	23.0%	9.0%	5.9%
Tree shrub:Closed:Alder	29,774	10,955	0	0	40,729	**73.1%**	26.9%	0.0%	0.0%
Tree shrub:Closed:Willow	174,723	51,631	711	252	227,317	**76.9%**	22.7%	0.3%	0.1%
Tree shrub:Open:Alder	0	0	555	308	863	0.0%	0.0%	**64.3%**	35.7%
Tree shrub:Open:Willow	34,740	11,280	425	295	46,740	**74.3%**	24.1%	0.9%	0.6%
Tall shrub:Closed:Alder	1,364,386	464,701	15,062	5,588	1,849,737	**73.8%**	25.1%	0.8%	0.3%
Tall shrub:Closed:Mix	386,501	121,015	2,832	836	511,184	**75.6%**	23.7%	0.6%	0.2%
Tall shrub:Closed:Willow	387,763	130,957	0	0	518,720	**74.8%**	25.2%	0.0%	0.0%
Tall shrub:Open:Alder	475,553	250,323	101,206	40,717	867,799	**54.8%**	28.8%	11.7%	4.7%
Tall shrub:Open:Mix	334,710	118,889	54,401	25,992	533,992	**62.7%**	22.3%	10.2%	4.9%
Tall shrub:Open:Willow	255,362	116,014	11,077	1,755	384,208	**66.5%**	30.2%	2.9%	0.5%
Mixed shrub:Open:Alder	19,943	28,588	27,077	7,662	83,270	23.9%	**34.3%**	32.5%	9.2%
Mixed shrub:Open:Mix	71,625	56,447	33,404	15,111	176,587	**40.6%**	32.0%	18.9%	8.6%
Mixed shrub:Open:Mix-Lichen	35,885	19,682	0	0	55,567	**64.6%**	35.4%	0.0%	0.0%
Mixed shrub:Open:Mix-Tussock	18,687	13,747	0	0	32,434	**57.6%**	42.4%	0.0%	0.0%
Mixed shrub:Open:Willow	54,183	20,045	0	0	74,228	**73.0%**	27.0%	0.0%	0.0%
Mixed shrub:Open:Willow-Lichen	0	0	31	34	65	0.0%	0.0%	**47.7%**	**52.3%**
Mixed shrub:Sparse:Alder	0	0	2,247	454	2,701	0.0%	0.0%	**83.2%**	16.8%
Mixed shrub:Sparse:Mix	0	0	36,548	8,868	45,416	0.0%	0.0%	**80.5%**	19.5%
Mixed shrub:Sparse:Mix-Lichen	0	0	7,442	2,093	9,535	0.0%	0.0%	**78.0%**	22.0%

Table 27: Land Cover Type Pixel Frequency and Percent by Source (continued)

Calc_class	Pixels SUP90	Pixels SUP99	Pixels ISO90	Pixels ISO99	Grand Total	Pct SUP90	Pct SUP99	Pct ISO90	Pct ISO99
Low shrub:Closed:Alder	0	0	4,855	946	5,801	0.0%	0.0%	**83.7%**	16.3%
Low shrub:Closed:Birch	312,754	178,161	0	0	490,915	**63.7%**	36.3%	0.0%	0.0%
Low shrub:Closed:Ericaceous	5,399	1,623	0	0	7,022	**76.9%**	23.1%	0.0%	0.0%
Low shrub:Closed:Mix	204,871	95,398	300	87	300,656	**68.1%**	31.7%	0.1%	0.0%
Low shrub:Closed:Willow	20,491	11,879	0	0	32,370	**63.3%**	36.7%	0.0%	0.0%
Low shrub:Closed:Willow-Birch Mix	110,193	48,308	0	0	158,501	**69.5%**	30.5%	0.0%	0.0%
Low shrub:Open:Alder	30,698	18,650	4,596	1,320	55,264	**55.5%**	33.7%	8.3%	2.4%
Low shrub:Open:Birch	638,296	319,291	23,266	4,472	985,325	**64.8%**	32.4%	2.4%	0.5%
Low shrub:Open:Birch-Lichen	5,042	32,441	0	0	37,483	13.5%	**86.5%**	0.0%	0.0%
Low shrub:Open:Birch-Tussock	24,413	11,972	0	0	36,385	**67.1%**	32.9%	0.0%	0.0%
Low shrub:Open:Ericaceous	54,859	22,701	4,810	1,903	84,273	**65.1%**	26.9%	5.7%	2.3%
Low shrub:Open:Ericaceous-Tussock	67,028	20,863	0	0	87,891	**76.3%**	23.7%	0.0%	0.0%
Low shrub:Open:Mix	830,212	357,123	32,683	10,122	1,230,140	**67.5%**	29.0%	2.7%	0.8%
Low shrub:Open:Mix-Tussock	343,720	169,539	2,758	1,084	517,101	**66.5%**	32.8%	0.5%	0.2%
Low shrub:Open:Silverberry	6,395	4,152	0	0	10,547	**60.6%**	39.4%	0.0%	0.0%
Low shrub:Open:Willow	615,935	244,303	36,622	6,076	902,936	**68.2%**	27.1%	4.1%	0.7%
Low shrub:Open:Willow-Birch Mix	1,432,302	530,880	82,577	21,032	2,066,791	**69.3%**	25.7%	4.0%	1.0%
Low shrub:Open:Willow-Birch Mix-Lichen	29,342	9,266	0	0	38,608	**76.0%**	24.0%	0.0%	0.0%
Low shrub:Open:Willow-Birch Mix-Tussock	42,871	23,007	0	0	65,878	**65.1%**	34.9%	0.0%	0.0%
Low shrub:Open:Willow-Lichen	17,845	24,279	0	0	42,124	42.4%	**57.6%**	0.0%	0.0%
Low shrub:Open:Willow-Tussock	21,665	8,362	0	0	30,027	**72.2%**	27.8%	0.0%	0.0%
Dwarf Shrub	1,157,433	679,364	87,996	20,002	1,944,795	**59.5%**	34.9%	4.5%	1.0%
Dwarf Shrub:Cassiope	171,167	102,195	1,458	112	274,932	**62.3%**	37.2%	0.5%	0.0%
Dwarf Shrub:Cassiope-Lichen	28,696	23,843	0	0	52,539	**54.6%**	45.4%	0.0%	0.0%
Dwarf Shrub:Dryas	283,353	211,099	34,956	4,283	533,691	**53.1%**	39.6%	6.5%	0.8%
Dwarf Shrub:Dryas-Lichen	37,949	41,144	0	0	79,093	48.0%	**52.0%**	0.0%	0.0%
Dwarf Shrub:Ericaceous	0	0	1,026	274	1,300	0.0%	0.0%	**78.9%**	21.1%
Dwarf Shrub-Lichen	666,415	270,018	10,110	3,253	949,796	**70.2%**	28.4%	1.1%	0.3%
Dwarf Shrub-Sage Bluff	9,835	11,102	0	0	20,937	47.0%	**53.0%**	0.0%	0.0%
Dwarf Shrub-Tussock	58,052	26,960	0	0	85,012	**68.3%**	31.7%	0.0%	0.0%

Table 27: Land Cover Type Pixel Frequency and Percent by Source (continued)

Calc_class	Pixels SUP90	Pixels SUP99	Pixels ISO90	Pixels ISO99	Grand Total	Pct SUP90	Pct SUP99	Pct ISO90	Pct ISO99
Herbaceous	289,064	199,002	42,129	27,561	557,756	**51.8%**	35.7%	7.6%	4.9%
Elymus	1,419	1,623	221	35	3,298	43.0%	**49.2%**	6.7%	1.1%
EriVag-Tussock	43,983	18,403	0	0	62,386	**70.5%**	29.5%	0.0%	0.0%
Graminoid	544,332	339,190	19,017	5,295	907,834	**60.0%**	37.4%	2.1%	0.6%
Graminoid-Lichen	19,747	18,747	0	0	38,494	**51.3%**	48.7%	0.0%	0.0%
Graminoid-Tussock	15,338	8,703	0	0	24,041	**63.8%**	36.2%	0.0%	0.0%
Moist Sedge-Shrub Meadow	463,522	254,634	95,493	21,584	835,233	**55.5%**	30.5%	11.4%	2.6%
Moist Sedge-Shrub Meadow-Lichen	68,483	35,128	5,560	1,354	110,525	**62.0%**	31.8%	5.0%	1.2%
Moist Sedge-Shrub Meadow-Tussock	27,675	12,136	0	0	39,811	**69.5%**	30.5%	0.0%	0.0%
Aquatic Forb	3,251	3,043	0	178	6,472	**50.2%**	47.0%	0.0%	2.8%
Water-Aquatic Forb	8,462	7,233	0	0	15,695	**53.9%**	46.1%	0.0%	0.0%
Lichen	143,286	126,339	24,921	2,939	297,485	**48.2%**	42.5%	8.4%	1.0%
Moss	88,596	70,506	11,324	1,569	171,995	**51.5%**	41.0%	6.6%	0.9%
Sparse Vegetation	2,555,724	1,627,012	616,678	92,760	4,892,174	**52.2%**	33.3%	12.6%	1.9%
Sparse Vegetation-Lichen	0	0	11,153	799	11,952	0.0%	0.0%	**93.3%**	6.7%
Sparse Vegetation-Sage Bluff	8,102	6,684	0	0	14,786	**54.8%**	45.2%	0.0%	0.0%
Water-Sparse Vegetation	2,919	9,696	12,645	4,023	29,283	10.0%	33.1%	**43.2%**	13.7%
Barren/NonVeg	7,517,038	4,937,310	6,109,021	655,900	19,219,269	**39.1%**	25.7%	31.8%	3.4%
Barren-Sage Bluff	2,218	1,675	0	0	3,893	**57.0%**	43.0%	0.0%	0.0%
Barren-Wet	399,478	286,424	206,645	25,881	918,428	**43.5%**	31.2%	22.5%	2.8%
Snow/Glacier	74,463	74,830	23,703,701	1,786,717	25,639,711	0.3%	0.3%	**92.4%**	7.0%
Water	383,637	226,862	343,125	2,958,667	3,912,291	9.8%	5.8%	8.6%	**75.7%**
Unknown ClSh	0	0	0	0	2,629	0.0%	0.0%	0.0%	0.0%
Unknown TSb	0	0	0	0	94,520	0.0%	0.0%	0.0%	0.0%
Unknown TSs	0	0	0	0	3,526	0.0%	0.0%	0.0%	0.0%
Unknown TSu	0	0	0	0	10,772	0.0%	0.0%	0.0%	0.0%
Unknown TSv	0	0	0	0	242,977	0.0%	0.0%	0.0%	0.0%
Unknown	0	0	3,277	1,614	28,289	0.0%	0.0%	11.6%	5.7%
Grand Total	**35,469,777**	**17,812,582**	**32,556,456**	**5,951,330**	**92,167,997**	**38.5%**	**19.3%**	**35.3%**	**6.5%**

Of the 118 types that were developed through classification and not modeling, all but 12 of them were developed through application of the supervised image classification processes. Of the 47 tree types, the supervised classification class maps were the source of all but one type class, which was the Spruce Mix:Woodland-Tussock class. This class was generated completely from unsupervised pixels indicating it is a heterogeneous mixture of other tree type class pixels. Of the shrub types, the supervised classifications were the primary source of 42 of the 49 classes. As with the one tree type class, the seven shrub classes were generated completely from the unsupervised classification data and represented mixed types which did not have a comparable supervised class. Four of these classes were Mixed Shrub:Sparse classes, while one was a Dwarf Shrub:Ericaceous mix. The other two classes were Tall Shrub:Open:Alder and Low Shrub:Closed:Alder; these two classes were also the result of shrub mixtures created during the unsupervised classifications that slightly diluted the typical Tall Shrub:Closed:Alder type to either an Open cover density class or to a Low (not Tall) Shrub type. Of the remaining 17 herbaceous, non-vascular and Sparse Vegetation types all but two were developed primarily from supervised classification maps. These two types were the Sparse Veg-Lichen and the Water-Sparse Veg types. While the Sparse Veg-Lichen type was comprised completely of unsupervised pixel data, the Water-Sparse Veg type was comprised of a 45%/55% mix of supervised and unsupervised pixel data. Surprisingly, the non-veg Barren types were primarily comprised of supervised pixel data, but the Snow/glacier class was overwhelmingly comprised of unsupervised pixel data.

It is apparent that the aforementioned mixed land cover type classes derived from the ISODATA classifications, with the exception of the Snow/glacier type, are an artifact of the classification process. It could be argued these types should be removed from the land cover map, as they were not found on the ground. What must be remembered is that these ISODATA classes were developed to fill holes in the supervised classification which was used to map known types visited and sampled on the ground. These holes likely represent the fringe of the known types, and while no areas of these derived land cover types were found or sampled, they may in fact exist as an aggregation or complex of pixels that are found in mixtures or associations of pixels as opposed to pure types. It is for the user of the map to decide whether or not these types should remain in the map or be merged into a known type of the most similar nature.

Data Display and Representation

The resulting WRST Land Cover Map data set represents the 10,062 pixel classes used in the classification of the spectral data. These data (*gridval*s) alone are not of much use, as they simply represent a unique value from 1001 to 62,999 that has been associated with a training site. However, when these *gridval*s are joined to the land cover information data associated with each training site, the resulting database includes many different types of information. These different types of information range from major land cover types to percent composition of individual specie groups, such as alder and willow. All of these different data may be used to develop any number of different maps based on the detailed information present in this data base, as well as ancillary data (spatially co-registered) that may enhance modeling efforts. Figure 18 demonstrates this capability, as it represents the field calculated types (*calc_class*) in an area dominated by tree and shrub types in the upper left portion of the figure, but also shows in the other portions of the figure separate maps of the tree, shrub, and herbaceous cover density for the same area. While the herbaceous cover (or any other cover component) is not a part of the land cover type (*calc_class*) in this particular figure, each cover component may be mapped separately based on site-specific database attributes. Most of the different land cover attributes listed in Table 17 may be represented in many different maps, thereby resulting in many maps of the WRST Project Area, rather than just one land cover type map. Similarly, these same attributes can be used to model the land cover data set and enhance or modify the land cover classification map and develop other maps representing related information, such as wildlife habitat suitability, major plant lifeform, or fire fuel classes.

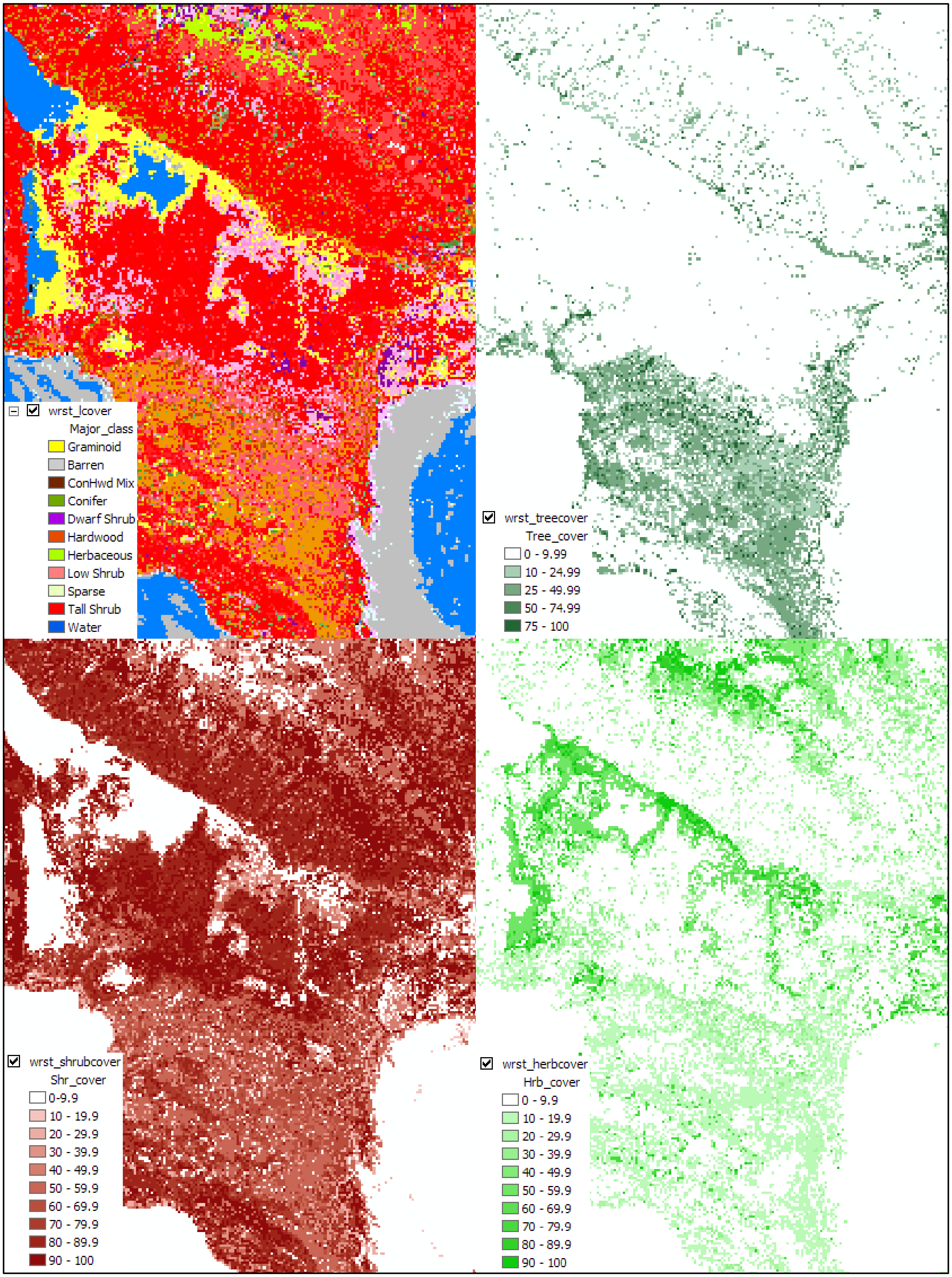

Figure 18: Land Cover Type Map and Associated Tree, Shrub, and Herbaceous Cover Component Maps

Data Source

The source of the information contained in the WRST Land Cover Map can be important in understanding the information and any questions or issues that may arise while using these data. There are two types of source information provided for the pixel data in the WRST Land Cover Map. The first type concerns the source of the *gridval* with respect to the classification process. This source information includes the image/subset area name, the classifier, the threshold, and the model(s) used (if one was used) to generate the specific *gridval*. All of this information is contained in the wrst_lcsource coverage and is contained in the attributes of the *wrst_lcsource.vat* table.

Figure 19 shows an area that represents the image/subset source and the classifier/threshold values for the same area. The lighter bluish swaths through the darker purple areas in the image source map represent the contrails that were present in image 6567 being filled in with pixel data from image 65678s. The unclassified purplish areas in the classification/threshold align quite well with the unvegetated barren areas at high elevation and in the river channel. This type of *gridval* information may be helpful in understanding potential differences in the reliability of the mapped land cover types. Pixels derived from supervised classifications are likely more accurate that those derived from unsupervised efforts, and pixels derived from the 90% thresholding are more reliable than those mapped at the higher threshold of 99%. Pixels that are the result of modeling may be suspect relative to unmodeled pixels, as these have been changed from their original mapped values based on post processing applications.

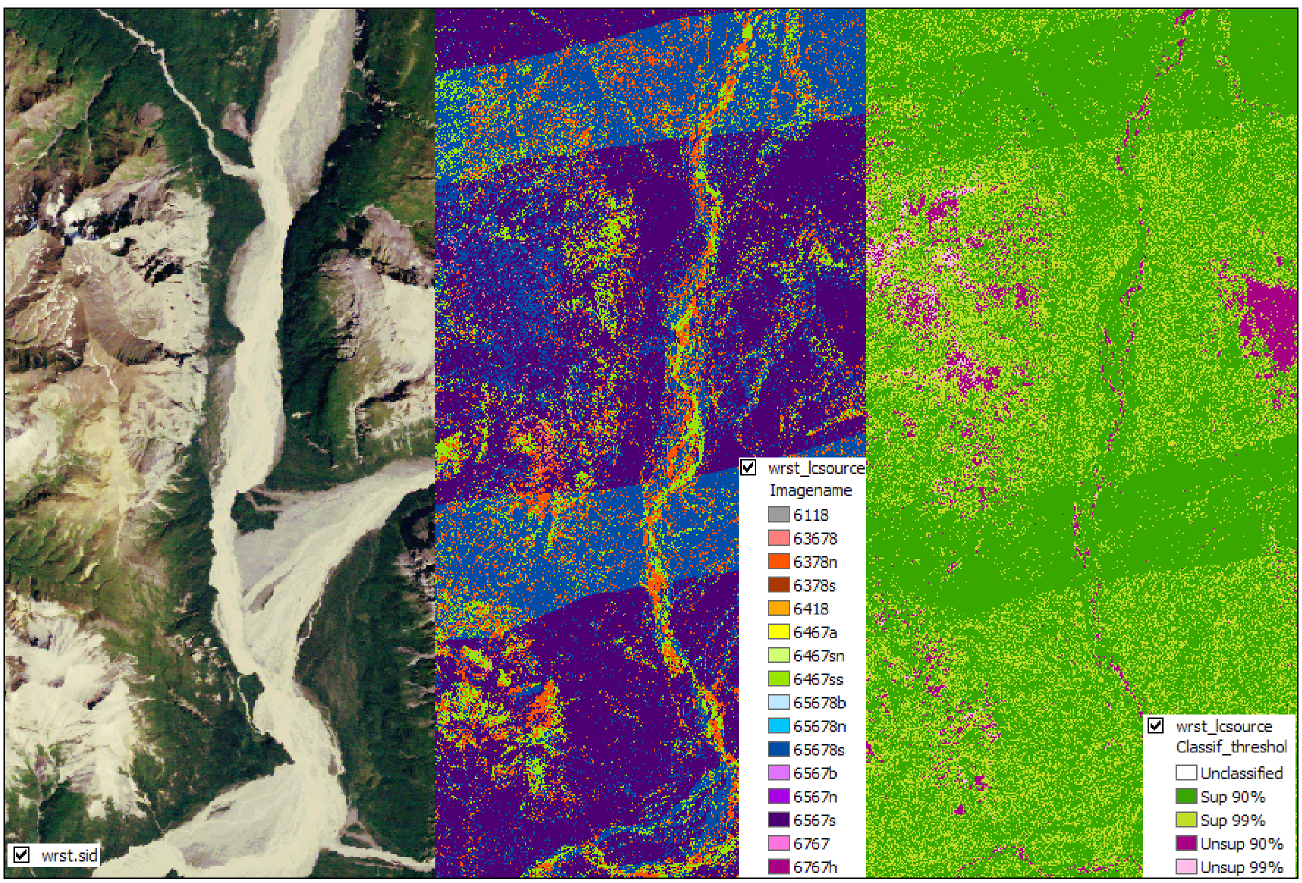

Figure 19: Land Cover Type Map Source (wrst_lcsource) Imagename and Classifier/Threshold Maps

The classifier/threshold information is available in the wrst_lcsource grid data set, but it may also be accessed in the WRST Land Cover Map (wrst_lcover data set) under the *source_gridval* attribute. This attribute contains information similar to that contained in the *wrst_lcsource.vat* table, but the classifier, threshold, and model types are all concatenated into the values of this one attribute. The right hand portion of Figure 20 shows the classification/threshold data as represented in the *source_gridval* attribute of the wrst_lcover data set. This portion of Figure 20 differs slightly from the comparable map in Figure 19 where the pixels in the Land Cover Map that were modeled to Terrain Shadow types are colored black in Figure 20.

The second type of source information pertains to the origin of the cover estimates that are mapped in each pixel of the wrst_lcover data set. The different contributors of cover data were GRS, ABR, AKRO (FirePro), and Ducks Unlimited (DU). In addition, classes are identified as ISO_CL if they were derived from the unsupervised ISODATA classifications. The contributor of the cover estimates is contained in the different values of the *source_cover* attribute of the wrst_lcover data set. The middle hand portion of Figure 20 shows a map of the *source_cover* attributes. In this case, the source of cover estimates is mostly the GRS aerial survey sites (GRSAIR), followed by the GRS supplemental sites, and the AKRO FirePro sites.

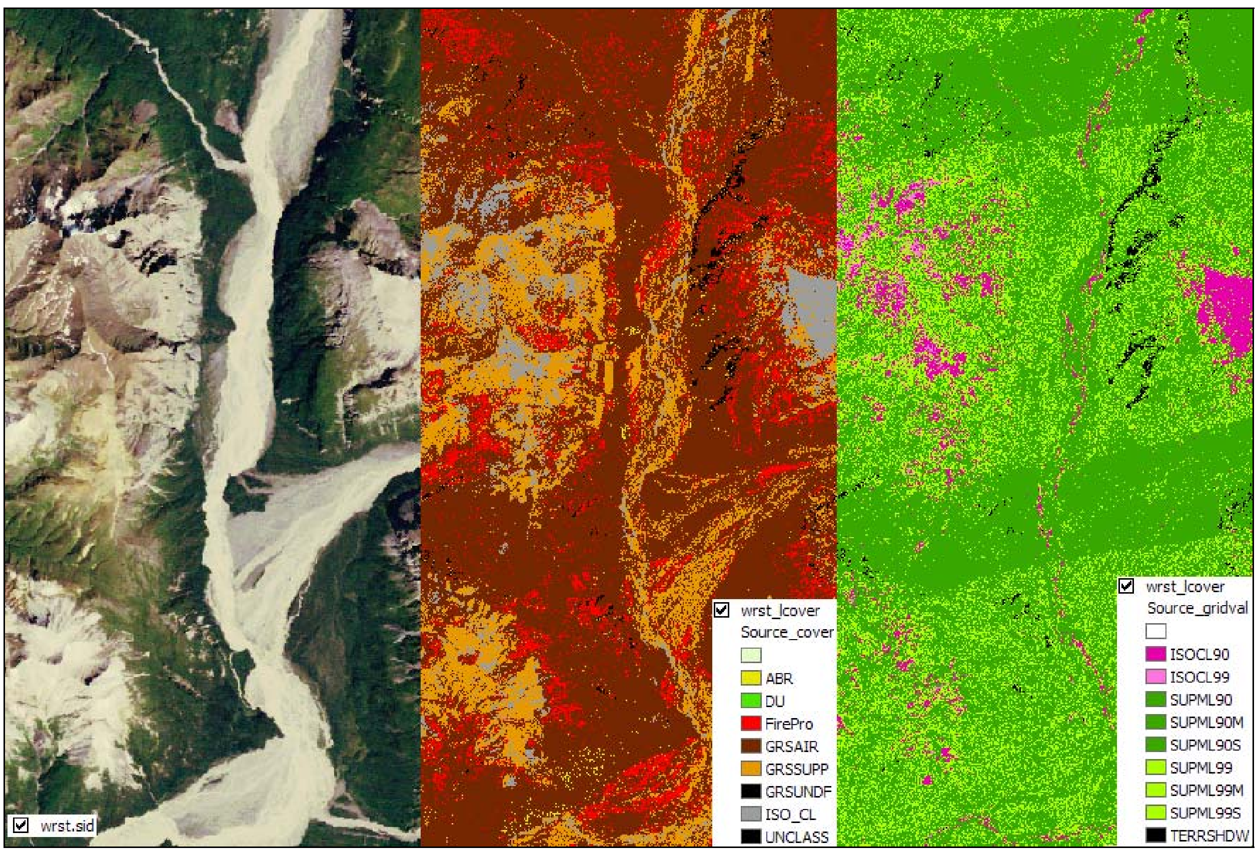

Figure 20: Land Cover Type Map (wrst_lccover) source_cover and source_gridval Maps

Reliability may also be inferred from this information. The pixels which are all associated with the supervised classification efforts and are indicated as being derived from cover specific data sources are likely more reliable than the unsupervised pixels that are identified by the ISO_CL value. Cover data from the GRSAIR sites are likely more reliable than the FirePro sites, as they were developed specifically based on the mapping methodology of this project while the FirePro site cover data were developed for another inventory project as long as twenty-five years ago.

The DU cover data estimates might be nearly comparable to the GRSAIR estimates, but they were collected in 2005 during a totally separate mapping project by a completely different field crew. In addition, many of these sites were outside of the WRST Project Area, whereas all the other cover data sources were from within the project area. The ABR cover estimates were from ground sites for which cover by species was estimated without respect to the “bird’s-eye view” concept. These cover estimates were later adjusted to conform to a “bird’s-eye view” approach of 100% total cover, and as a result should be viewed differently from the other cover data sources, if questions about these pixel cover estimates arise. The GRSSUPP site cover estimates are supplemental in nature and determined mostly from photo-interpreted estimates or nearby similar sample data. In all probability, these pixels’ land cover estimates are quite likely less reliable than the GRSAIR, DU, ABR, and FirePro cover estimates.

Deliverables

Deliverables for this mapping project included the following data themes and tables:

1. **wrst_lcover** – an ArcInfo grid coverage and associated attribute data that represents the final composite pixel map of unique *gridval*s representing the results of the supervised and unsupervised classification efforts implemented during this project.

2. **gridval_cover.dat** – an ArcInfo table that contains the species-specific cover descriptions for each supervised training site associated with a pixel class in the wrst_lcover grid.

3. **wrst_lcsource** – an ArcInfo grid coverage that corresponds to the wrst_lcover grid and represents the source, in terms of the scene and classification, of each pixel's classification information.

4. **wrst_lc_raw** – an ArcInfo grid coverage that corresponds to the wrst_lcover grid and represents the raw land cover type classification prior to any modeling of each pixel's classification information.

5. **wrst_lcoverC** – an ArcInfo grid coverage and associated attribute data that is the same information as **wrst_lcover**, except that data records have been compressed so that cover data are uniquely represented for individual training sites and ISODATA classes in 5,251 records.

6. **wrst_imageFootprints** - an ArcInfo coverage that represents the boundaries of the Landsat images used to develop the land cover map. Image names are truncated to represent the same names as used in this report.

7. **wrst_dem** - an ArcInfo grid coverage that corresponds to the wrst_lcover grid and represents the elevation, in terms of feet, as developed from the USGS DEMs.

8. **wrst_slope** - an ArcInfo grid coverage that corresponds to the wrst_lcover grid and represents the slope, in terms of degrees, as developed from the USGS DEMs.

9. **wrst_aspect** - an ArcInfo grid coverage that corresponds to the wrst_lcover grid and represents the aspect, in terms of degrees counter clockwise from North, as developed from the DEMs.

10. **wrst_boundaries** - an ArcGIS shapefile that represents the WRST Park and Preserve boundaries and the 10-mile buffer boundary.

11. **trsites** – an ArcInfo point coverage that represents the location and associated information describing each supervised training site used or considered during the supervised classification efforts.

12. **GRSgpstracks** – an ArcGIS shapefile that represents the gps tracks collected using the Garmin 76S during **GRS**'s aerial data sampling efforts.

13. **trareasxxxx** – a set of ArcInfo coverages that represents the spectral training site boundaries used to build the supervised training sets. There is a coverage specific to each individual image as represented by the value of xxxx.

14. **ecotypes** – an ArcInfo area coverage provided by AKRO that represents the original set of ecoregions used during the initial candidate site selection processing. Stratification was based on the value in the *ecotype* column of the ecotypes.pat table, which is a numerically coded unique value for the ecotypes *sect* (section) column.

15. **wrst_confusion.rpt** – a text file that contains the confusion data summary for the supervised classification training data sets. It was generated before the training sets were split into subsets for application with the winter masks so it does not represent any refinement due to use of the winter masks.

16. **wrst_fidelity_review.xls** – an Excel spreadsheet that contains the fidelity data summary by site, as well as calculated summaries and field calls by site. It was generated before the training sets were split into subsets for application with the winter masks so it does not represent any refinement due to use of the winter masks.

17. Sample ArcGIS layer files (*.lyr) to assist in viewing these data.

18. Original Landsat Imagery in a tif format.

19. Illumination corrected Landsat Imagery in a tif format.

20. Winter Landsat Imagery in a tif format.

21. Images (jpg format) from the **GRS** Aerial Survey sites.

22. Scanned images (pdf format) of field data sheets completed at the **GRS** Aerial Survey sites.

All of these deliverables were referenced to the WRST Project Alber's coordinate system, as defined in Table 2. All data were delivered on DVD in both an ArcInfo grid/cover/shapefile format. All deliverables are located under the 'WRST_Mapping_2007' directory on the DVD. Coverages are delivered under the 'WRST_Maps' directory, satellite images are delivered in zip files under the 'Imagery' directory, aerial survey site data are delivered under the GRSAIR directory, and reports and documentation were delivered under the 'reports' directory. This information is contained in a readme.txt file found under the main WRST_Mapping_2007 directory.

Conclusions and Discussion

Training Data Collection Efforts

Land Cover Data Estimates

The estimation of land cover components formed the basis of the Land Cover Type Classification used during this project. The approach that was applied was that species specific (if possible) cover components would be estimated by a botanist separately on the field data collection forms and the Land Cover Type class (*calc_class*) would be assigned on the basis of the cover components that had been estimated. The land cover estimates were recorded on the aerial field survey sheets from a helicopter, as it slowly circled the area of interest. Two issues arose with this method of data collection. The first issue concerns verification of the cover estimates. Only one aerial survey site (71859) was field verified on the ground (71207) to determine the accuracy of the cover estimates (10% difference in tree cover, but found a nearly 50/50 mix of White Spruce/Black Spruce on the ground that was all called White Spruce from the air). Another field data site was sampled by both **GRS** (71261) and Ducks Unlimited (15179) and had a 5% difference in Alder (80% versus 75% cover). Lastly, one site was revisited from the air to confirm the type of spruce (White or Black) that was called on the site, confirming the lack of Black Spruce at the site (70957 and 70710) and estimating the tree cover at 10 and 12% respectively.

While it is entirely possible to develop accurate estimates with little or no field verification, the assumption is that the aerial estimates, as collected, are accurate enough for the purposes of this project. In reality, these estimates should be verified in some way to determine that they are accurate. It is doubtful that estimates of this nature can be much more accurate than ± 10 percent of the true value (on the average), as this is the typical level of error for a ground-based cover survey using 100 point transects. The Confusion Report and Fidelity Report can provide insight into this issue, as they relate the cover estimates on any site to other confused (similar) sites. There were instances where either too much or too little cover may have been estimated for a particular species, possibly resulting in mistyping of the site. An illustrative example of this scenario was training site 70422. The cover components of this site included an estimate of 75% Cottonwood cover, resulting in a type assignment of "Cottonwood:Closed." However, this site was confused with a number of Tall shrub:Closed:Alder (with between 10 and 25% Cottonwood cover) and Cottonwood:Open (between 25 and 60% Cottonwood cover) sites. A review of the photo record for this site indicated that there was very likely much less than the aerially estimated 75% Cottonwood cover. This training site, with a lower estimate of Cottonwood cover would have been typed as a "Cottonwood:Open" type, a type which would have been more consistent with its "confused" types. There are also cases, such as site 70401, where cover estimates span thresholds of very different types (tree type versus a shrub type). In this case the cottonwood cover is estimated at 34% cover. The site is confused with at least six other Tall Shrub:Closed and Open:Alder sites that have between 10 and 15% cottonwood cover. Care must be exercised to accurately estimate the key cover components that determine the type designation of an area as calculated by the project's land cover classification rules.

The second data collection issue involved the estimation of field data without verification of the consistency of the estimates. During the three field data collection seasons four different botanists participated in the GRS aerial survey efforts. The inherent assumption in using multiple botanists is that the data estimates by the different botanists will be of a comparable nature. While they used the same instructions, standards, and procedures we must assume that they were consistent in their application of the project procedures as they viewed the sample areas and developed their cover estimates. Unfortunately, there is no way to test this assumption and the use of different

botanists was based on knowing that if the data from any given training site were bad, that this would show up as an inconsistency in the resulting map products and reports. No such erroneous map results were noted due to the different botanists used in the project. The most troublesome situation that did occur concerned incomplete cover estimates. After all the data were collected in the field in 2004 and 2005, it was determined several weeks later that some of the cover data estimates did not add up to 100% cover, as was the stated procedure. Data from these particular sites were then reviewed by the appropriate botanists with respect to all other field notes and photos and adjusted to estimate the missing cover data. Errors may have been introduced by fixing these anomalies in the office, rather than in the field as the data were collected. Fixing these errors in the office not only introduced the possibility of additional errors, but also took a substantial amount of time as all data were subjected to rigorous checks and editing. No such problems occurred during the 2006 field data season.

This issue of data consistency also concerns the use of data collected during different projects (FirePro vs DU vs GRSAIR) as well as data collected during this project. As before, the inherent assumption in using data from different projects is that the data collection standards and procedures yield estimates of a comparable nature. All data from different projects were reviewed and evaluated to assure that species codes were consistent and cover estimates added to 100 percent. Photos were reviewed and any questionable data/sites were rejected.

Although these issues were identified, their existence indicated that methods used to estimate and record land cover data for each survey site may have allowed data of a lesser accuracy and reliability into the project's database from which subsequent cover data were developed and mapped. Uncertainty regarding cover component data and class calls should be avoided through the incorporation of procedures to verify land cover data estimates on the ground in future projects. Possible solutions could include: ground verification of a certain percentage of aerial survey sites to provide verification of estimates and help the field observers calibrate their "eyes"; hovering as close as possible over the center of each training site, and/or mounting a remote-controlled high-resolution stereo-capable film camera on the aircraft (which would obtain high resolution, stereo pairs for subsequent photo-interpretation to verify observations). In addition, it would be desirable to have field survey personnel trained immediately prior to making the actual training site estimates using paired ground/air plots to recognize differences in cover, species, and size/height. Problems concerning incomplete data records and forms are another matter that could possibly be avoided through the used of hand-held data recorders. Rather than log field estimates on field forms with written notes and numbers the use of data recorders is strongly recommended. These data recorders may be programmed to perform data validity checks to be certain that not only are all the data collected, but that the data are consistent with each other. All instances where the "bird's-eye" cover estimates did not total 100% would be resolved before leaving the site. Inconsistent type calls would be flagged for review and correction in the field. Erroneous data would be avoided eliminating potential data inaccuracies as well as the time required to review and resolve these problems. Some of these problems were not uncovered until they were identified as problems in the fidelity test or confusion reports. Unfortunately, while elimination of erroneous data would save considerable post-processing of the data, it was the consensus of the aerial survey crew members that a hand-held data collector would be difficult if not impossible to use due to the vibrations of the helicopter and limited screen size and forms interfaces used with such instruments. The best way to avoid data recording problems is to identify and discuss these issues and potential problems before field efforts are undertaken and then check the results on a daily basis to verify the validity of the data estimates.

What is most unfortunate is that the cost of the aerial survey efforts is quite expensive. The training costs to fully train field data collection personnel might likely cost as much as the actual data collection efforts. Time and budget limitations necessitate that efforts focus on covering as much ground as possible rather than training different personnel to perform consistently and accurately. Variability in cover estimates by different personnel seems to be a consequence that is thought to be within the variances of the results of a project of this nature, rather than a method that possibly contributes to those variances and inaccuracies and makes them larger. Possible inconsistency of this nature should be avoided if possible. For this reason, only experienced personnel should be used in such a mapping project, and changes in personnel should be limited, if they occur at all.

Aerial Survey Data Collection Efforts

A total of 29 days were dedicated to collecting aerial survey data. During these days a total of 104.3 hours of actual aerial survey flight time were logged, or an average of 3.6 hours/day. Other flight time was spent (lost) due to refueling flights, transportation of ground personnel, and down time due to fuel availability, bad weather, and OAS daily and weekly flight-time limits and regulations. The average number of aerial survey training sites visited per day was 25.5. Of the total of 739 sites surveyed during GRS's aerial survey efforts, 726 (98%) were ultimately used in the supervised classification efforts. On the basis of the project area being 18.5 million acres, each aerial site represented approximately 25,000 acres of the total area, and one day's sampling efforts represented covering over 650,000 acres or more than 1,000 square miles.

Reduced aerial survey time during the 2004 and 2005 field seasons resulted in fewer surveyed areas than were originally anticipated. An additional six-day field season was added during 2006 to supplement and complement prior data collection efforts. Even with this additional time several areas could have been sampled more, if there were more helicopter time available. This limitation was most notable in the southeastern portion of WRST near Icy Bay, which was not sampled at all. Other areas that could be described as potentially undersampled were the northeastern portion of WRST in the White River Vicinity north to the Tetlin National Wildlife Refuge, the area north of the Wrangell Mountains between Glen Allen and Slana, the area between Glen Allen and Chitina, and the area east of May Creek in the Tana and Chitina River drainages.

On the basis of these field data collection efforts and taking into account such factors as weather, safety, and fuel availability, as many as 40 sites could have been visited during a full aerial sampling day (i.e., nearly 75% flight time dedicated to aerial training site surveying instead of 50%). One could conservatively estimate a 50% increase in the total number of aerial survey training areas, if such a schedule could have been followed, but this would require sacrificing other uses of the helicopter. The primary competition for helicopter time involved transportation of field crews to and from the field. Linking the aerial and field data collection efforts together necessitated moving the aerial survey efforts to coincide with field data collection efforts, as aerial sampling has to be initiated from the same base camp as the field data collection efforts. Aerial survey time was in essence the helicopter down time between field data crew transportation flights. On several days aerial survey efforts were actually shut down to preserve overall flight time and stay within OAS daily and 6-day rolling period time requirements. While the number of aerial sites appear adequate for this project, sampling could have been accomplished more effectively had the aerial efforts been separated from the field data collection efforts. Another possible solution would be to have fewer field crews (2 rather than 3) and extend the field season to accommodate sampling the same number of field sites. This would have decreased the daily field crew transportation time requirements and provided more time for aerial sampling. However, either alternative likely would have increased overall project data collection costs, but more aerial data would have been collected without sacrificing field data sites. The levels of productivity experienced during this project should be kept in mind for future projects for which a minimum number of training areas would be necessary and other data sources, such as the FirePro data plots, are not available to supplement aerial data collection efforts.

Image Processing Issues

Some (a small portion) of the 92,167,997 pixels of the WRST Land Cover Map are problematic pixels that are mapped incorrectly. In spite of all the efforts made to collect and process accurate field data there were certain image processing issues concerning spectral confusion that limited the ability to map every pixel correctly. Other limitations, such as DEM errors, precluded the ability to correct or model every erroneous pixel that was mapped. Understanding these issues will enable better interpretation of the mapped data and recognition of potentially erroneous map information.

Water and Non-Water Confusion in Mountainous Regions

Image classification efforts were based on acquiring and using as many training sites as possible in order to reduce confusion and misclassification of data. Particularly noteworthy was the need to partition training sets related to the different Winter Mask classes and reduce the assignment of Water type pixels at higher elevations and on steeper northerly aspects related to the "terrain shadowed" dark pixels. While this situation was somewhat resolved in this manner by integrating the incidence angle information into the winter masks, significant amounts of terrain shadow related Water classes occurred, often at slopes as low as 30 degrees (this was likely due to the low sun angle during acquisition of the later season imagery in late August and early September). After evaluation of these situations, we found elevation was not a useful attribute to model the steep-Water types to Terrain Shadow types, as there were steep areas influenced by terrain shadowing at elevations as low as 1000 feet near the coast. While modeling was used to filter out many of these terrain related steep-Water pixels, the modeling was not implemented in as many situations as it could have been, as numerous areas were observed where actual lakes and bodies of water were being changed to Terrain Shadow classes due to erroneous USGS DEM data. In some cases the DEM slope data appeared to be misaligned by several pixels with the land cover map. In other cases, such as Icy Bay, or where glaciers had changed their position, the data were simply wrong (possibly out-of-date). Modeling efforts of this nature could be further refined if more accurate DEM data could be acquired and if terrain shadowing was modeled on a scene-by-scene basis rather than simply as a post-processing effort across the entire map.

In addition, certain Water types were easily confused with some other non-vegetation features. In particular, shallow silty turbid water, such as that found in many of the streams and rivers draining the glaciers was confused with areas typed as Snow/glacier that were comprised of wet glacial till, dirty wet ice, silt/gravel laden stream beds, and wet areas along the edges of glaciers. There appeared to be a spectral gradient that spanned these water-wet barren land cover situations resulting in confusion of type assignments derived from unsupervised classification efforts. While these situations were modeled to remove as much Snow/glacier from stream beds and Water from the surface of glaciers, there are still instances where these data are somewhat confused and may be misapplied. The "–Wet" designation was developed to indicate Barren types that appear to also have a wet/water component, such as river bars with very shallow water and the damp edges and surfaces of glaciers; however, there is no designation for Water types that may also have a significant Barren cover component.

Water, Aquatic Forb, and Sparse Vegetation Type Pixels

In certain water situations "Aquatic Forb" or "Sparse Vegetation" classes were assigned resulting in pixilated water bodies. In this situation, the vegetation cover attributed to the pixel data was comprised of emergent grasses and other aquatic vegetation in types that were dominated by water. In the original classification rules, "Aquatic Forb" or "Sparse Vegetation" types were

assigned if either the herbaceous cover was greater than 25% cover, or if the sum of the vegetation cover was greater than 15% cover. Therefore, an "Aquatic Forb" type could be assigned if the class had 25% herbaceous cover and 75% water, and a "Sparse Vegetation" class with only 15% vegetation cover and 85% water. These classification rules resulted in a few training classes that looked spectrally similar to water, but were classified as a non-water pixel class. As a result of these situations, the classification thresholds were adjusted such that if these types had a water cover component of at least 50% then the type would be changed to Water and a "–Aquatic Forb" or "–Sparse" Vegetation designation was added depending on the original vegetation type. This modification to the rules appeared to result in a more representative type map in areas dominated by water cover and tended to separate the water dominated areas from the areas dominated by wet vegetation. The presence of the cover by lifeform component in the database record is a tremendous help in both identifying and further resolving this situation, as these types may be modified and updated based on other water cover thresholds, if desired.

Spruce/Herbaceous Confusion

Throughout the image training process, confusion between a few Herbaceous *carex* dominated types and White Spruce types became apparent. In the Yakutat area this confusion involved a Sitka Spruce type (see trsite_ids 70518 and 70532). After undertaking exhaustive spectral training efforts to separate these types some confusion still remained. In order to resolve this issue the Winter Masks were developed, one for each image. In essence, these masks were used to identify where forested cover was thought to exist, as opposed to where it was not present. In this way, training areas containing white spruce cover were excluded from areas thought to lack spruce cover and the wet Herbaceous classes were not applied in areas thought to be forested. While an accuracy assessment was not performed on this data set, the implementation of the Winter Masks during classification efforts provided significantly different results in areas of observed confusion. Areas completely misclassified as coniferous forest were now nearly pure wet Herbaceous types, and forested areas that had been misclassified as a wet Herbaceous type were now predominately forest cover. The use of the Winter Masks appeared to greatly resolve the confusion of this nature.

Potential errors that would occur of this nature would be wet Herbaceous areas that did not correspond with bright areas in the winter imagery. Situations were observed where these type areas were dark indicating they were frozen and not covered with snow, as opposed to snow covered and bright. Such dark frozen areas would result in White Spruce pixels occurring in wet Herbaceous areas. As a result, any White Spruce type inclusions within wet Herbaceous areas should definitely be viewed with suspicion. Where the White Spruce pixels are isolated and surrounded by wet Herbaceous types, additional efforts, such as an aggregation or modeling process could possibly be used to identify and resolve these inconsistencies.

However, there are many valid situations where White Spruce types will be found next to wet Herbaceous pixels. Such situations frequently occur in the many forested areas pock-marked with small ponds and lakes, such as those found south of the Copper River between Gakona and Slana. In these cases the wet Herbaceous pixels actually form what appear as bathtub rings within the outer coniferous forest type edges of the small bodies of water, with deeper Water type pixels in the middle of the small lakes. On the basis of many visual observations, these areas appear to be mapped quite accurately.

White Spruce and Black Spruce

While **GRS** has sensed skepticism by the AKRO Project Manager regarding the accurate mapping of White Spruce and Black Spruce land cover types, **GRS**'s review of the Confusion and Fidelity Reports indicated that these two species types were fairly discernible. In one instance, the confusion report actually identified an aerial site typed as a White Spruce type (trsite_id 71613)

that was confused with a number of Black Spruce types. This led the **GRS** image processing analyst to believe that the site should possibly have been typed a Black Spruce type. Upon review of the field data form for this site (collected over a year before any classification efforts and review of the confusion report) the ABR botanist had noted in her remarks “Maybe PicMar.” The confusion report logic did fairly well at reporting groupings of similar sites, and it appeared in many cases that White Spruce sites were most often grouped separately from Black Spruce sites.

Past image processing problems of this nature may be more the result of difficulty in correctly identifying the species of spruce in the field during data collection efforts, rather than poor spectral separability of the many different White and Black Spruce signatures. Recognizing that species identification is difficult and confusion quite possible, **GRS** and ABR made significant efforts to correctly identify the correct species of spruce present on each of the aerial survey plots. Following the initial 2004 field season, whenever there was any question regarding the species that were present on a site with tree cover, both the ABR and GRS aerial personnel reached mutual agreement on which species were present.

GRS found that there were cases of valid confusion between White Spruce and Black Spruce stands that had been sampled as aerial sites. Stands that exhibited this sort of confusion were White Spruce stands that were low in tree cover with apparently stunted growth and stand composition that exhibited very similar stand morphology to Black Spruce stands growing under similar conditions. Figure 21 shows photos of two such stands that were confused. In addition, stands of mixed White/Black Spruce composition tended to show confusion with other mixed species stands, as well as Black or White Spruce stands. Rather than there being random confusion between Black and White Spruce stands there appeared to be pretty consistent confusion between White Spruce, mixed spruce, and Black Spruce stands.

Figure21: Confused White Spruce (71267) and Black Spruce (71853) Sites

While there was not an accuracy assessment **GRS** did review these mapped spruce types relative to ancillary data. The AKRO provided the Spruce Bark Beetle Mapping (SBBM) coverage which covered much of the McCarthy corridor north of the Chitina River. WRST land cover map pixels were summarized within SPBB polygons and calculated type calls were reviewed relative to the SBBM type calls. IKONOS imagery provided by AKRO was viewed as a backdrop to the type map data. In general, type designations appeared to correspond well with the SBBM coverage in areas where the SBBM map aligned well with the satellite imagery. Black Spruce types were mostly mapped in flatter areas of sparser cover than the often denser and taller White Spruce types. A further more detailed comparative analysis of this information could be performed if the SBBM data were adjusted to align better with the satellite imagery.

Dead and Live White Spruce

ABR and **GRS** estimated the status of the tree cover that was observed, noting the percent cover of dead trees as opposed to live trees. In some watersheds nearly every White Spruce tree appeared to have been killed. The result was that some types that were dominated by dead cover were actually described as a White Spruce Dead class. The result was that a significant acreage of land with dead spruce cover was mapped. A total of 28,355 acres were mapped as “Dead” indicating at least 66.7% of the spruce cover was dead, while another 193,751 acres were mapped as a “Complex(Cmplx)” or mix of “Dead” and live trees, in which a minimum of 33.3% percent of the spruce cover was estimated as “Dead.” Figure 22 shows examples of the White Spruce cover types that were typed as “Dead” and “Cmplx” types. Mapping these types corresponded pretty well with areas of observed Spruce Bark Beetle mortality.

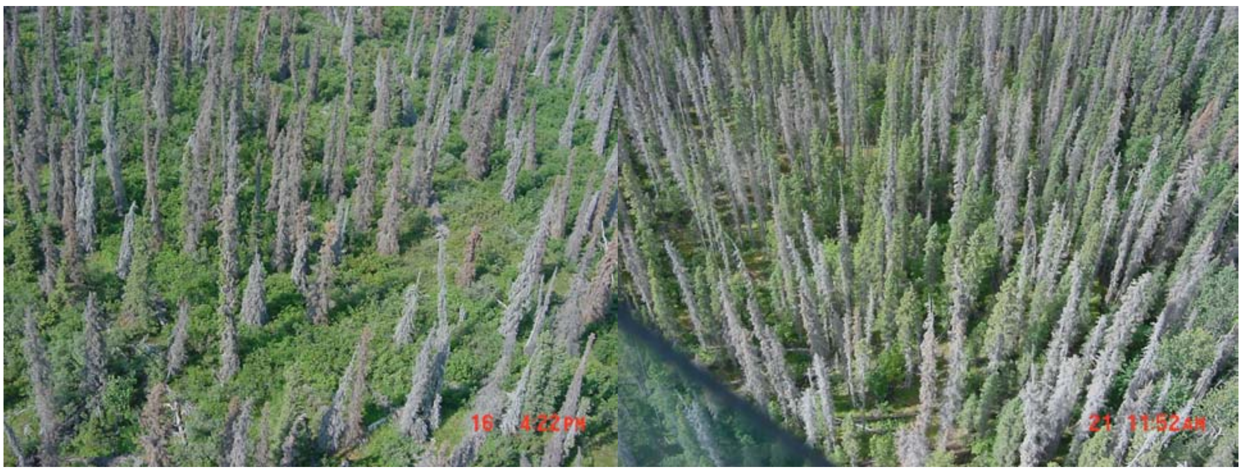

Figure 22: Dead (71628) and Cmplx (72106) White Spruce Sites

The “Dead” and “Cmplx” mapped pixels were also reviewed relative to the SBBM type information as it appears that the “Dead” tree cover was discernible from the living tree cover. Unfortunately, during the three years since the inception of the project, there has likely been additional spruce mortality and being able to check the WRST mapped information relative to the actual status of Spruce Bark Beetle mortality will be difficult. It would be much easier to see if there are areas mapped as “Dead” or “Cmplx” that do not show a significant amount (at least a third of the cover) of spruce mortality. As with the White Spruce and Black Spruce, a more accurate estimate of mortality could be developed at a polygon level after aggregating pixels into polygons or summarizing them by a set of existing polygons.

Deciduous Hardwoods and Tall Willow

The Confusion and Fidelity Reports indicated that there was confusion in several of the hardwood types. While many hardwood sites were not confused with other hardwood species types, there were a number of Aspen sites that were confused with Paper Birch and Balsam Poplar sites. Hardwood training areas were modified and reevaluated relative to GPS data, but in most cases the confusion persisted. This was mostly a problem in stands that were not pure homogeneous stands of one species, but rather stands dominated primarily by one species that had a somewhat uneven canopy structure that created shadowing in the tree canopy when viewing the stand from above. Paper Birch stands tended to grow with this uneven canopy structure, as did the more dense (near 60% cover) Open Aspen and Balsam Poplar stands (Closed stands often had a more even canopy structure). What became even more apparent during the evaluation of this confusion

was that additional spectral confusion existed with sites that were typed as Tall Shrub:Closed:Willow. In fact, a review of the preliminary classification maps indicated some stands which appeared to be mixtures of Hardwood:Closed and these Tall Shrub:Closed:Willow pixels.

A review of the confused training sites and refinement of training areas did not resolve this hardwood confusion. Several locations that manifested this type of confusion were selected for aerial sampling during the 2006 field season. Surprisingly, when these sites were visited we found different stand conditions than had been expected. Many of these confused areas were not Aspen, Balsam Poplar, Paper Birch, or Tall Shrub:Closed:Willow. Instead they were dense stands of what was determined to be Salix scouleriana that had grown to be at least 30-45 feet tall. The Tall Shrub:Closed:Willow label for these areas was a misnomer as these stands, while comprised of a species of willow, were of a treelike form more similar to Paper Birch or Aspen trees, rather than a shrub form. Figure 23 shows one of these dense willow stands (71104) compared to a Paper Birch:Closed stand. This situation repeated itself a number of times, in particular in the McCarthy Corridor, near May Creek, and on the sidewalls of the Hanagita Valley. Continued efforts to resolve this type of confusion were unsuccessful and as a result there remains some confusion between Aspen, Balsam Poplar, Paper Birch, and these very tall dense willow stands. However, there was not confusion between the hardwood types and Tall Shrub:Closed:Willow types that were actually tall shrubs rather than trees, nor was there significant confusion between the tree-form willow and the shrub-form (it appears the canopy texture of a real Tall Shrub:Closed:Willow type is much more uniform in appearance and shading than the canopy structure of one of the tree-form willow stands). For these reasons, the classification rules were modified to recognize the differences between these tree-form willow stands and the shrub-form willow stands. The tree-form willow stands would be called a Tree Shrub type rather than a Tall Shrub type so they could be distinguished from each other. The types of all sites dominated by *Salix scouleriana* were modified from Tall Shrub:Closed:Willow to Tree Shrub:Closed:Willow. Lastly, one alder type of a tree-form nature was found in the data set. It too was renamed to be a Tree Shrub type, rather than a Tall Shrub type to avoid potential misunderstanding of these mapped types.

Figure 23: Confused Paper Birch (72114) and Tree Shrub:Willow (71104) Stands

Land Cover Map Accuracy

Unfortunately the size of Wrangell-St. Elias National Park & Preserve, overall lack of access, and limited budget precluded implementation of a formal accuracy assessment. In all likelihood, the cost of such an accuracy assessment performed at a statistically valid level of sampling (random stratified sample with a minimum number of sites per land cover type) would have exceeded the total cost of WRST project field data collection efforts. Checks have been performed against some other known data sources like the FirePro and ABR field sites that were not used to train the classification process. However, it is very difficult to check mapped results at the pixel level, as there may be slight differences of at least one half pixel width (15m) between pixel locations and actual ground/field site coordinates just due to the accuracy of the GPS devices used to record the field locations. In addition, caution must be used in any WRST map review relative to ancillary information to be certain that the same land cover type definitions are being applied when comparing the map to other data sources. For example, as there is not one pixel of a Deciduous:Woodland type mapped, one must be careful comparing the map to another source that includes Deciduous:Woodland classes, as they will obviously disagree due to differences in type definitions rather than cover component estimates. Similarly, the Viereck field type calls on the ABR sites were made prior to modification of the WRST land cover classification rules and on the basis of visual observations and not the processing of a "bird's-eye view" of cover that totaled 100% cover.

Pixel types can show trends in land cover typing, and there are many areas in the WRST data set where the transition of land cover types as you proceed from valley bottoms to ridge tops follow the patterns that are visible in the field; there are no areas that represent a hodgepodge of pixel types that cannot be explained other than those steep northerly slopes effected by terrain shadowing. In addition, there are many species related patterns of both nearly pure groups of species-specific related pixels, as well as common mixes of pixels that occur too often to have been random occurrences generated through the classification processes. Verification also included review of the map data relative to field crew observations and notes, as well as the correction of erroneous training data in cases where erroneously mapped information was observed. The visual patterns of the WRST Land Cover Map tend to correspond well with what is observed in the field.

A better means of verification would be to build data for areas or polygons that represent aggregations of similar or related pixel types. Homogeneous areas would form polygons of the same type. Mixed pixels would form polygons of a mixed type (White and Black Spruce pixels would form a mixed-spruce type). Isolated pixels of different types would be absorbed into larger areas formed by the more frequently occurring types smoothing the appearance of the pixels data. Polygon attributes would represent the weighted average of the individual pixels and be easier to verify than individual pixels. Field observations by NPS/AKRO staff will have to be recorded and mapped relative to WRST Land Cover Map values to gradually develop a sense of the accuracies and reliabilities of the many different types and features in the WRST Land Cover Map data set. There may be differences found that indicate some species-specific types are not as accurate as desired, but that the overall type is accurate, thereby indicating that the species-specific association should be dropped from the type name. However, such conclusions should only be reached through a numerical analysis of the type information relative to "ground truth." If a concerted directed effort is made to develop and maintain such comparative information, a level of confidence and understanding will be developed that will enable users of this map to have as much confidence in this information as do those that have developed the WRST data set.

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Appendices

Appendix A: WRST Land Cover Mapping Project Aerial Survey Form

2006 WRST LANDCOVER MAPPING PROJECT; FVA "FLY-OVER" DATA FORM Date:__________ Air Photo#: ___ ___ ___ ___ -___ ___ ___ ___

Polygon code: Lat/Long: / Azimuth: Slope (0-100 °): Aspect (0-360 °):

Surveyors: T. Cater K. Stumpf J. Grunblatt Landcover class code: Landcover class name:

Photos: Roll #: Frame # Dig photo: ses. #: photo #: azimuth:

Modifer(circle all that apply): Alpine Subalpine Upland Lowland Riparian Boreal Tussock Bog Meadow Video:tape #: Footage:

Hydrologic Regime (circle one): Dry - Mesic - Wet - Aquatic % Tussocks: Landform:

Hgt (m)	Tree (>5m)	%	Tall shrub (5m >1.5m)	%	Low shrub (1.5m >20cm)	%	Dwarf shrub (>20 cm)	%	Herbaceous	%	Herbaceous including moss, lichen & bare	%
	Total		Total		Total		Total		Total		Total	

Spruce >5m	Deciduous forest	Mixed forest <=25% tree	Low shrub 20cm -1.5m	Dwarf shrub 25-100%, <20cm	Herbaceous 25-100%	TOTAL
Closed White Spruce 60-100%	60-100%	Closed Mixed 60-100%	75-100%/sp	Dryas Dwarf Shrub >50%/sp	>50%g, <25% tuss	
	Closed Birch >50%/sp	Open Mixed 25-59%	Closed Low Alder-Willow	Mixed Dwarf Shrub	Dry/Mesic Grainoid	
Open White Spruce 25–59%	Closed Aspen	Woodland Mixed 10-24%	Closed Low Shrub Birch-Willow	Mixed Dwarf Shrub-Sedge	>25% g, >25% forb, <25% tuss	
Open Black Spruce	Closed Balsam Poplar		Closed Low Willow	Mixed Dwarf Shrub-Lichen	Dry/Mesic Graminoid-Forb	
Open Stunted Spruce-PIMA	>=25%	Tall shrub >1.5m	Closed Low Shrub Birch-Ericaceous Shrub-Willow			
Open Spruce Lichen	Closed Mixed Deciduous	Closed Tall Alder-Willow	Closed Low Shrub Birch	>25% rock	Tussock >25% tuss	
	25-59%	Closed Tall Alder 75-100%	25-74%/sp	Mixed Dwarf Shrub-Rock	>50% emerg herb	
Woodland Spruce 10–24%	Open Birch >50%/sp	Closed Tall Willow	Open Low Alder-Willow		Wet Salt Marsh Herbaceous	
Woodland Stunted Spruce	Open Aspen		Open Low Alder		Wet Freshwater Herbaceous	
Woodland Spruce Lichen	Open Balsam Poplar	Open Tall Alder 25-74%	Open Low Shrub Birch-Ericaceous Shrub- Willow			
		Open Tall Willow	Open Low Willow		Aquatic >50% submerged, floating or perm h20	
	Open Mixed Deciduous >25%		Open Low Shrub Birch-Ericaceous Shrub		Sparse Vegetation 15-25%	
Other						
Marine Mudflat <15%	Bedrock <15%	Silty Water	Snow/Ice	Human Development	rock gravel talus	
Sand/Gravel <15%	Shadow/Indeterminate	Clear Water	Marine Water	Burn Site	sand mud soil	

INCLUSION:

COMMENTS:

20cm = 8", 30cm=1', 1.5m= 5', 1km= .62 1"=2.54cm, 1'=30.48cm,1yd=.91m,1mi=1.61km

Appendix B: WRST Land Cover Mapping Project Classification Rules

Type Assignment C++ Source Code:

```
//
// start of WRST type rules
//
// thresholds
//
        treecovLimit[0]=10.0;
        treecovLimit[1]=25.0;
        treeClassMajDensity=(float)75.0;
        treeStatusMajDensity=(float)66.67;
        treeTypeMajDensity=(float)66.67;
        shrubTypeMajDensity=(float)66.67;
        maxLiveTreeClass=ptypeIdx[maxcon]-3;

        lichenFlag=tussFlag=waterType=watFlag=0;
//
// minimum tree cover ??
//
        if(((cfsum + hwdsum) >= treecovLimit[0] && cfsum > 7.5 )
         || (cfsum + hwdsum) >= treecovLimit[1] )
        {
//
// have a tree type
//
          denscf=(cfsum/(cfsum+hwdsum))*(float)100.0;
          denshd=(float)100.0-denscf;

// determine tree density class
          for( i = 0 ; i < pmaxtden ; i++)
          if((cfsum + hwdsum) >= treecovLimit[i])treeDCl=treecovLimitClN[i];

// determine predominant component

         for( i = 0 ; i <= maxhwd ; i++)
          if(trans[i][maxsizT][ii] > densmx)
          {
           densmx=trans[i][maxsizT][ii];
           maxden=i;
          }
//
// conifer type ??  set default to mixed conifer type
//
         if( denscf > treeClassMajDensity )  // was 75.0
         {
          typeIndex=mvType[maxcon];

// tally cover of major tree species groups up through maxLiveTreeClass -
// index is group code

          sumpgl=trans[1][maxsizT][ii]+trans[2][maxsizT][ii]+trans[3][maxsizT][ii];
          sumpma=trans[4][maxsizT][ii]+trans[5][maxsizT][ii]+trans[6][maxsizT][ii];
          sumpsi=trans[7][maxsizT][ii]+trans[8][maxsizT][ii]+trans[9][maxsizT][ii];
          sumthe=trans[10][maxsizT][ii]+trans[11][maxsizT][ii]+trans[12][maxsizT][ii];
          sumtme=trans[13][maxsizT][ii]+trans[14][maxsizT][ii]+trans[15][maxsizT][ii];
          sumoth=trans[16][maxsizT][ii]+trans[17][maxsizT][ii]; // 070710
```

```
// tally status/vigor

        sumliv=(float)0.;
        sumstn=(float)0.;
        summor=(float)0.;
        for( i = 1 ; i <= maxLiveTreeClass ; )
        {
         sumliv=sumliv+trans[i][maxsizT][ii];
         if(i < 16)
         {
          sumstn=sumstn+trans[i+1][maxsizT][ii];
          summor=summor+trans[i+2][maxsizT][ii];
         }
         else
         {
          summor=summor+trans[i+1][maxsizT][ii];
         }
         i+=3;
        }

        sumspr=sumpgl+sumpma+sumpsi;

// determine major conifer type - test by type
// white spruce
         if(sumpgl/cfsum >= minPure[1])typeIndex=1;
// black spruce
         else if(sumpma/cfsum >= minPure[5])typeIndex=5;
// sitka spruce
         else if(sumpsi/cfsum >= minPure[9])typeIndex=9;
// hemlock
         else if(sumthe/cfsum >= minPure[13])typeIndex=13;
// mtn hemlock
         else if(sumtme/cfsum >= minPure[17])typeIndex=17;
// other
         else if(sumoth/cfsum >= minPure[21])typeIndex=21;
// spruce mix
         else if((sumpgl+sumpma)/cfsum >= minPure[24])typeIndex=24;
// spruce hemlock mix
         else if((sumspr+sumtme+sumthe)/cfsum >= minPure[28])typeIndex=28;

// determine status/vigor - living, stunted, dead, or mixed
// tree Status Density threshold
         if(sumliv/cfsum < (float)(treeStatusMajDensity/100.0))
         {
            if(typeIndex != 21)
            {
             if(sumstn/cfsum >= (float)(treeStatusMajDensity/100.0))typeIndex += 1;
             else if(summor/cfsum >= (float)(treeStatusMajDensity/100.0))typeIndex += 2;
             else typeIndex += 3;
            }
            else
            {
             if(summor/cfsum >= (float)(treeStatusMajDensity/100.0))typeIndex += 1;
             else typeIndex += 2;
            }
         }
```

```
         }
         else
         {
// hardwood
          if( denscf < (float)(100.0 - treeClassMajDensity)) // 25.0
          {
           typeIndex=mvType[maxhwd];
// Balsam Poplar or ...
           for( i = minhwd ; i < maxhwd ; i++)
           {
             if(trans[i][maxsizT][ii]/hwdsum >= minPure[mvType[i]])typeIndex=mvType[i];
           }
          }
          else
//
// hardwood/conifer mix
//
          typeIndex=mvType[mhcindx];
         }

// assign shr density class too ?
         for( i = 0 ; i < pmaxsden ; i++)
          if(shrsum >= shrcovLimit[i])shrDCl=shrcovLimitClN[i];
        }
//
// end of tree
//
        else
        {
//
// non-tree types
//
// shrub
//
         if ( shrsum >= shrcovLimit[0] ||
            ((shrsum+dshsum) >= shrcovLimit[0] && shrsum >= dshsum) )
//
// (tall + low shrubs) ! dsh
//
         {
//
//        set default to low shrub for viereck
//
//          determine tall+low density class
//
           shrDCl=0;
           for( i = 0 ; i < pmaxsden ; i++)
             if(shrsum >= shrcovLimit[i])shrDCl=shrcovLimitClN[i];

// sum by species groups - alder, willow,ericaceous, and birch

           sumaln=trans[26][maxsizall][ii]+trans[28][maxsizall][ii]+trans[31][maxsizall][ii];
           sumsal=trans[27][maxsizall][ii]+trans[29][maxsizall][ii]+trans[32][maxsizall][ii];
           sumbir=trans[33][maxsizall][ii];
           sumeri=trans[34][maxsizall][ii];
           sumsalbet=sumsal+sumbir;
```

```
//
// enough for Tall Shrub ?
//

          if(tshsum >= shrcovLimit[0])
          {
           typeIndex=mvType[maxtsh];
           mmnshr=mintsh;
           mmxshr=maxtsh;
           sumaln=trans[26][maxsizall][ii]+trans[28][maxsizall][ii];
           sumsal=trans[27][maxsizall][ii]+trans[29][maxsizall][ii];
           tsum=tshsum;
          }
          else
//
// enough for Low Shrub ?
//
           if( lshsum >= shrcovLimit[0] )
           {
            typeIndex=mvType[maxlsh];
            mmnshr=minlsh;
            mmxshr=maxlsh;
            tsum=lshsum;
           }
           else
           {
            typeIndex=MShIdx;  // index for mixed shrub type
            mmnshr=minshr;
            mmxshr=maxshr;
            tsum=shrsum;
            if(tsum < shrcovLimit[0])tsum=shrsum+dshsum;
           }

           for( i = mmnshr ; i <= mmxshr ; i++)
            if(trans[i][maxsizall][ii] > densmx)
            {
             densmx=trans[i][maxsizall][ii];
             maxden=i;
            }
//
// species dominance of shrub types - based on tall + short
//

           if(sumaln/tsum >= (float)shrubTypeMajDensity/100.0)  // alder dominated (tsum)
           {
             if(typeIndex==mvType[maxtsh])  // tall shrub ?
             {
                 if(trans[26][maxsizall][ii] > trans[28][maxsizall][ii])
                 {     maxden=26;    typeIndex=mvType[maxden]; }// tree
                 else
                 {     maxden=28;    typeIndex=mvType[maxden]; }//tall
             }
             else if(typeIndex==mvType[maxlsh]){ maxden=31;typeIndex=mvType[maxden]; } // low
             else {typeIndex-=5;}  // mixed shrub
           }
            else if(sumsal/tsum >= (float)shrubTypeMajDensity/100.0)  // willow dominated (tsum)
            {
```

```
           if(typeIndex==mvType[maxtsh])// tall shrub ?
           {
              if(trans[27][maxsizall][ii] > trans[29][maxsizall][ii])
              {     maxden=27;    typeIndex=mvType[maxden]; }        // tree shrub
              else
              {     maxden=29;    typeIndex=mvType[maxden]; }        //tall
           }
           else if(typeIndex==mvType[maxlsh]){ maxden=32;typeIndex=mvType[maxden]; }// low
           else {typeIndex-=4;}  // mixed shrub
         }
         else if(sumbir/tsum >= (float)shrubTypeMajDensity/100.0) // birch dominated (tsum)
         {
          if(typeIndex>=mvType[maxlsh]){maxden=33; typeIndex=mvType[maxden]; }
         }
          else if(sumeri/tsum >= (float)shrubTypeMajDensity/100.0)  // ericaceous dominated (tsum)
         {
          if(typeIndex>=mvType[maxlsh]){maxden=34; typeIndex=mvType[maxden]; }
         }
          else if(sumsalbet/tsum >= (float)shrubTypeMajDensity/100.0)  // willow-birch dominated (tsum)
         {
          if(typeIndex>=mvType[maxlsh]){maxden=36; typeIndex=mvType[maxden]; }
         }
          else if(trans[elaIdx][maxsizall][ii]/tsum >= (float)shrubTypeMajDensity/100.0)  // elacom dominated
         {
          if(typeIndex>=mvType[maxlsh]){typeIndex=mvType[maxden]; }
         }
       }
       else
        if( (dshsum + shrsum) >= shrcovLimit[0])
        {
         typeIndex=mvType[maxdsh];
//
// determine density class of Dsh
//
         shrDCl=0;
         for( i = 0 ; i <= pmaxsden ; i++)
          if(dshsum >= shrcovLimit[i])shrDCl=shrcovLimitClN[i];

         for( i = mindsh ; i <= maxdsh ; i++)
          if(trans[i][maxsizall][ii] > densmx)
          {
           densmx=trans[i][maxsizall][ii];
           maxden=i;
          }

         sumbir=trans[39][maxsizall][ii];
         sumdry=trans[40][maxsizall][ii];
         sumeri=trans[41][maxsizall][ii];
         sumcas=trans[casIdx][maxsizall][ii];

         if(sumbir/dshsum >= (float)shrubTypeMajDensity/100.0)typeIndex-=5;
          else if(sumdry/dshsum >= (float)shrubTypeMajDensity/100.0)typeIndex-=4;
          else if(sumeri/dshsum >= (float)shrubTypeMajDensity/100.0)typeIndex-=3;
          else if(sumcas/dshsum >= (float)shrubTypeMajDensity/100.0 ||
                     sumcas/vegsum > (float)0.3)typeIndex-=2;
```

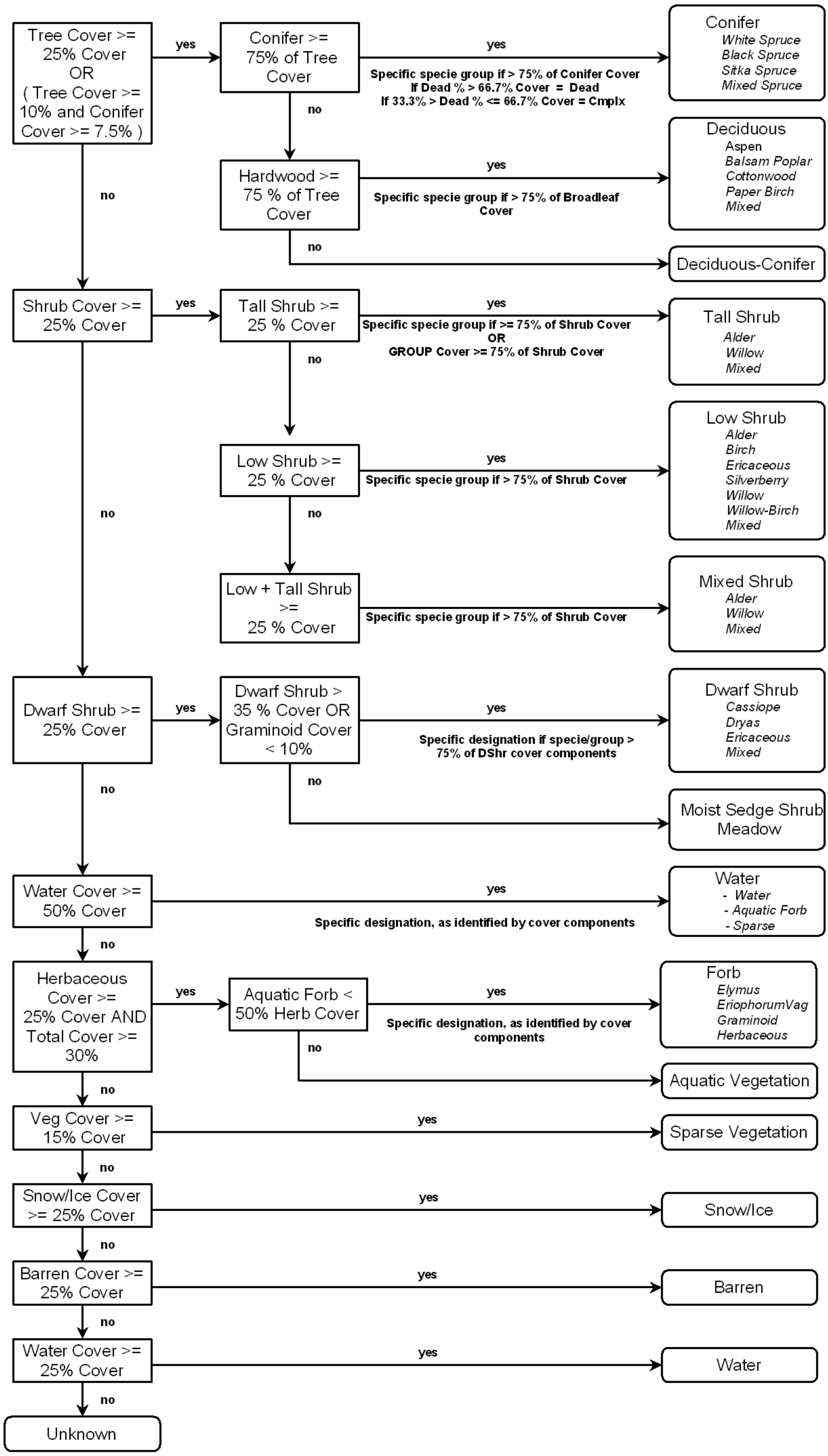
```
//
// graminoid - dwarf-alpine – Moist Sedge Shrub
//
            if(grmsum >= (float)10.0 && dshsum < (float)35.)
            {
               typeIndex=HrDIdx;

               if(grmsum >= densmx)
               {
                densmx=grmsum;
                maxden=gramIdx;
               }
            }
          }
          else          // herbaceous - limit raised to 30% other cover and 25% herb
           if ( hrbsum >= shrcovLimit[0] &&
                (shrsum+dshsum+hrbsum) >= (shrcovLimit[0]+5.0) && hrbsum > aqusum )
           {
            typeIndex=mvType[maxhrb];
            maxden=maxhrb;

            for( i = minhrb ; i <= maxhrb ; i++)
             if(trans[i][maxsizall][ii] > densmx)
             {
              densmx=trans[i][maxsizall][ii];
              maxden=i;
             }
//
// specific type of forb majority ?
//
           if(densmx/hrbsum >= minPure[mvType[maxden]])typeIndex=mvType[maxden];
            else
              if(grmsum/hrbsum >= minPure[mvType[maxden]]){maxden=gramIdx;typeIndex=mvType[gramIdx];}
            if(maxden==gramIdx)densmx=grmsum;

            if(typeIndex == AqFIdx)
            {
                watFlag=1;  // wet site
                aqusum = aqusum + trans[aquIdx][maxsizall][ii];
                hrbsum = hrbsum - trans[aquIdx][maxsizall][ii];
            }
           }
           else
//
// non-vascular veg
//
           if ( othsum >= shrcovLimit[0] )
           {
            typeIndex=mvType[maxoth];
            maxden=maxoth;
            for( i = minoth ; i <= maxoth ; i++)
             if(trans[i][maxsizall][ii] > densmx)
             {
              densmx=trans[i][maxsizall][ii];
              maxden=i;
             }
             typeIndex=mvType[maxden];
```

```
          }
          else
//
// aquatic
//
          if ( aqusum >= shrcovLimit[0] )
          {
           typeIndex=mvType[maxaqu];
           watFlag=1;
           for( i = minaqu ; i <= maxaqu ; i++)
            if(trans[i][maxsizall][ii] > densmx)
            {
             densmx=trans[i][maxsizall][ii];
             maxden=i;
            }
          }
          else
//
// sparse
//
          if ( shrsum+hrbsum+dshsum+cfsum+hwdsum+othsum+aqusum >= 15.0 )
          {
           typeIndex=SpVIdx;

           for( i = minhrb ; i <= maxhrb ; i++)
            if(trans[i][maxsizall][ii] > densmx)
            {
             densmx=trans[i][maxsizall][ii];
             maxden=i;
            }

           aqusum = aqusum + trans[aquIdx][maxsizall][ii];
           hrbsum = hrbsum - trans[aquIdx][maxsizall][ii];

//
// default to misc forb
//
           if(densmx < 10.0)maxden=maxhrb;

           if(aqusum >= hrbsum)maxden=aquIdx;

            if(othsum >= hrbsum &&
              othsum >= aqusum )
            for( i = minoth ; i <= maxoth ; i++)
             if(trans[i][maxsizall][ii] > densmx)
             {
              densmx=trans[i][maxsizall][ii];
              maxden=i;
             }

            if(dshsum >= hrbsum &&
               dshsum >= othsum &&
              dshsum >= aqusum )maxden=maxdsh;

           if(lshsum >= dshsum &&
              lshsum >= hrbsum &&
              lshsum >= othsum &&
```

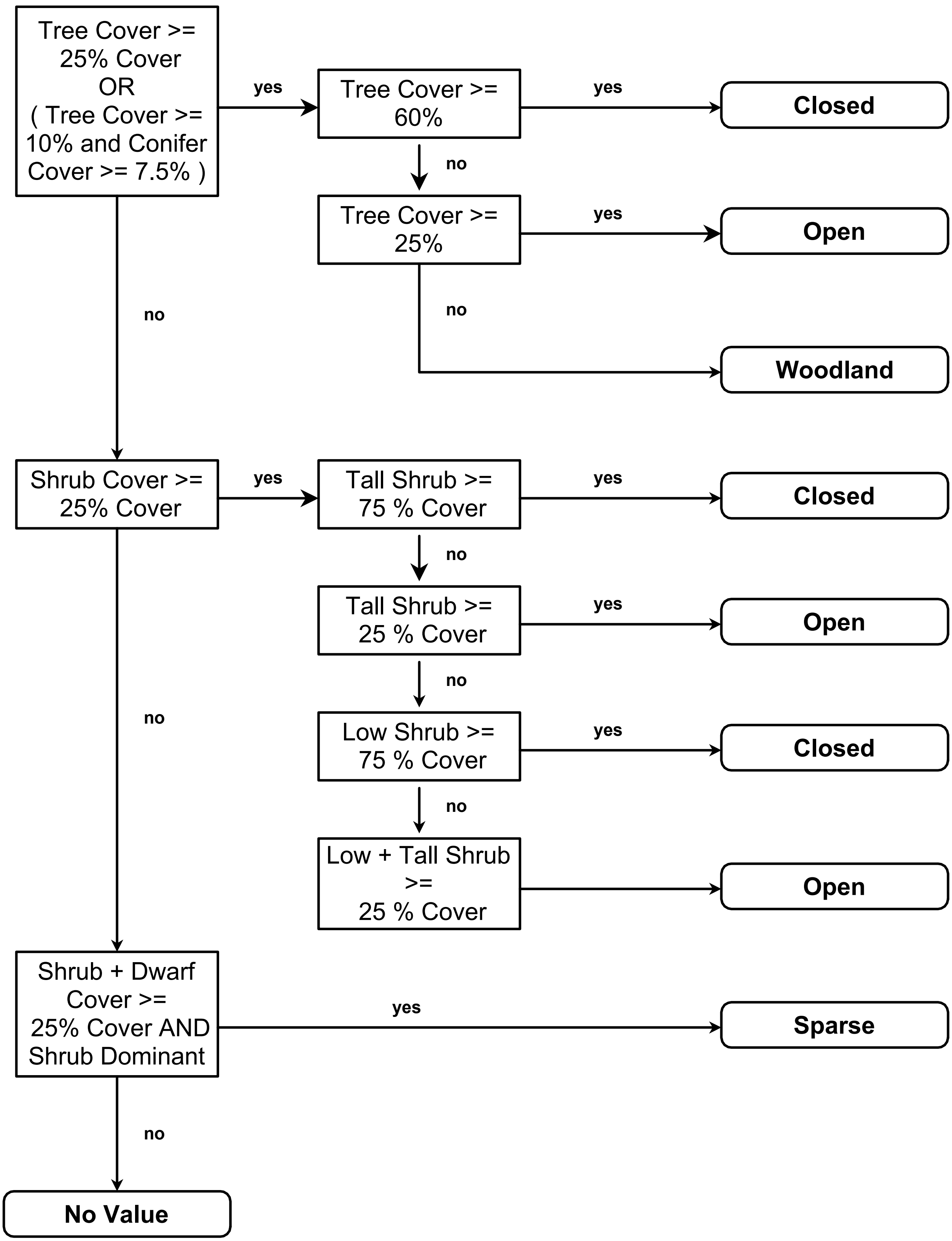
```
            lshsum >= aqusum )maxden=maxlsh;

         if(tshsum >= lshsum &&
            tshsum >= dshsum &&
            tshsum >= hrbsum &&
            tshsum >= othsum &&
            tshsum >= aqusum )maxden=maxtsh;

         if((hwdsum+cfsum) >= shrsum &&
            (hwdsum+cfsum) >= lshsum &&
            (hwdsum+cfsum) >= dshsum &&
            (hwdsum+cfsum) >= hrbsum &&
            (hwdsum+cfsum) >= othsum &&
            (hwdsum+cfsum) >= aqusum )
         {
             maxden=mhcindx;
             if(hwdsum > cfsum)maxden=maxhwd;
             if(hwdsum < cfsum)maxden=maxcon;
         }
        }
        else
//
// barren
//
         if(barsum >= (float)25.0 && barsum > watsum )
         {
          typeIndex=mvType[maxbar];
          for( i = minbar ; i <= maxbar ; i++)
           if(trans[i][maxsizall][ii] > densmx)
           {
            densmx=trans[i][maxsizall][ii];
            maxden=i;
           }
           typeIndex=mvType[maxden];
           if(maxden == 57)typeIndex=mvType[57];
//
// organic material – litter ….
//
           if( (trans[58][maxsizall][ii]+trans[59][maxsizall][ii]) > densmx)
           {
               typeIndex=mvType[58];
               if(trans[58][maxsizall][ii] > trans[59][maxsizall][ii])maxden=58;
                else maxden=59;
           }
         }
        else
//
// h2o
//
         if(watsum >= (float)25.0)
         {
          typeIndex=mvType[maxwat];
          for( i = minwat ; i <= maxwat ; i++)
           if(trans[i][maxsizall][ii] > densmx)
           {
            densmx=trans[i][maxsizall][ii];
            maxden=i;
```

```
          }
        }
        else
//
// undef or cloud shadow
//
        if(trans[62][maxsizall][ii] > trans[63][maxsizall][ii])
        {
           typeIndex=mvType[62];
           maxden=62;
           densmx=trans[62][maxsizall][ii];
        }
        else
        {
           typeIndex=mvType[63];
           maxden=63;
           densmx=trans[63][maxsizall][ii];
        }
      }

      if(watsum >= (float)20.0)watFlag=1;
//
// set to h2o if water >= 50%
//
      if(watsum >= (float)50.0)waterType=1;

//
// Lichen designation if % > 20
//
      if(trans[licIdx][maxsizall][ii] >= (float)20.0)lichenFlag=1;

//
// tussock threshold set at 15%
//
      if(trans[tussIdx][maxsizall][ii] >= (float)15.0)tussFlag=1;

//
// size class
//
      if((hwdsum+cfsum) >= (float)5.0)
      {
        for( i = 0 ; i < pmaxsiz ; i++)
          if(qmd[ii][maxsizT] >= sizLimit[i])iszCl=sizLimitClN[i];
      }

//
// cover density class
//
      densCls = ( treeDCl > 0 ) ? treeDCl : shrDCl;
//
// tree composition
//
      pctcon = ((cfsum+hwdsum) > (float)0.0) ? cfsum/(cfsum+hwdsum)*(float)100. : (float)0.0;
      pcthwd = ((cfsum+hwdsum) > (float)0.0) ? (float)100.0 - pctcon : (float)0.0;
//
// end of rules
//
```

Appendix C: WRST Mapping Project Land Cover Type Classification



Appendix D: WRST Mapping Project Land Cover Density Classification



Appendix E: Table Item Listings and Definitions

Items for table wrst_lcover.vat:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	INDEXED?
1	VALUE	4	10	B	-	Indexed
5	COUNT	4	10	B	-	-
9	TRSITE_ID	11	11	I	-	-
20	ELEVATION_FT	6	6	I	-	-
26	SLOPE_DEGREES	6	6	I	-	-
32	ASPECT	6	6	I	-	-
38	X_COORD	8	23	F	4	-
46	Y_COORD	8	23	F	4	-
54	LATITUDE	20	20	C	-	-
74	LONGITUDE	20	20	C	-	-
94	PHOTO_ID	12	12	C	-	-
106	SOURCE_GRIDVAL	10	10	C	-	-
116	SOURCE_COVER	10	10	C	-	-
126	SCENE_IND	10	10	C	-	-
136	OTHER_ID	10	10	C	-	-
146	SPEC_CLASS	50	50	C	-	-
196	GRIDCLVAL	11	11	I	-	-
207	MAJOR_CLASS	50	50	C	-	-
257	REGIME	20	20	C	-	-
277	MODIFIER	20	20	C	-	-
297	REMAP_VAR	6	6	I	-	-
303	TYPE	50	50	C	-	-
353	CALC_CLASS	50	50	C	-	-
403	PR_COMP	20	20	C	-	-
423	PR_COMP_COVER	8	23	F	4	-
431	COVER_CLASS	10	10	C	-	-
441	TREE_COVER	8	23	F	4	-
449	OTHER_VEG_COVER	8	23	F	4	-
457	CONF_COVER	8	23	F	4	-
465	HDWD_COVER	8	23	F	4	-
473	PCT_CONF	8	23	F	4	-
481	PCT_HDWD	8	23	F	4	-
489	SHR_COVER	8	23	F	4	-
497	TSH_COVER	8	23	F	4	-
505	LSH_COVER	8	23	F	4	-
513	DSH_COVER	8	23	F	4	-
521	HRB_COVER	8	23	F	4	-
529	OTH_COVER	8	23	F	4	-
537	AQU_COVER	8	23	F	4	-
545	BAR_COVER	8	23	F	4	-
553	H2O_COVER	8	23	F	4	-
561	UNDF_COVER	8	23	F	4	-
569	ALNUS_COVER	8	23	F	4	-
577	SALIX_COVER	8	23	F	4	-
585	GRAM_COVER	8	23	F	4	-

Items for the table trsites.pat

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	INDEXED?
1	AREA	8	18	F	5	-
9	PERIMETER	8	18	F	5	-
17	TRSITES#	4	5	B	-	-
21	TRSITES-ID	4	11	B	-	Indexed
25	TRSITE_ID	11	11	I	-	-
36	ISO_CLASS	11	11	I	-	-
47	ELEVATION_FT	6	6	I	-	-
53	SLOPE_DEGREES	6	6	I	-	-
59	ASPECT	6	6	I	-	-
65	X_COORD	8	23	F	4	-
73	Y_COORD	8	23	F	4	-
81	LATITUDE	20	20	C	-	-
101	LONGITUDE	20	20	C	-	-
121	OTHER_ID	10	10	C	-	-
131	PHOTO_QC	2	2	C	-	-
133	PHOTO_TIME	6	6	C	-	-
139	SCENE_IND	10	10	C	-	-
149	COVER_TYPE_DES	40	40	C	-	-
189	GRIDVAL	11	11	I	-	-
200	GRIDCLVAL	6	6	I	-	-
206	HABITAT	55	55	C	-	-
261	REGIME	20	20	C	-	-
281	MODIFIER	20	20	C	-	-
301	MAJOR_CLASS_DES	40	40	C	-	-
341	SOURCE	20	20	C	-	-
361	NOTES	240	240	C	-	-
601	COVER_TYPE	4	4	C	-	-
605	CLOSURE_CLASS	1	1	C	-	-
606	DENSITY	4	14	F	4	-
610	CONIFER_COVER	4	14	F	4	-
614	HDWOOD_COVER	4	14	F	4	-
618	PCT_CONIFER	4	14	F	4	-
622	PCT_HDWOOD	4	14	F	4	-
626	PR_SPECIES	16	16	C	-	-
642	PRED_SP_PCT	4	14	F	4	-
646	OTHER_COVER	4	14	F	4	-
650	CV_SHR	4	14	F	4	-
654	CV_TSH	4	14	F	4	-
658	CV_LSH	4	14	F	4	-
662	CV_DSH	4	14	F	4	-
666	CV_HRB	4	14	F	4	-
670	CV_OTH	4	14	F	4	-
674	CV_AQU	4	14	F	4	-
678	CV_BAR	4	14	F	4	-
682	CV_WAT	4	14	F	4	-
686	CV_UNDF	4	14	F	4	-
690	LICHEN_FLAG	6	6	I	-	-
696	TUSSOCK_FLAG	6	6	I	-	-
702	WET_FLAG	6	6	I	-	-
708	COVER_TYPE_DESC	40	40	C	-	-
748	CV_ALNUS	4	14	F	4	-
752	CV_SALIX	4	14	F	4	-
756	CV_GRAMINOID	4	14	F	4	-

Items for table wrst_lcsource.dat:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	INDEXED?
1	VALUE	4	10	B	-	Indexed
5	COUNT	4	10	B	-	-
9	IMAGENUMBER	6	6	I	-	-
15	IMAGENAME	8	8	C	-	-
23	CLASSIF_THRESHOL	4	4	C	-	-
27	MERGEFUNCTION	4	4	C	-	-
31	MODEL	6	6	I	-	-

Items for table gridval_cover.dat:

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	INDXED?
1	TRSITE_ID	11	11	I	-	-
12	SOURCE	20	20	C	-	-
32	SPECIES	50	50	C	-	-
82	SPCODENUM	6	6	I	-	-
88	SPCODE	10	10	C	-	-
98	COVER	8	23	F	4	-
106	STRATA	10	10	C	-	-
116	COMMENT	50	50	C	-	-
166	GRIDVAL	11	11	I	-	-

Table Definitions:

ALNUS_COVER	The estimated cover of Alnus sp.
ASPECT	The estimated aspect (azimuth) at the training site location
AQU_COVER	The estimated cover of aquatic vegetation
BAR_COVER	The estimated cover of barren area
CALC_CLASS	The Land Cover Class estimated through application of the Land Cover Classification rules to the class cover components
CLOSURE_CLASS	
COMMENT	Comment field
CONF_COVER Or CONIFER_COVER	The estimated tree cover comprised by conifers
COUNT	The frequency of the pixel value in the map
COVER	The estimated percent land cover of a component
COVER_CLASS	The density class of the Land Cover Type: For tree types: Woodland = 10 - 24.9% tree cover Open = 25 - 59.9% tree cover Closed >= 60% tree cover For shrub types: Sparse = 10 - 24.9% shrub cover only for a Mixed Shrub type Open = 25 - 74.9% shrub cover Closed >= 75% shrub cover
COVER_TYPE	see TYPE
COVER_TYPE_DES Or COVER_TYPE_DESC	see CALC_CLASS
CV_SHR	The sum of Tall and Low Shrub cover
CV_TSH	Estimate of Tall Shrub cover
CV_LSH	Estimate of Low Shrub cover
CV_DSH	Estimate of Dwarf Shrub cover
CV_HRB	Estimate of Herbaceous cover
CV_OTH	Estimate of Non-vascular plant cover
CV_AQU	Estimate of Aquatic plant cover

CV_BAR	Estimate of Barren (non-vegetated) cover
CV_WAT	Estimate of Water cover
CV_UNDF	Estimate of Undefined cover
DENSITY	see TREE_COVER
DSH_COVER	The estimated cover of Dwarf Shrubs
ELEVATION_FT	The estimated elevation (feet) at the training site location
GRAM_COVER	The estimated cover of graminoids
GRIDCLVAL	Major class grid value - a numeric code for MAJOR_CLASS
GRIDVAL (VALUE)	The pixel value of this class in the final pixel map
HDWD_COVER Or HDWOOD_COVER	The estimated percent of tree cover comprised by hardwoods
HRB_COVER	The estimated cover of herbaceous plants
H2O_COVER	The estimated cover of water
OTHER_ID	Original FirePro (IMA), DU, or ABR ID number
ISO_CLASS	The original iso_class number used during candidate site development and selection
LATITUDE	The latitude of the training site location
LICHEN_FLAG	Set to 1 if at least 20% Lichen cover
LONGITUDE	The longitude of the training site location
LSH_COVER	The estimated cover of Low Shrubs
MAJOR_CLASS	The major land cover class descriptive name – a generalized Land Cover Type.
MAJOR_CLASS	same as MAJOR_CLASS
MODIFIER	Modifier (morphologic) Code – only valid for GRS sites where indicated.
NOTES	Notes regarding the training site
OTHER_ID	An alternate id for the training site, if the site is from a non-GRS source. This is the FirePro, DU, or ABR id for the training site.

OTHER_VEG_COVER Or OTHER_COVER	The sum of all non-woody vegetation cover (shrub + herb. + other)
OTH_COVER	The estimated cover of other (non-vascular) plants
PCT_CONF Or PCT_CONIFER	The estimated percent of tree cover comprised by conifers
PCT_HDWD Or PCT_HDWOOD	The estimated percent of tree cover comprised by hardwoods
PHOTO_ID	The digital photo name for the image of the training site. Usually corresponds with the training site id. An 'x' at the end of the name indicates multiple pictures, with a suffix of a,b,c, … exist.
PHOTO_QC	Photo issues and concerns XX = none OO = missing or partial photo NULL = non-GRS site no photo
PHOTO_TIME	The time of photo acquisition
PR_COMP	The predominant component of the land cover - specific to species or group of similar species (same as PR_SPECIES)
PR_COMP_COVER	The estimated percent land cover of the PR_COMP
PR_SPECIES	The predominant component of the land cover - specific to species or group of similar species (same as PR_COMP)
PRED_SP_COVER	The estimated percent land cover of the PR_SPECIES
REGIME	Hydrologic Regime – only valid for GRS sites where indicated.
REMAP_VAR	ReMap Value - scratch column used to store sql derived values and generate different map representations
SALIX_COVER	The estimated cover of Salix species
SCENE_IND	A 9 character Indicator value to identify in which scenes a training site was used: 0 = not trained 1 = trained C = clouded or hazy Scenes are indicated by the column of the value - From left to right: 6118, 63678, 6378, 6418, 6467a, 6467s, 6567, 65678, and 6767.
SHR_COVER	The sum of Tall and Low Shrub cover

SLOPE_DEGREES	The estimated slope (degrees) at the training site location
SOURCE	The source of the trsite information - same codes as SOURCE_COVER
SOURCE_COVER	The source of the cover data estimates:

ABR	= ABR Field Site
FirePro	= AKRO FirePro Data Site
DU	= Ducks Unlimited Aerial Survey
GRSAIR	= Aerial Survey Site
GRSSUPP	= supplemental GRS site
GRSUNK	= modeled GRS Terrain Shadow site
ISO_CL	= Unsupervised class data
UNCLASS	= Unclassified

SOURCE_GRIDVAL — The source of the pixel classification:

ISOCL90	= Unsupervised 90%
ISOCL99	= Unsupervised 99%
SUPML90	= Supervised Max-likelihood 90%
SUPML90M	= Supervised Max-likelihood 90% PicMar=>PicGla modeling
SUPML90S	= Supervised Max-likelihood 90% Conifer/Shrub Elevation modeling
SUPML99	= Supervised Max-likelihood 99%
SUPML99M	= Supervised Max-likelihood 99% PicMar=>PicGla modeling
SUPML99S	= Supervised Max-likelihood 99% Conifer/Shrub Elevation modeling
TERRSHDW	= Modeled to Terrain Shadow
n/a	= unknown

SPECIES	The species/name of the land cover component
SPEC_CLASS	The original Land Cover Class estimated through application of the Land Cover Classification rules before this type was derived or changed through modeling.
SPCODENUM	The species code number of the land cover component
SPCODE	The species code symbol of the land cover component

STRATA	The vegetation profile of the land cover component:
	B = Barren C = Conifer D = Dwarf Shrub F = Herbaceous/Forb H = Broadleaf L = Low Shrub T = Tall Shrub U = Unknown W = Water
TREE_COVER	The estimated percent tree cover (density or canopy closure)
TRSITE_ID	Training site id number - the unique identifier of the training site
TRSITE-ID	The unique identifier of the training site point
TSH_COVER	The estimated cover of Tall Shrubs
TUSSOCK_FLAG	Set to 1 if at least 15% EriVag cover
TYPE	The 3 character Land Cover Type of the Land Cover Class

AqF	=	Aquatic Forb
AqW	=	Water-Aquatic Forb
BPa	=	Paper Birch
BaW	=	Barren-Wet
Bar	=	Barren/NonVeg
DSC	=	Dwarf Shrub:Cassiope
DSD	=	Dwarf Shrub:Dryas
DSE	=	Dwarf Shrub:Ericaceous
DSh	=	Dwarf Shrub
H2O	=	Water
HrC	=	Graminoid
HrD	=	Moist Sedge-Shrub Meadow
HrE	=	Elymus
HrT	=	EriVag-Tussock
Hrb	=	Herbaceous
Hwd	=	Mixed deciduous
LSA	=	Low shrub:Alder
LSB	=	Low shrub:Birch
LSE	=	Low shrub:Ericaceous
LSS	=	Low shrub:Willow
LSh	=	Low shrub:Mix
LSi	=	Low shrub:Silverberry
LSm	=	Low shrub:Willow-Birch Mix
Lic	=	Lichen
MSA	=	Mixed shrub:Alder
MSS	=	Mixed shrub:Willow
MSh	=	Mixed shrub:Mix
Mos	=	Moss
PBa	=	Balsam Poplar

PGD	=	White Spruce Dead
PGU	=	White Spruce Cmplx
PGl	=	White Spruce
pgs	=	White Spruce Stunted
pms	=	Black Spruce Stunted
PHw	=	Mixed deciduous-conifer
PMU	=	Black Spruce Cmplx
PMa	=	Black Spruce
PSi	=	Sitka Spruce
PTi	=	Cottonwood
PTr	=	Aspen
SVW	=	Water-Sparse Vegetation
SVg	=	Sparse Vegetation
SnG	=	Snow/Glacier
TSA	=	Tall shrub:Alder
TSS	=	Tall shrub:Willow
TSh	=	Tall shrub:Mix
TTA	=	Tree shrub:Alder
TTS	=	Tree shrub:Willow
UP	=	Spruce Mix
UPU	=	Spruce Mix Cmplx
UTb	=	Unknown Terrain Shadow-Barren ?
UTs	=	Unknown Terrain Shadow-Snaow/Ice ?
UTu	=	Unknown Terrain Shadow-Unknown
UTv	=	Unknown Terrain Shadow-Vegetation ?
UnC	=	Unknown Cloud/Shadow
???	=	Unknown

UNDF_COVER — The estimated cover of an undefined component

VALUE (GRIDVAL) — Pixel value used to associate grid to attribute tables

WET_FLAG — set to 1 if at least 20% water cover or an Aquatic site

X_COORD — The X coordinate value (Albers Projection) at the training site location

Y_COORD — The Y coordinate value (Albers Projection) at the training site location

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