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ASSESSMENT OF LAND COVER AND RIPARIAN ZONES FOR THE FORD RESEARCH FOREST - HICKEY CREEK/STURGEON RIVER AND FALLS RIVER SUBWATERSHEDS

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ASSESSMENT OF LAND COVER AND RIPARIAN ZONES FOR THE FORD RESEARCH FOREST – HICKEY CREEK/STURGEON RIVER AND FALLS RIVER SUBWATERSHEDS

By

Fay Dearing

A REPORT

Submitted in partial fulfillment of the requirements for the degree of

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This report has been approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE in Applied Ecology

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

For landowners, knowing the contents of their land is always a primary concern. Traditional field based assessments can be challenging and expensive for large landholdings as well. However, by utilizing remote sensing and GIS models the land cover/land use and riparian areas can be more easily identified on a larger landscape level. To this end two remote sensing techniques were explored to create a land cover/land use map for the study area. The first, utilizing object-oriented techniques and high spatial resolution generated an overall accuracy of 71.97% which indicated a moderate agreement with the classified image and the field truthed ground data. The second method which utilized Landsat 5 TM multi-temporal imagery and more traditional classification techniques had an overall accuracy of 75.05%. Lastly a GIS model for finding the delineated border of riparian areas was run to determine the extent of riparian zones on the Ford Research Forest. The results of this indicated that utilizing a flood height of 1 meter and incorporating hydric soil and wetland data into the model generated the most conservative model results.

CHAPTER 1

A LOOK AT THE STUDY SITE

1.1 Overview

The Michigan Technological University (MTU), School of Forest Resources and Environmental Science (SFRES) Ford Research Forest is the School's largest landholding. As these landholdings are the school's largest outdoor laboratory and a vital training ground for undergraduates and graduates, it is important to know and understand the area's land cover and riparian zones in order to better understand the ecosystem itself. As such, the following three objectives were undertaken to develop a better understanding of the forest and improve long term forest management plans:

I. Assess the utility of high spatial resolution (1 meter) NAIP aerial imagery for creating a detailed land use/cover map for the Ford Research Forest lands in the Hickey Creek/Sturgeon River and Falls River subwatersheds.

II. Assess the use of Landsat 5 Thematic Mapper (TM) multi-temporal imagery, and traditional pixel based classification techniques to develop a smaller scale land use/cover map for the same area as noted in objective 1

III. Assess the use of the Riparian Buffer Delineation Model (RBDM) and identify riparian zones through the Ford Research Forest in the same area.

1.2 Study Area Description

The study area was located in the northwestern Upper Peninsula (UP) of Michigan in Baraga County (Figure 1.1), and was comprised of two National Hydrography Dataset (NHD) HUC 11 subwatersheds encompassing approximately 27,561 hectares of mostly

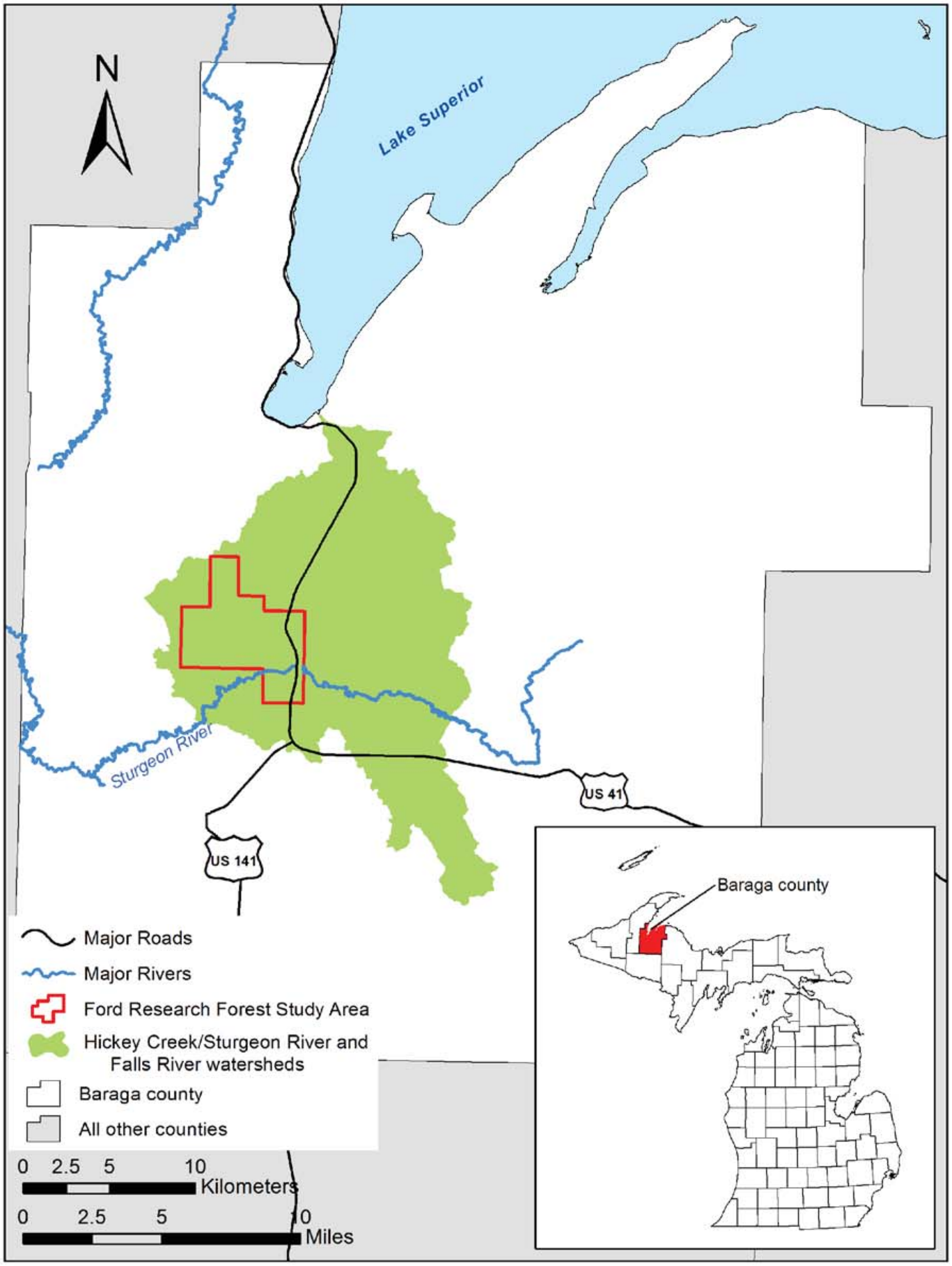

Figure 1.1 – Study area for Hickey Creek/Sturgeon River and Falls River watersheds located in Baraga County, Michigan.

forested landscapes. The two subwatersheds were the Hickey Creek/Sturgeon River watershed (HUC code # 40201050602) and the Falls River watershed (HUC code # 40201040103). Subwatershed boundaries were downloaded from the USGS's National Map Viewer (URL: http://viewer.nationalmap.gov/viewer/).

This study area was chosen as the two subwatersheds contain the MTU Ford Center Research Forest. A 1,470 hectare series of parcels primarily composed of timber land and Alberta Village; a small historic community containing an early Ford Motor Company sawmill. Alberta was founded and constructed by Henry Ford beginning in 1935 and completed by 1938. The sawmill in Alberta was used to provide Ford Motor Company with lumber needed to produce early model vehicles as well as present a positive idealized image to the public of a working company town. However, as wood in early model cars was replaced with other materials, the company no longer needed the forest lands and the sawmill, and donated the village and some 700 hectares of surrounding land to the Michigan College of Mining and Technology, now MTU. Additional land was gifted to the university from the Michigan Department of Conservation.

Topography for the area is comprised of rolling hills that vary between 180 to 550 meters above sea level. The climate of the area is characterized by warm summers and cold winters with the area receiving approximately 34 inches of rain each year and 148 inches of snow in the winter.

Major soil types include but are not limited to (Figure 1.2): Alstad, Carbondale, Champion, Kalkaska, Net, Peshekee, Rubicon, Sturgeon, and Tacoosh series soils (Soil Conservation Service, 1988).

There is a great variety of overstory tree species in the area, and common species include: jack pine (*Pinus banksiana*), white pine (*Pinus strobus*), red pine (*Pinus*

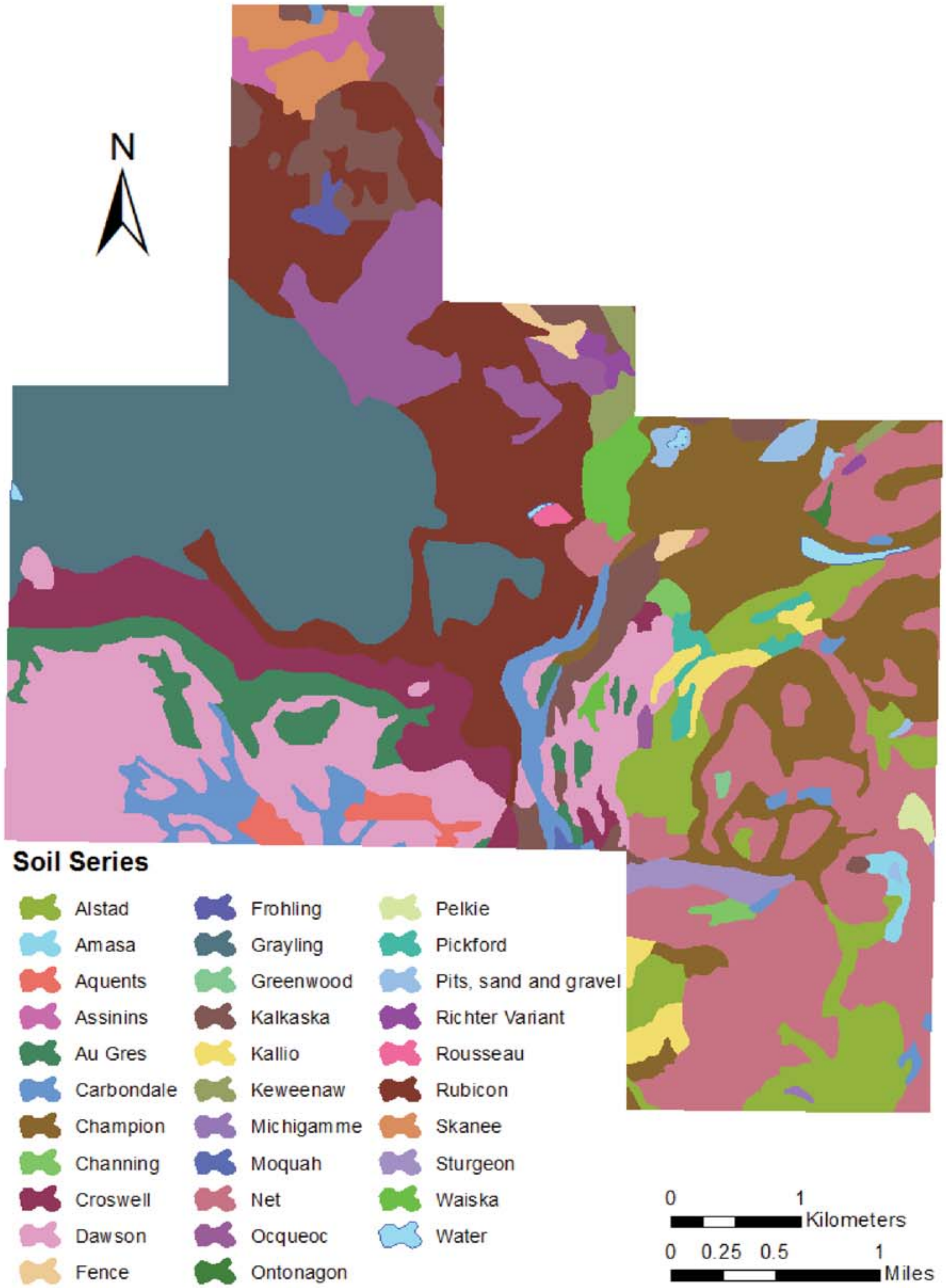

Figure 1.2 – Soil map for NAIP imagery study area.

resinosa), Eastern hemlock (*Tsuga Canadensis*), balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), tamarack (*Larix laricina*), northern white cedar (*Thuja occidentalis*), trembling aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), American basswood (*Tilia americana*), white ash (*Fraxinus americana*), and red oak (*Quercus rubra*) among others (Barnes and Wagner, 1981). Due to the variety of forest cover types, this area was considered to be a representative sample of the various ecosystems located in the Western UP.

Common habitat types include: PVDc/PVCx (*Pinus strobus/Vaccinium angustifolium – Deschampsia flexulosa* or *Carex spp.*), PQE (*Pinus strobe – Quercus rubra/Epigaea repens*), PArV[w] (*Pinus strobus/Vaccinium angustifolium* [Wisconson variant]), PArVAa[w] (*Pinus strobus/Vaccinium angustifolium – Aralia nudicaulis* [Wisconson variant]), AVVb (*Acer saccharum/ Vaccinium angustifolium – Viburnum acerfolium*), TMC (*Tsuga Canadensis/Maianthemum canadense – Coptis groenlandica*), ATM (*Acer saccharum - Tsuga Canadensis/Maianthemum canadense*), ATD (*Acer saccharum - Tsuga Canadensis/Dryopteris spinulosa*), ATD-Hp (*Acer saccharum - Tsuga Canadensis/Dryopteris spinulosa – Hepatica* variant), and AOCa (*Acer saccharum/Osmorhiza claytoni – Caulophyllum thalictroides*) among others (Burger and Kotar, 2003).

1.3 Geomorphology and Early European Settlement Influences

The UP is a variable landscape of differing landforms, streams, and soils overlain by a complex network of vegetation. This variation in landform and land cover is due to a long history of glaciation and human activities that have resulted in the current forest cover.

While the Great Lakes region has been glaciated at least six times (Fullerton, 1986; Johnson, 1986), the advance and retreat of the last ice sheet had the greatest influence on current landforms (Larson and Schaetzl, 2001). This last glacial event, referred to as the Wisconsin glaciation, resulted in the Laurentide Ice Sheet expanding southward from northern and eastern Canada to cover the entire Great Lakes region. Johnson *et al.* (1997) describes how the this ice sheet advanced across the area starting ~26,000 years ago and reached its southernmost position in east-central Illinois by 20,000 to 19,000 years before present. Its borders then fluctuated over a period of ~3,000 years before beginning a retreat northward approximately 17,000 to 16,000 years before present. While the glacier was in its retraction phase, there were several additional advances made in 15,500, 13,000, 11,800, and 10,000 years before present as well as the development of several glacial lakes. These glacial lakes included Lake Nipissing which covered much of the area now within Lake Superior's borders.

The glacial advance of 10,000 years ago in particular greatly affected the landscape of the UP as it created a prominent end moraine across much of the area and resulted in the creation of most of current landforms and soils (Larson and Schaetzl, 2001). By 9,000 years before present the glaciers retreated completely from the Great Lakes region (Karrow *et al.,* 2000).

This extensive glaciation created a variety of landforms and resulting soils. Large areas of moraines, eskers, outwash plains, drumlins, etc. became the building blocks for the area's soils. Soil substrate is one of the primary reasons (along with disturbance history) behind the differentiation of habitat types and the vegetative communities growing on them (Ewing, 2002; Seymour *et al.,* 2002; Stephenson, 1990; Whitney, 1986). Due to this great variation in soils and habitat types over 80 species of native trees and shrubs can be found in Michigan with exotic species introduced as well (Barnes and Wagner, 1981).

The second greatest impact on the UP's vegetative diversity has been anthropogenic. While there is evidence that humans began to inhabit the southernmost portions of Michigan roughly 12,000 years ago (Anderson, 1991), very little seems to be known about these earliest inhabitants. More is known about the tribal groups collectively known as the Anishinaabe who moved into the area during the 1600s (Clifton *et al.,* 1986). However little has been written about the ecological impact they had on the forests of the Great Lakes region. Mann (2005) describes in his book, *1491: New revelations of the Americas before Columbus,* much of the controversy about what the Americas were like before permanent European settlement. However, the fact remains that there is no consensus between researchers on the magnitude of ecological impact the Anishinaabe had on the UP or their population numbers. Instead, the primary focus of anthropogenic ecological research has been the impact European settlers had on changing the landscape of the area.

After the Government Land Office completed its surveys in the 1880s, the UP was opened to settlement and exploitation. According to Dickmann and Leefers (2009) excellent book, *The Forests of Michigan*, the logging of Michigan's forests occurred in waves as companies looked for specific species. The first wave of logging activity harvested white pine (*Pinus strobus*) due to its pale coloration, ease of working, and light weight. These trees were considerably larger than many found on the current landscape; often 120 to 170 feet tall with a diameter at breast height (DBH) of 3 to 5 feet or greater. At this time red pine (*Pinus resinosa*) was sometimes cut, but as logging operations increased and the plethora of large white pine decreased, loggers began to harvest different species and smaller diameters as well. The bark of hemlock (*Tsuga canadensis*) was collected due to its value to the tanning industry though the trees themselves were often left behind. Oaks (*Quercus sp.*), maples (*Acer sp.*), and other

hardwoods were also harvested, but at much reduced numbers when compared to pine, mostly due to the fact that it took early loggers additional effort to fell each tree.

As logging operations moved on, fire swept through the areas they left behind. Logging practices at the time left built up slash on the ground and massive forest fires burned through the region in the late 1800s. According to Dickmann and Leefers (2009), the regional fires ignited in October of 1871 after a summer of severe drought. The Great Chicago Fire was the first, destroying much of the early city and was immediately followed by the Peshtigo Fire which burned over 1.28 million acres near current day Green Bay, WI and north into Michigan's Menominee County. At the same time as the Peshtigo Fire was burning, the Great Michigan Fire was sweeping the Lower Peninsula (LP) of Michigan and ultimately burned over 2.5 million acres. More fires struck the LP in the late 1800s, but according to Dickman and Leegers (2009), the UP had only minor forest fires until August 1896 when an out of control forest fire burned the Diamond Match Company timber yards and Ontonagon, MI, destroying over 228,000 acres. A separate forest fire burned L'Anse in the same year with more fires striking the UP through the early and mid-1900s. Some areas were so badly burned by fire and the soil structure destroyed that they've yet to recover and are still barren of anything but the hardiest of sedges.

This history of change makes the UP a complex and interesting landscape. Unlike other parts of the country where single species dominate thousands of acres of land, the UP is a variable ecosystem exceedingly dependent on glaciated landforms, the resulting soils and anthropogenic influences. While this makes the landscape more interesting, it also makes the area much more difficult to map and study as dramatic changes occur within short distances. For example, within the study area, cover types change from mesic deciduous forests dominated by sugar maple to the dry Baraga plains supporting jack pine in less than a mile. Other habitat changes occur within even

shorter distances where small woody wetlands or mixed hemlock stands are found in tiny areas or on south facing slopes.

Utilizing advanced geospatial analysis tools, researchers are able to more easily study and understand this complex landscape. From computer models designed to assist land managers to protect riparian zones and water quality to aerial and satellite imagery used to classify modern day forest land cover, researchers can determine the best way to study the landscape in order to better protect it for the future while still utilizing its resources today.

CHAPTER 2

DELINEATION OF FOREST OVERSTORY SPECIES UTILIZING OBJECT-ORIENTED CLASSIFICATION IN THE HICKEY CREEK/STURGEON RIVER AND FALLS RIVER WATERSHEDS

2.1. Introduction

Forest landowners and managers are concerned with land cover and its structure. Whether attempting to assess the forest's health, composition, and/or growth, land cover is important as it impacts land values and resource sustainability. Traditionally, land cover has been studied via field surveys, such as semi-regular timber-cruises and fixed point plots, but with the improvement of aerial and satellite based imagery, remotely sensed data and its classification has become a more cost effective method of mapping land cover across large areas.

Object-oriented classification is a relatively new digital image processing technique best suited for high spatial resolution imagery. While the idea was proposed in the 1970s, the technology was limited by computing power and did not become widely implemented until the 1990s (Platt and Rapoza, 2008). Object-oriented classification is unique when compared to more traditional pixel based classification techniques, as the imagery is first segmented into discrete image objects. An object is defined as an area where pixel values are relatively continuous in value or recorded reflectance (Benz *et al.,* 2004). While object-oriented classification tends to be more commonly applied to imagery with a high spatial resolution (Leckie *et al.,* 2003; Johansen *et al.,* 2007; Mathieu *et al.,* 2007) or even LiDAR (Antonarakis *et al.,* 2008), there have been techniques developed that combine traditional pixel-based classifiers with object-oriented classification.

Geneletti and Gorte (2003) attempted to combine the two techniques together. Utilizing Landsat Thematic Mapper (TM) 30 meter imagery and black and white orthophotos with 1 meter spatial resolution, they attempted to improve the land cover classification accuracy for a study area in northern Italy. The methods were quite unique as they classified the Landsat TM imagery with a traditional maximum likelihood technique; then separately segmented the orthophoto using a region-growing segmentation algorithm. The segmented orthophoto was then classified utilizing the completed Landsat land use/cover classification. The results of their study indicated that the orthophoto classification had a high level of accuracy.

In a paper by Johansen *et al*. (2007), QuickBird satellite imagery was used to identify riparian forested corridors in British Columbia. In addition to utilizing object-oriented analysis techniques, the researchers also undertook a texture analysis of the imagery to identify various vegetation structural classes. Ultimately the image's classification accuracy was improved by combining the two techniques. However, the imagery's overall accuracy was only improved by 5%. This may indicate that while combining object-oriented classification with texture analysis can improve classifications for forested ecosystems, the additional work of completing a texture analysis may not be cost-effective.

Platt and Rapoza (2008) evaluated whether or not object-oriented analysis techniques improved classification accuracy. They utilized the program, Definiens eCognition® to classify an IKONOS 4 band satellite image with a 4 meter spatial resolution utilizing eight different combinations of pixel and object-oriented classification technique models. These models tested not only the differences between the object-oriented and pixel based analysis techniques, but also the classification algorithms (nearest-neighbor and maximum likelihood), whether expert knowledge was included, and whether or not feature space optimization was utilized. Ultimately, the model that

utilized all of the object-oriented specific techniques had the highest classification accuracy. That said, the maximum likelihood algorithm typically associated with traditional pixel-based classifications did outperform the nearest-neighbor algorithm when evaluated as a standalone approach. However, as Definiens eCognition® also utilizes expert knowledge, feature space optimization, and the segmentation of the image itself, the slight weakness in the nearest neighbor algorithm was overcome with the additional techniques. The objective of this project was to create and assess a land use/land cover map for the Ford Research Forest properties utilizing high spatial resolution imagery and an object-oriented classification technique.

2.2 Methods

2.2.1 NAIP Aerial Imagery

A high spatial resolution (1 meter) digital mosaicked orthophoto (Figure 2.1) was used to delineate land cover types for the study site. This image was a four-band National Agriculture Imagery Program (NAIP) orthophoto displaying three visible color bands (blue, green and red) as well as near-infrared reflectance acquired on July 21, 2012. It was downloaded from The National Map Viewer (URL: http://viewer.nationalmap.gov/viewer/). The image was clipped to the Ford Research Forest boundary plus a 200-400 meter buffer to match the extent of the Ford Research Forest LiDAR DEM.

2.2.2 Object-Oriented Classification

The segmentation and classification of the image was done in SPRING which is produced by the National Institute for Space Research based in São José dos Campos, Brasilia. This program was used because a study by Meinel and Neubert (2004) gave it an excellent review and high ranking when compared to other digital image processing

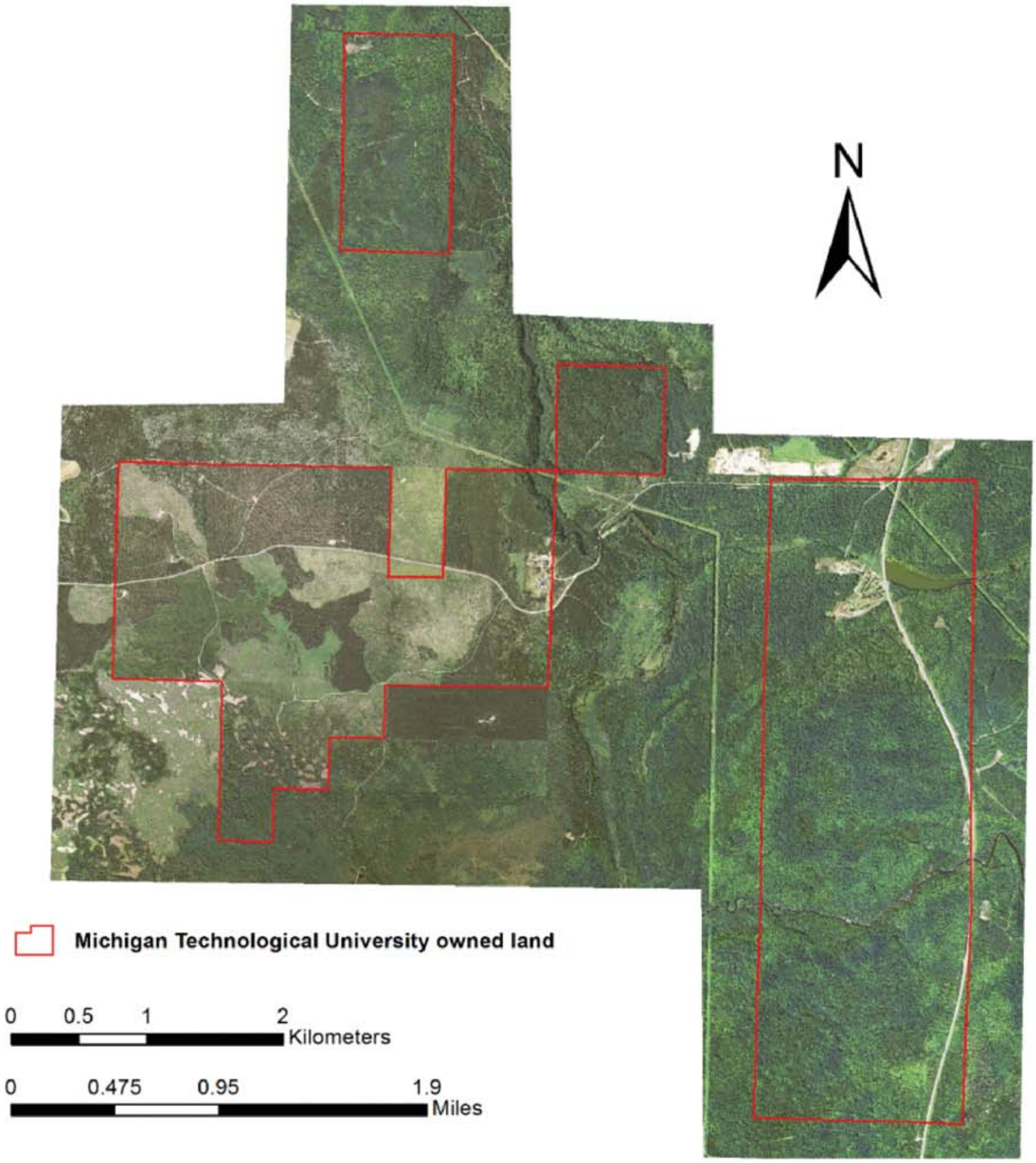

Figure 2.1 – True color mosaicked NAIP imagery of study area with Ford Research Forest boundary overlaid.

programs. It is also readily available as a free download (URL: http://www.dpi.inpe.br/spring/english/). SPRING is a computationally intensive program and can be very unstable when processing large image files or when the image is segmented too finely. Hence a delicate balance must be met with the image segmented enough to meet the desired classification goals while not overwhelming the program's computational limitations causing it to crash.

The program's built in segmentation algorithms utilized the four bands of the NAIP imagery and the land cover classification scheme presented in Table 2.1 and a region growing method. This approach was chosen as it has been shown to provide better results than the program's basin detection method which is designed primarily for segmenting topographic imagery (Meinel and Neubert, 2004). The similarity parameter for the segmentation was set to 10 while the minimum area parameter was set to 1000 pixels. These parameters were chosen based on multiple runs to determine the best segmentation results. Once the segmentation of the image was completed, SPRING was also used to classify the image.

Table 2.1 – Object-oriented information classes for the NAIP imagery.

Classification Category	Description of class
Aspen	>75% trembling and/or bigtooth aspen, also paper birch
Conifer	>75% conifers with a canopy of red pine and/or white pine
Deciduous	>75% deciduous species including sugar maple, red maple, red oak, American bassword, yellow birch, and/or white ash
Jack Pine	>75% jack pine
Mixed	A 40 - 60% mix of the conifer and deciduous class, commonly including hemlock
Open	>75% grasslands and agricultural areas
Paved	>75% impermeable surfaces, gravel roads and/or bare earth including gravel pits and buildings
Tamarack	>75% tamarack
Water	>75% water
Woody Wetland	>75% wet, forested wetlands including areas with canopies of tag alder, balsam fir, black spruce, and/or northern white cedar

Training sets were input into the program based on field data. Image classification was done utilizing the Bhattacharya distance (Bhat) for the feature selection and followed by a nearest-neighbor classifier with a 95% acceptance threshold. The Bhattacharya distance algorithm (Equation 1) was chosen as it is capable of determining the spectral reflectance separability of two or more given classes, assuming that they have a Gaussian distribution and the means and covariance matrix can be calculated (Jensen 2005). As the NAIP imagery meets these requirements, the Bhattacharya distance algorithm was chosen. The Bhattacharya distance equation is (Duda *et al.,* 2001):

$$Bhat_{cd} = \frac{1}{8}(M_c - M_d)^T \left(\frac{V_c + V_d}{2}\right)^{-1} (M_c - M_d) + \frac{1}{2}\log_e \left[\frac{\left|\frac{V_c + V_d}{2}\right|}{\sqrt{(|V_c| * |V_d|)}}\right] \tag{1}$$

$Where\ M_c\ and\ M_D\ equal\ the\ means\ of\ classes\ c\ and\ d\ and$

$V_c\ and\ V_D\ equal\ the\ movariance\ matrices\ of\ classes\ c\ and\ d$

2.2.3 Accuracy Assessment

Guidelines developed by Congalton and Green (2008) were used to collect field ground truth data. These guidelines recommend having a minimum of 50 samples per class in study areas less than 1 million acres and containing fewer than 12 classes. Following these guidelines, 50 non-overlapping random points were generated for each of the 10 classes present in Table 2.1. Plot locations were randomly generated via ArcMap based on a stratified random sampling design. Due to some points being located on posted private land or otherwise inaccessible, 29 points were eliminated and a total of 471 ground truth points were collected. The distribution of the accuracy points is displayed in Figure 2.2 with the coordinates, classification, and field checked results in Appendix A.

Accuracy points were loaded onto a GPS unit and visited to determine their field results. Due to the small spatial resolution, assessment was simple. After arriving at the designated point location the user identified landcover type by class and recorded the results. Utilizing this ground truth data, an error matrix was created. Error matrixes are an easy, effective way to display image classification accuracy as they show errors of commission and omission for each information class or land cover type. A commission error is defined by Congalton and Green (2008) as "including an area in a category (or information class) when it does not belong to that category" while an omission error is defined as "excluding that area from the category in which it truly does belong." A sample error matrix, based on one found in Congalton and Green (2008) is shown in Figure 2.3.

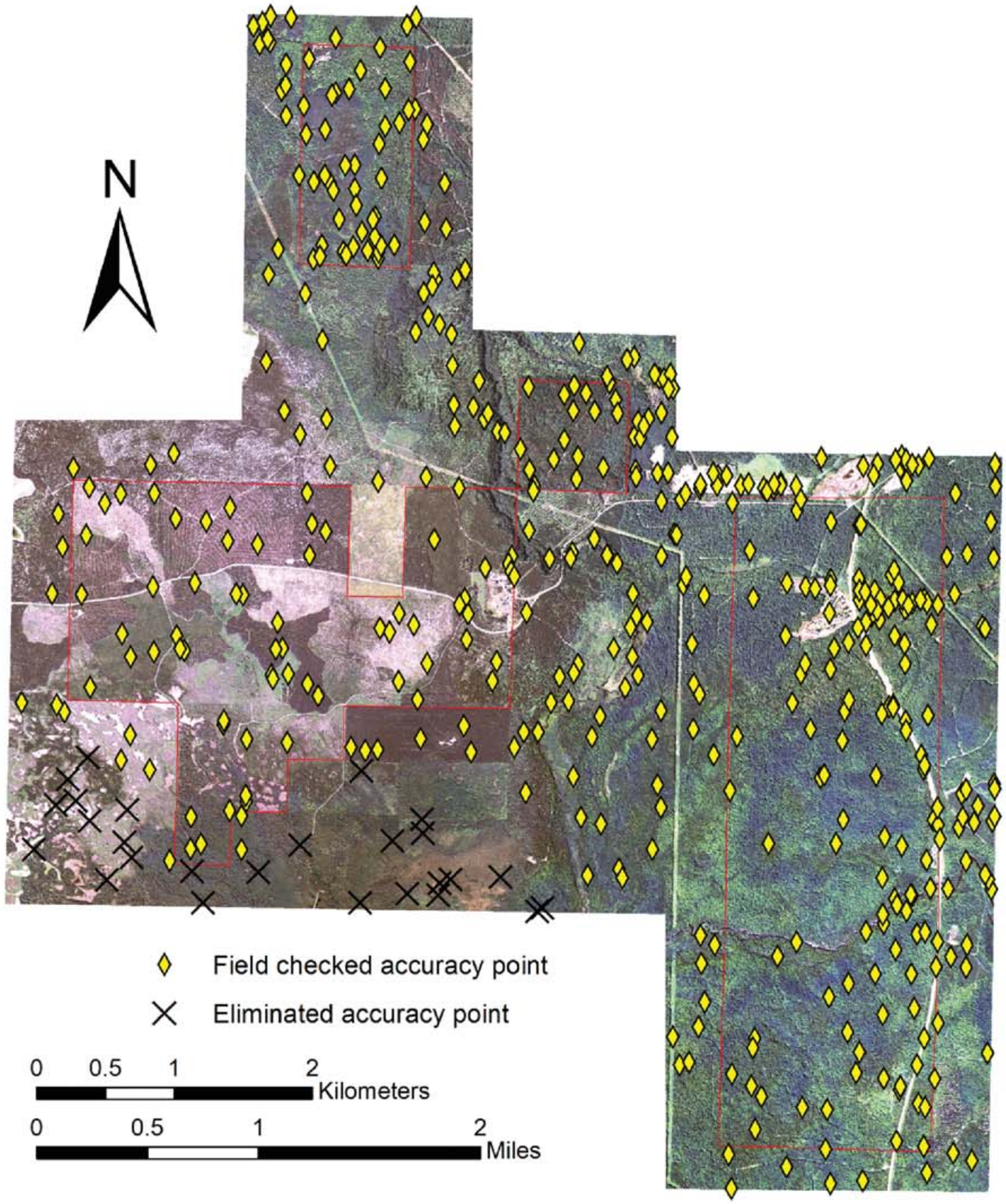

Figure 2.2 - Distribution of field accuracy points for the NAIP imagery.

j = columns
(field reference points)

		1	**2**	**k**	**Row Total n_{i+}**
i= rows	**1**	n_{11}	n_{12}	n_{1k}	n_{1+}
(classified	**2**	n_{21}	n_{22}	n_{2k}	n_{2+}
image points)	**k**	n_{k1}	n_{k2}	n_{kk}	n_{k+}
	Column Total n_{+j}	n_{+1}	n_{+2}	n_{+k}	n

Figure 2.3 - Sample error matrix widely employed in assessing classified remotely sensed imagery.

Besides illustrating commission and omission errors, the error matrix also can be used to generate overall accuracy and kappa analysis results as well as producer's accuracy and user's accuracy for each information class. According to Congalton and Green (2008), the overall accuracy of an image is calculated by summing the major diagonal of the error matrix, which are the correctly classified sample points, then dividing the value by the total number of sample points collected (Equation 2).

$$Overall\ Accuracy = \frac{1}{n}\sum_{i=1}^{k} n_{ii} \quad (2)$$

Unlike the overall accuracy which rates the accuracy of the entire image, the producer's and user's accuracy are broken down by information class and determine the accuracy of each. The producer's accuracy calculates the probability that an information class for an area on the ground is classified correctly while the user's accuracy calculates the probability that a pixel labeled as a certain class is actually part of that class. The producer's accuracy is calculated by dividing the number of correctly

classified sample points in a single class by the total column number of sample points for that class (Equation 3). Refer to Figure 2.2 for variable definition.

$$Producer's\ Accuracy_j = \frac{n_{jj}}{n_{+j}} \tag{3}$$

The equation for user's accuracy (Equation 4) is very similar to the producer's accuracy. However, instead of dividing by the information class's column total, the number of correctly classified sample points in a class is divided by the row total for each class (Congalton and Green, 2008). Refer to Figure 2.2 for variable definition.

$$User's\ Accuracy_i = \frac{n_{ii}}{n_{i+}} \tag{4}$$

The error matrix can also be used to calculate secondary classification statistics such as the Kappa analysis (KHAT or $\widehat{K}$) (Equation 5). Congalton and Green (2008) define Kappa analysis as the "measure of agreement [that] is based on the difference between the actual agreement in the error matrix (i.e., the agreement between the remotely sensed classification and the reference data as indicated by the major diagonal) and the chance of agreement which is indicated by the row and column totals (i.e., marginal)." The strength of the Kappa analysis is that if an image is being classified by multiple analysts or using multiple techniques, the variance and the z-statistic of the image can be calculated and compared to see which analyst or technique produces the most accurate results. While for the purposes of this study only one analyst using a single technique was used, reporting the $\widehat{K}$ value should still be done as it is considered to be a standard accuracy assessment measurement.

$$\widehat{K} = \frac{n\sum_{i=1}^{k} n_{ii} - \sum_{i=1}^{k} n_{i+}n_{+i}}{n^2 - \sum_{i=1}^{k} n_{i+}n_{+1}} \tag{5}$$

A second analysis technique for analyzing the accuracy of remotely sensed data is Margfit analysis. Margfit analysis is "applied to normalize or standardize the error

matrices for comparison purposes" and is a better representation than the overall accuracy assessment due to the fact that the error matrix is normalized. The Margfit analysis is a relatively simple procedure. First the error matrix is normalized by dividing the number of points for each cell of the matrix by the total number of points collected for each information class. This normalizes all of the error matrix cells and can be easily multiplied by 100 to generate a percentage for each cell. The resulting values are then averaged along the major diagonal axis to generate a single value.

The paper by Landis and Koch (1977) describes the possible values of $\widehat{K}$ by dividing them into three groupings. Values with a $\widehat{K}$ greater than 80% represent a strong agreement between the classified image and the field collected reference data while values between 40% and 80% represent moderate agreement and values less than 40% represent poor agreement. For the purposes of this paper all of the accuracy assessments shall be judged by these groupings to determine if the classification is meaningful.

2.3 Results

2.3.1 Segmentation

Figure 2.4 depicts the final segmentation at Alberta. While requiring the minimum area to be at least 1,000 pixels (which equates to being 1,000 meters^2) the approach did tend to leave stand-alone trees grouped with larger objects. It also greatly simplified tree crown classification with entire tree crowns grouped together and somewhat reduced the impact of shadows.

Figure 2.4 – Segmentation of NAIP imagery at Alberta, Michigan.

2.3.2 Resulting Land Cover Map for Study Area

Figure 2.5 shows the final land cover classification completed with SPRING. After completion, the image was exported out of SPRING as an .img (image) file in order that it could be imported into other programs for further analyses.

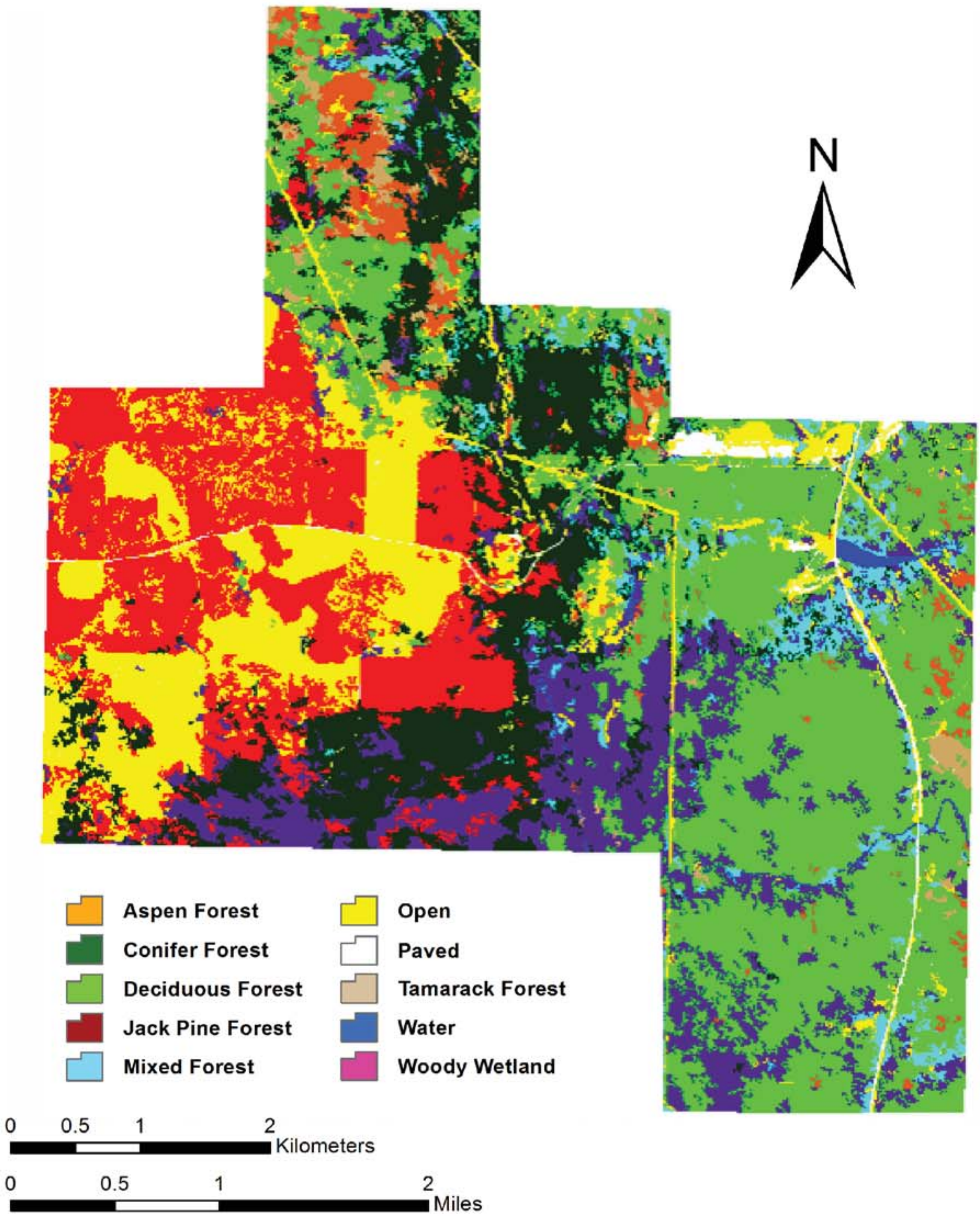

Figure 2.5 – Final classification utilizing SPRING and NAIP mosaic.

2.3.3 Error Matrices

Table 2.2 displays the error matrix, depicting the breakdown of ground truth points versus the classification by information class. The major diagonal axis is highlighted in yellow for ease of reading as this axis represents how many ground truth points were correctly classified by information class.

Table 2.2 – Object-oriented classification error matrix

Classified Imagery	Ground Truthed Field Data: Aspen	Conifer	Deciduous	Jack Pine	Mixed	Open	Paved	Tamarack	Water	Woody Wetland	**Sum Row**
Aspen	40	3	2	-	-	-	-	21	-	-	**66**
Conifer	1	26	2	1	-	-	-	-	3	1	**34**
Deciduous	9	-	42	-	5	-	-	4	1	10	**71**
Jack Pine	-	3	-	42	-	2	-	-	-	2	**49**
Mixed	-	1	2	-	34	-	-	7	3	7	**54**
Open	-	1	-	1	2	38	2	-	6	-	**50**
Paved	-	-	-	-	-	2	48	-	1	-	**51**
Tamarack	-	-	-	-	-	-	-	11	-	-	**11**
Water	-	-	-	-	-	-	-	-	36	-	**36**
Woody Wetland	-	7	2	3	9	2	-	4	-	22	**49**
Sum Colum	**50**	**41**	**50**	**47**	**50**	**44**	**50**	**47**	**50**	**42**	**471**

The normalized error matrix used to calculate the Margfit analysis is depicted in Table 2.3 in percentages. The highlighted values represent the proportional percentage of points that were correctly classified in each information class. Overall the normalized values represent strong or moderate agreement with the exception of Tamarack which, at 23.04%, represents poor agreement.

Table 2.3 – Normalized object-oriented classification error matrix

Normalized Error Matrix

Classified Imagery	Aspen	Conifer	Deciduous	Jack Pine	Mixed	Open	Paved	Tamarack	Water	Woody Wetland
Aspen	80.00%	7.32%	4.00%	-	-	-	-	44.68%	-	-
Conifer	2.00%	63.41%	4.00%	2.13%	-	-	-	-	6.00%	2.38%
Deciduous	18.00%	-	84.00%	-	10.00%	-	-	8.51%	2.00%	23.81%
Jack Pine	-	7.32%	-	89.36%	-	4.55%	-	-	-	4.76%
Mixed	-	2.44%	4.00%	-	68.00%	-	-	14.89%	6.00%	16.67%
Open	-	2.44%	-	2.13%	4.00%	86.36%	4.00%	-	12.00%	-
Paved	-	-	-	-	-	4.55%	96.00%	-	2.00%	-
Tamarack	-	-	-	-	-	-	-	23.40%	-	-
Water	-	-	-	-	-	-	-	-	72.00%	-
Woody Wetland	-	17.07%	4.00%	6.38%	18.00%	4.55%	-	8.51%	-	52.38%

The final classification represents a moderate agreement with the ground truth data with an overall accuracy of 71.97%; though the results of the Kappa analysis and the Margfit analysis were both slightly lower at 68.83% and 71.49% respectfully (Table 2.4). However these results were well within the margins of Landis and Koch (1997) grouping for moderate agreement and while not high, are considered acceptable classification percentages.

Table 2.4 – Overall statistics associated with the error matrix

Assesment Method	Result
Overall Accuracy	71.97%
Kappa Analysis	68.83%
Margfit analysis	71.49%

Table 2.5 depicts the producer's and user's accuracy broken down by information class. Overall, each information class exhibits strong or moderate agreement except for Tamarack which only has a producer's accuracy of 23.40%. Another particularly low accuracy information class was the Woody Wetland class with a producer's accuracy of 52.38% and a user's accuracy of 44.90%. While both of these values are still considered to represent moderate agreement, they are in the lower end of the value range.

Table 2.5 – Producer and User accuracy statistics associated with the error matrix.

Classification Category	Producer's Accuracy	User Accuracy
Aspen	80.00%	60.61%
Conifer	63.41%	76.47%
Deciduous	84.00%	59.15%
Jack Pine	89.36%	85.71%
Mixed	68.00%	62.96%
Open	86.36%	76.00%
Paved	96.00%	94.12%
Tamarack	23.40%	100.00%
Water	72.00%	100.00%
Woody Wetland	52.38%	44.90%

2.4 Discussion

2.4.1 Accuracy assessment

Overall, the classification for the 10 information classes performed well. SPRING was adept at determining land cover types, doing an excellent job of differentiating between Paved, Open, and the various forested land cover types. However, it was found during field data collection that the Tamarack class was greatly over-estimated likely due to the lack of training sets available for this information class. Within the study area there is only one known larch (*Larix sp.*) plantation which covers approximately 13 hectares. While all training sets for this class were located within this area, there was considerable amount of land classified as being part of the Tamarack class, especially in Township 49N 34W, Section 02 of the Ford Research Forest. This part of the Ford Research Forest is admittedly a difficult area to classify as it seems to be in the process of undergoing a land cover type change. While there are many large conifers and jack pine on the landscape the area is largely being overtaken by aspen in the stem exclusion stage. However, it is possible that the combination of new aspen and older

conifers and jack pine were spectrally similar enough to established larch to result in the misclassification.

Besides the Tamarack class, the other class that seemed unusually low was the Woody Wetland class with a producer's accuracy of 52.38% and a user's accuracy of 44.90%. As seen in Table 2.3 there was considerable confusion between this class and the Deciduous, Conifer, and Mixed classes. While the precise reason for this confusion are unknown, it is likely due to the Woody Wetland class being a particularly broad class in terms of the range of spectral reflectance values which included deciduous wetland species such as tag alder and willow along with evergreen species such as black spruce, northern white cedar, and balsam fir. Dividing up this class into separate deciduous and coniferous woody wetland classes may correct this issue in future assessments.

Additionally, the Water class with a producer's accuracy of 72.00% was also lower than expected. Due to water's ability to absorb almost all near infrared electromagnetic radiation, clear and deep water typically is depicted on imagery as black and can be one of the easiest information classes to classify. However, field checking showed many of the erroneous water areas were located on edges where tree and open areas met or where there was a rapid change in tree heights due to past logging activity. These locations generated dark shadows which closely resembled the spectral signature of water. Creating a separate information class specifically for shadows could correct this issue. However, error assessment in particular could be made more difficult as shadows are not stationary objects and can easily move depending on season, time of day, and amount of cloud cover.

2.4.2 Potential sources of error and variability

Although attempts were made to reduce bias and error across data collection and processing, there are still potential error sources that should be mentioned. Due to the accuracy assessment plots being randomly generated via stratified random sampling, there were 21 plots that were located on either private posted land or areas otherwise inaccessible for assessment purposes. As this land was largely grouped in the south-west portion of the image this area has been largely unexplored and it is uncertain how accurate the classification is for the area.

2.5 Conclusions

For high resolution spatial imagery, using an object-oriented classification program such as SPRING produces a high overall accuracy. While the addition of an information class specifically for shadows could further improve accuracy, determining the accuracy of a shadow class could be difficult. Additionally, while increasing the minimum pixel area to 1000 pixels (approximating an area of 1000 meters^2 on the ground) left stand-alone objects, such as trees, grouped in with larger feature objects it partially negated the effect of shadows on the classification as well as allowed the user to classify entire stands of trees as a single object which more closely approximates how we, as humans, perceive them.

CHAPTER 3

DELINEATING LAND USE/COVER FROM MULTI-TEMPORAL LANDSAT THEMATIC MAPPER (TM) DATA FOR HICKEY CREEK/STURGEON RIVER AND FALLS RIVER WATERSHEDS

3.1 Introduction

Accurately classifying forest cover and habitat types for the Upper Great Lakes region using Landsat TM imagery is difficult and has been the topic of considerable research (Bryant *et al.*,1980; Nelson *et al.*, 1984; Mickelson *et al.*, 1998; Olthof *et al.*, 2008). As many forest management plans require a forest cover type classification, it is important to accurately delineate and map these diverse landscapes. Additionally, land cover changes can also be identified and monitored more efficiently utilizing remotely sensed imagery.

Landsat is the longest, continuous satellite based image acquisition program in the world, with data collection beginning with Landsat 1 in July, 1972. The moderate temporal (16 days) and spatial (30m for Landsat 5 missions) resolutions make it idea for monitoring forests both in the short term and from a historical perspective (USGS, 2014). However, despite the availability and acquisition characteristics of Landsat imagery, mapping the landscape at the individual tree species level can be a very difficult process due to spectral reflectance variation within species (Hill *et al.*, 2010) and spectral reflectance similarity between species. Additionally spectral reflectance for a single pixel often includes shadows and understory reflectance combining with tree crown reflectance.

Hyperspectral imagery helps correct this issue via improved spectral resolution using many narrow width bands and improves forest cover type classification accuracy. However, high spatial resolution hyperspectral imagery is not widely available and is not

always cost effective (Gaveau and Hill, 2003). Additionally, some hyperspectral classification techniques require researchers to collect and maintain a spectral library of all the materials and species they desire to classify which can be expensive and time consuming. Vegetation is particularly difficult to build a spectral library for due to its dynamic life cycle and the many environmental factors, such as drought, which influence this cycle and hence the spectral reflectance curves. To overcome these obstacles, image classification techniques have been developed using multi-temporal imagery composites to take advantage of the seasonal variability of reflectance and use it to advantage (Schriever and Congalton, 1995; Wolter *et al*., 1995; Mickelson *et al.,* 1998; Key *et al*., 2001; Oetter *et al.,* 2001; Hill *et al*., 2010). The key to using multi-temporal imagery composties is to select scenes that cover the spring leaf-out, summer growth, and autumn senescence to improve classification accuracy based on the known phenology of different tree species. Utilizing these data, it is possible to improve classification accuracy. Both Eder (1998) and Schriever and Congalton (1995) found that autumn imagery had the highest classification accuracy and should be incorporated into studies utilizing this method.

Keeping all this in mind, the objective of this project was to create a land cover/land use map utilizing Landsat 5 TM multi-temporal imagery and traditional pixel based classification techniques.

3.2 Methods

3.2.1 Landsat 5 Imagery

A total of four images were downloaded for this project. All images were acquired by the Landsat 5 TM sensor and were obtained from the USGS Earth Explorer website (URL: http://earthexplorer.usgs.gov/). TM imagery is composed of 7 spectral bands

(Table 3.1) which includes a thermal band. The spatial resolution is 30 meters for the 6 reflective bands and 120 meters for the thermal band.

Table 3.1 – Spectral and spatial resolutions for Landsat 5 TM.

Band	Type	Range	Pixel Size
1	Visible	0.45 - 0.52 µm	30 meters
2	Visible	0.52 - 0.60 µm	30 meters
3	Visible	0.63 - 0.69 µm	30 meters
4	Near-IR	0.76 - 0.90 µm	30 meters
5	Mid-IR	1.55 - 1.75 µm	30 meters
6	Thermal	10.40 - 12.50 µm	120 meters
7	Mid-IR	2.08 - 2.35 µm	30 meters

Two summer and two fall images were selected for the study site. No suitable spring imagery was available due to extensive cloud cover. Details for each image are presented in Table 3.2. While the percent cloud cover for the September 26, 2001 image is quite high at 40%, cloud cover was absent for the study area except for a small portion near the town of L'Anse, and was included in the study.

Table 3.2 – Season, dates, ID numbers, and % cloud cover of the selected TM images.

Season	Date of Acquisition	Scene ID #	% Cloud Cover
Summer	June 2, 2011	LT50240282011153PAC01	0%
Summer	July 11, 2002	LT50240282002192LGS01	0%
Fall	September 26, 2001	LT50240282001269LGS01	40%
Fall	October 5, 2010	LT50240282010278EDC00	0%

The images were downloaded and converted to an .img format. Pixel values were transformed from geometrically and radiometrically corrected digital numbers (DN) to top-of-atmosphere reflectance using ERDAS Imagine. The approach developed by Chander *et al.* (2009) was utilized. Additionally, a simple histogram based dark-object

correction was done for each image as there were several clear, deep lakes in the image to represent true dark bodies (Chavez, 1988). No further atmospheric correction was required due to the lack of cloud cover or haze in the images. A 500 m buffer was generated around each watershed utilizing ArcMap 10.2 with the resulting area becoming the study area boundary. The images were then clipped to the extended study area and are shown in Figure 3.1.

3.2.3 Principal Components Analysis

The images were combined into several composites: a summer composite made up of the 2 summer images, a fall composite made up of the 2 fall images, and an all season composite made up of all 4 images. A principal component analysis (PCA) of each composite was generated with the resultant components evaluated for redundant information and noise. Covariance and correlation were calculated utilizing methods detailed in Jensen (2004) and are presented below.

The process of completing a PCA takes several steps. The first generates eigenvalues to determine the percent of total variance explained by each component. From the eigenvalues the total variance can be calculated using a simple summation of the values (Equation 6).

$$Total\ Variance = \sum_{p=1}^{n} eigenvalue\ \lambda_p \tag{6}$$

$Where\ eigenvalue\ \lambda_p\ is\ the\ ERDAS\ Imagine\ generated$

$eigenvalue\ for\ component\ p\ and\ n\ is\ the\ total\ number\ of\ components$

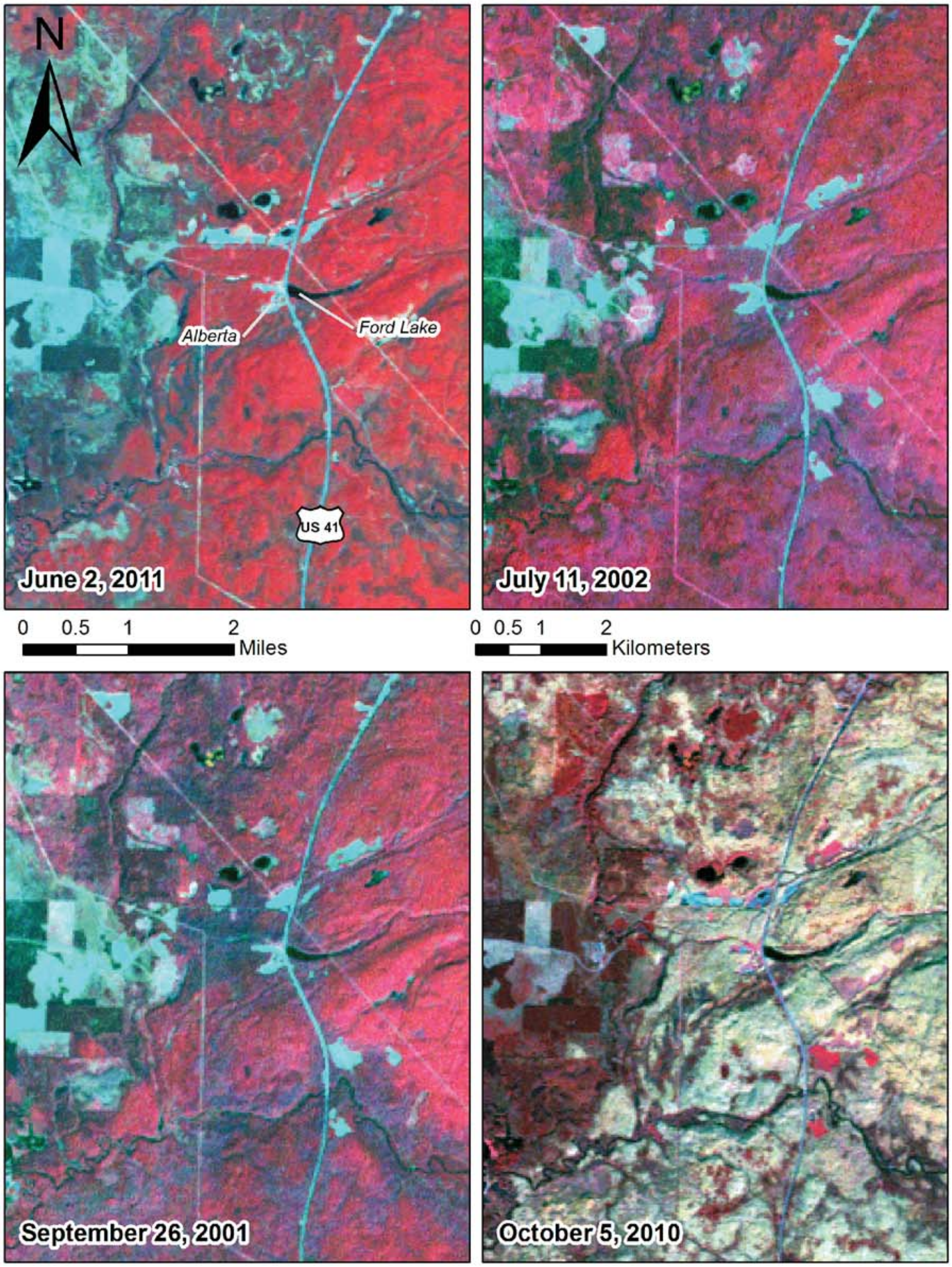

Figure 3.1 – Color infrared composites (Band 4, 3, 2 or near-IR, green, blue) Landsat TM imagery for the study area.

The total variance for the components is calculated, and the percentage of variance explained by each component is determined (Equation 7):

$$Percentage\ of\ variance\ explained\ by\ component\ p = \frac{eigenvalue\ \lambda_p * 100}{Total\ Variance} \quad (7)$$

Next the eigenvectors and covariance matrix for the components are directly calculated by ERDAS Imagine. Next, the factor loading matrix was calculated. Factor loadings tell the user the contribution each band of imagery makes to each PCA component and is calculated using Equation 8 where the information contribution by r each band (k) to principal component (p) is represented by R_{kp}:

$$R_{kp} = \frac{a_{kp} * \sqrt{\lambda_p}}{\sqrt{Var_k}}$$

$$a_{kp} = eigenvalue\ for\ band\ k\ and\ component\ p \quad (8)$$

$$\lambda_p = pth\ eigenvalue$$

$$Var_k = variance\ of\ band\ k\ from\ the\ covariance\ matrix$$

After the factor loadings were calculated, components were removed from the composites due to noise, scanner errors, or otherwise poor data contribution. Components that contained low factor loading values but did not contain considerable noise were kept as they did not otherwise slow down the final analysis. Additionally, while these factor loading values were minimal, it was hoped that the components would still contribute meaningful data to the analysis so they were kept.

3.2.4 Classification

Once the number of components was reduced, ERDAS Imagine was used to classify the composites. A multiple classification technique was used. First the images were classified using unsupervised classification. A total of 75 spectral classes were identified utilizing the ISOdata classification algorithm with a 95% convergence level. Utilizing field data the classes were identified by cover type using Imagine's Signature Editor. Spectral classes representing multiple information classes were eliminated during this process with the "purer" spectral classes that best represented the information classes retained. These spectral classes were then grouped together by information class or cover type. Once this process was completed the signatures were input into Imagine's supervised classification program for final processing. For the supervised classification the Maximum Likelihood parametric rule was used, utilizing all available signature statistics. The resulting 3 classifications (spring, fall, all) were overlaid to generate a composite multi date classification. A 3x3 majority filter used to smooth the image and reduce the salt and pepper appearance. Salt and pepper effect is an error seen in classification in which single pixels are misclassified resulting in greater classification inaccuracy. This is primarily an issue only in traditional pixel-based classifications (Weih and Riggan, 2010).

A total of ten information classes were developed for the classification of the Landsat composites (Table 3.3): Aspen, Conifer, Deciduous, Emergent Wetland, Jack Pine, Mixed, Open, Tamarack, Water, and Woody Wetland.

Table 3.3 – Classification scheme for the Landsat 5 TM imagery.

Classification Category	Description of class
Aspen	>75% trembling and/or bigtooth aspen, also paper birch
Conifer	>75% conifers with a canopy of red pine and/or white pine
Deciduous	>75% deciduous species including sugar maple, red maple, red oak, American bassword, yellow birch, and/or white ash
Emergent Wetland	>75% wet, unforested wetlands including reeds, sedges, shrubs, and willow
Jack Pine	>75% jack pine
Mixed	A 40 - 60% mix of the conifer and deciduous class, commonly including hemlock
Open	>75% grasslands, agriculture, impermeable surfaces, gravel roads and/or bare earth including gravel pits and buildings
Tamarack	>75% tamarack
Water	>75% water
Woody Wetland	>75% wet, forested wetlands including areas with canopies of tag alder, balsam fir, black spruce, and/or northern white cedar

3.2.4 Accuracy Assessment

For the purposes of this project, the accuracy assessment for the Landsat TM pixel-based classification was analyzed using the same methods and equations detailed in Chapter 2, Section 2.2.4. A total of 50 field points were randomly generated for each information class for a total of 500 accuracy assessment points. A total of 473 accuracy assessment points were field checked with 27 points not visited due to private posted lands and/or physical inaccessibility. Figure 3.2 displays the distribution of the field accuracy points for the area of interest and the coordinates, classification, and field checked results in Appendix B.

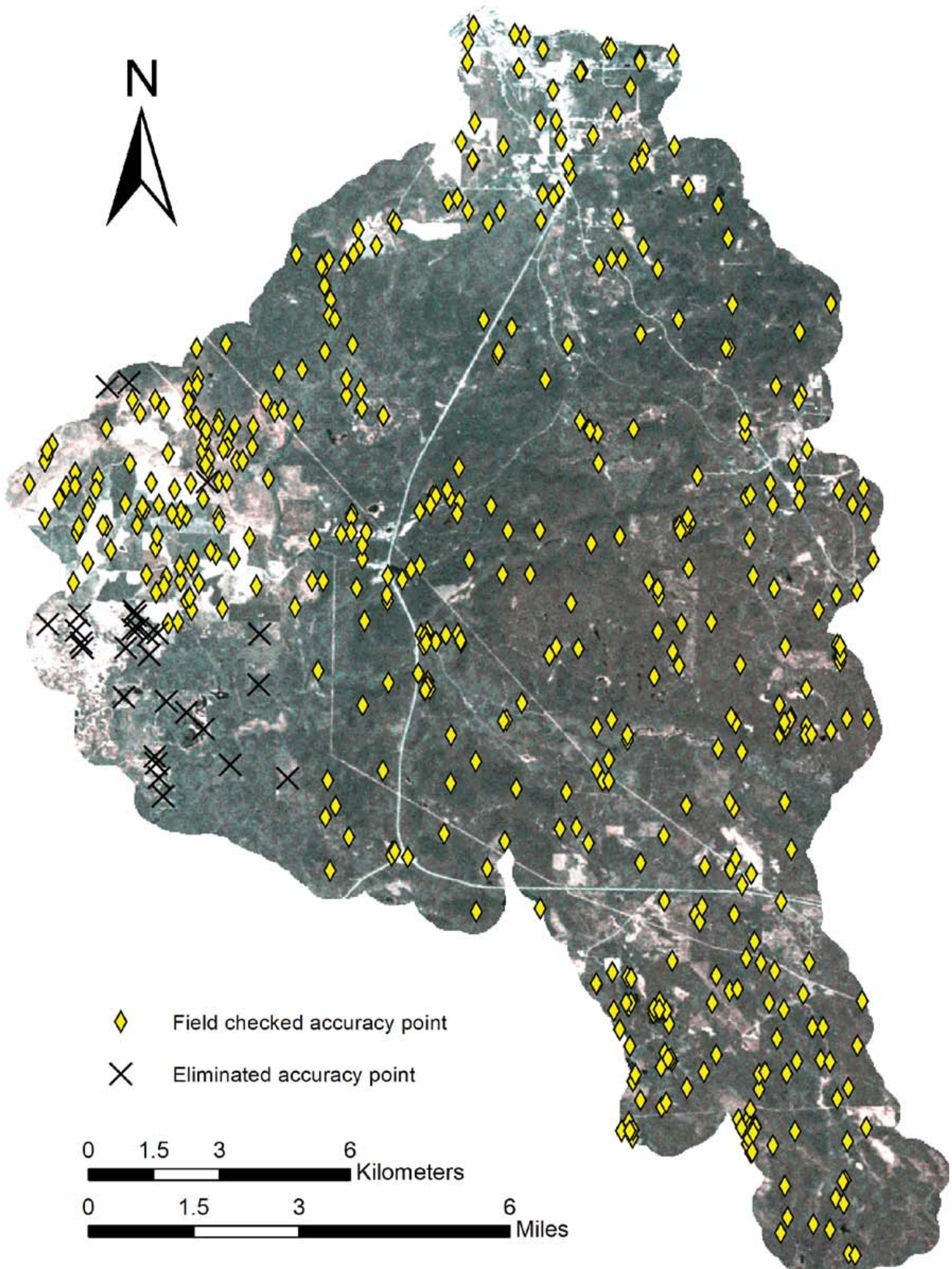

Figure 3.2 – Distribution of field accuracy points for the Landsat composite.

3.3 Results

3.3.1 Principal Components Analysis

Tables 3.4, 3.5, and 3.6 display the eigenvalues calculated for each component by ERDAS Imagine and for each seasonal composite. These values were utilized to calculate their respective total variance which is displayed in Table 3.7.

Table 3.4 – Eigenvalues computed for the covariance matrix by ERDAS Imagine for the Summer Composite.

Component	Eigenvalue	Component	Eigenvalue
1	418.529	7	0.990
2	109.743	8	0.763
3	49.301	9	0.377
4	11.716	10	0.062
5	2.862	11	0.048
6	1.336	12	0.022

Table 3.5 – Eigenvalues computed for the covariance matrix by ERDAS Imagine for the Fall Composite.

Component	Eigenvalue	Component	Eigenvalue
1	189.308	7	1.127
2	45.487	8	0.816
3	31.261	9	0.678
4	9.830	10	0.425
5	3.043	11	0.094
6	1.664	12	0.016

Table 3.6 – Eigenvalues computed for the covariance matrix by ERDAS Imagine for the combined seasonal composite.

Component	Eigenvalue	Component	Eigenvalue
1	581.133	13	1.126
2	139.859	14	0.896
3	69.436	15	0.711
4	27.366	16	0.604
5	18.993	17	0.511
6	13.283	18	0.366
7	9.534	19	0.247
8	7.275	20	0.094
9	3.590	21	0.061
10	1.719	22	0.048
11	1.570	23	0.027
12	1.042	24	0.008

Table 3.7 – Total variance for each seasonal composite.

	Total Variance
Summer	595.750
Fall	283.750
Combined	879.500

Utilizing the above eigenvalues and the total variance for each composite, the percentage of variance explained by each component was calculated with their cumulative variance expressed in percent for each seasonal image. As Table 3.8 depicts, for the Summer composite over 99% of the cumulative variance was explained by the first five components, while it takes 7 components for the Fall composite (Table 3.9) and 10 components for the combined seasonal composite (Table 3.10).

Table 3.8 – Percentage of variance explained by each component for the Summer composite.

Component	1	2	3	4	5	6
Percentage	70.253	18.421	8.275	1.967	0.480	0.224
Cumulative	70.25	88.67	96.95	98.92	99.40	99.62
Component	**7**	**8**	**9**	**10**	**11**	**12**
Percentage	0.166	0.128	0.063	0.010	0.008	0.004
Cumulative	99.79	99.91	99.98	99.99	100.00	100.00

Table 3.9 – Percentage of variance explained by each component for the Fall composite.

Component	1	2	3	4	5	6
Percentage	66.716	16.031	11.017	3.464	1.073	0.586
Cumulative	66.72	82.75	93.76	97.23	98.30	98.89
Component	7	8	9	10	11	12
Percentage	0.397	0.288	0.239	0.150	0.033	0.006
Cumulative	99.28	99.57	99.81	99.96	99.99	100.00

Table 3.10 – Percentage of variance explained by each component for the combined seasonal composite.

Component	1	2	3	4	5	6
Percentage	66.0754382	15.9021525	7.89498015	3.11156558	2.15955229	1.51026008
Cumulative	66.0754382	81.9775907	89.8725708	92.9841364	95.1436887	96.6539488
Component	7	8	9	10	11	12
Percentage	1.08403592	0.82719912	0.40814408	0.1954457	0.17851792	0.11846237
Cumulative	97.7379847	98.5651838	98.9733279	99.1687736	99.3472915	99.4657539
Component	13	14	15	16	17	18
Percentage	0.12806194	0.10185247	0.08081273	0.06866893	0.0581319	0.04162123
Cumulative	99.5938158	99.6956683	99.776481	99.8451499	99.9032819	99.9449031
Component	19	20	21	22	23	24
Percentage	0.02808048	0.01065888	0.00691274	0.00544005	0.00305566	0.00094913
Cumulative	99.9729836	99.9836424	99.9905552	99.9959952	99.9990509	100

The eigenvectors (Table 3.11) and the covariance matrix (Table 3.12) were both generated and exported by ERDAS Imagine for the Summer composite. This process was repeated for the Fall eigenvectors (Table 3.13) and Fall covariance matrix (3.14) as well as combined seasons eigenvectors (Table 3.15 & Table 3.16) and covariance matrix (Table 3.17 & Table 3.18). For ease of reading all of these tables have been included at the end of the section.

All of the above data was used to generate the factor loadings going into the degree of correlation for the Summer (Table 3.19), Fall (Table 3.20) and combined seasons (Table 3.21 & Table 3.22). Again, for ease of reading these tables have been included at the end of the section. The shaded values depict the components that were ultimately removed from the stacked composite for various reasons. As the number of bands was not overwhelmingly computational intensive, components were primarily removed due to noise. Image noise was considered to be due to issues such as visible scanner paths and/or lines, sensor noise, or otherwise redundant information found in another component. Figure 3.3 depicts examples of these image noise errors.

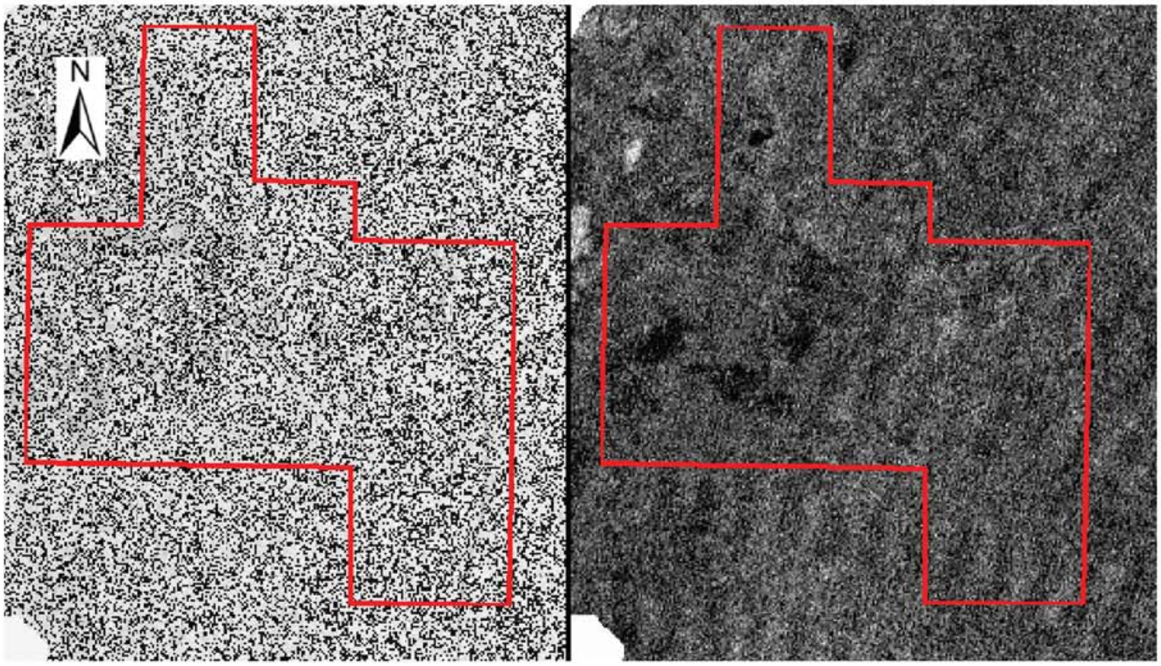

Figure 3.3 – Examples of removed components due to noise errors. Component 22 of the combined seasonal composite representing popcorned imagery (left) and component 16 of the same composite depicting noise error (right).

Table 3.11 – Eigenvectors for Summer composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
6/2/2011	Band 1	0.026	0.119	0.064	0.376	-0.191	-0.587	0.428	-0.506	0.143	-0.011	0.001	0.006
	Band 2	-0.003	0.177	0.045	0.507	0.012	-0.103	-0.805	-0.180	-0.129	0.031	0.000	-0.020
	Band 3	0.054	0.231	0.146	0.644	0.129	0.258	0.377	0.445	-0.284	-0.027	0.000	0.054
	Band 4	-0.675	0.163	-0.708	0.093	-0.036	-0.012	0.053	0.047	-0.034	0.002	0.000	-0.003
	Band 5	-0.046	0.096	0.018	0.201	0.279	0.494	0.030	-0.270	0.741	-0.003	-0.004	0.068
	Band 6	0.003	0.014	0.011	0.042	0.029	0.045	0.048	0.008	0.038	0.188	0.016	-0.978
7/11/2002	Band 1	0.064	0.317	0.010	-0.094	-0.276	0.125	-0.001	-0.031	0.001	0.020	0.890	0.016
	Band 2	0.127	0.629	0.019	-0.187	-0.536	0.236	-0.003	-0.058	-0.002	-0.006	-0.454	-0.013
	Band 3	0.116	0.573	-0.023	-0.230	0.552	-0.434	-0.048	0.274	0.179	-0.045	0.006	-0.006
	Band 4	-0.710	0.088	0.685	-0.114	-0.027	-0.048	-0.018	0.042	0.017	0.006	0.000	0.001
	Band 5	-0.027	0.174	0.014	-0.161	0.436	0.265	0.125	-0.594	-0.541	-0.143	0.005	-0.027
	Band 6	0.008	0.048	-0.001	-0.035	0.089	0.015	0.048	-0.065	-0.078	0.970	-0.023	0.187

Table 3.12 – Covariance matrix for Summer composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
6/2/2011	Band 1	815.709											
	Band 2	600.642	443.950										
	Band 3	327.857	242.950	136.420									
	Band 4	1273.374	940.924	501.339	2118.625								
	Band 5	124.367	92.590	50.984	201.586	20.470							
	Band 6	15.156	11.256	6.407	23.038	2.413	0.318						
7/11/2002	Band 1	548.624	404.771	222.485	851.047	83.998	10.304	373.761					
	Band 2	1087.820	802.587	441.149	1687.472	166.553	20.429	741.049	1469.391				
	Band 3	320.315	237.797	134.199	485.406	49.892	6.289	224.352	444.875	145.686			
	Band 4	1041.376	769.709	411.352	1731.770	166.467	19.021	693.085	1374.255	390.861	1462.376		
	Band 5	126.221	93.718	51.602	202.441	20.396	2.421	87.113	172.739	54.309	166.582	21.995	
	Band 6	18.079	13.455	7.712	27.168	2.883	0.370	12.923	25.627	8.805	21.818	3.295	0.590

Table 3.13 – Eigenvectors for Fall composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	0.013	-0.336	-0.355	0.002	-0.462	0.332	-0.480	-0.393	-0.155	0.168	0.000	-0.003
	Band 2	0.051	-0.362	-0.424	-0.001	-0.054	0.040	-0.051	0.821	0.004	-0.071	-0.003	0.015
	Band 3	-0.004	-0.456	-0.453	-0.004	0.211	-0.337	0.392	-0.405	0.192	-0.271	0.002	-0.033
	Band 4	0.795	0.455	-0.385	-0.080	-0.002	0.026	0.033	-0.050	0.014	-0.034	-0.001	0.001
	Band 5	0.064	-0.108	-0.104	-0.012	0.309	-0.367	-0.021	0.004	-0.299	0.808	0.002	-0.027
	Band 6	0.000	-0.014	-0.011	-0.003	0.013	-0.019	0.015	-0.026	-0.003	0.016	-0.001	0.999
10/5/2010	Band 1	0.044	-0.136	0.012	-0.215	0.483	0.577	-0.038	-0.036	0.547	0.255	0.001	-0.001
	Band 2	0.169	-0.245	0.168	-0.255	0.088	0.431	0.458	-0.023	-0.638	-0.090	-0.006	-0.003
	Band 3	0.353	-0.340	0.418	-0.557	-0.328	-0.311	-0.058	0.036	0.252	0.048	0.006	-0.002
	Band 4	0.442	-0.353	0.346	0.742	0.037	0.047	-0.014	-0.004	0.074	0.007	-0.002	0.002
	Band 5	0.089	-0.090	0.071	-0.126	0.477	-0.127	-0.553	-0.033	-0.243	-0.356	0.476	0.003
	Band 6	0.047	-0.049	0.040	-0.072	0.257	-0.074	-0.302	-0.021	-0.126	-0.190	-0.879	0.000

Table 3.14 – Covariance matrix for Fall composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	437.108											
	Band 2	314.602	228.148										
	Band 3	173.151	126.638	73.391									
	Band 4	662.044	477.246	254.201	1085.972								
	Band 5	67.682	49.495	27.773	106.362	11.515							
	Band 6	10.791	7.801	4.369	16.232	1.706	0.278						
10/5/2010	Band 1	304.772	218.976	119.095	468.280	47.409	7.528	215.566					
	Band 2	247.676	178.372	96.806	387.906	39.292	6.124	175.506	146.234				
	Band 3	229.371	165.504	88.934	372.132	37.476	5.671	163.794	139.948	140.624			
	Band 4	375.467	270.829	145.972	602.304	60.588	9.254	265.695	222.993	216.385	351.095		
	Band 5	56.698	41.167	22.380	92.257	9.607	1.417	40.846	34.550	34.324	53.507	9.135	
	Band 6	28.867	20.971	11.405	47.093	4.916	0.722	20.830	17.660	17.620	27.354	4.680	2.460

Table 3.15 – Eigenvectors for components 1 through 12 for the combined seasonal composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	0.010	0.169	0.003	-0.373	0.164	-0.105	-0.042	0.394	0.125	-0.196	0.093	0.035
	Band 2	-0.008	0.211	0.041	-0.404	0.186	-0.067	-0.045	0.268	-0.054	0.096	0.198	0.331
	Band 3	0.026	0.255	0.005	-0.430	0.232	-0.041	-0.031	0.154	-0.215	0.071	-0.226	-0.374
	Band 4	-0.428	0.024	0.474	-0.333	-0.652	0.175	0.143	0.009	0.016	0.001	-0.033	0.005
	Band 5	-0.031	0.079	0.015	-0.089	0.061	0.016	-0.004	-0.029	-0.275	0.236	-0.174	-0.044
	Band 6	0.001	0.007	-0.002	-0.014	0.005	0.001	0.005	-0.001	-0.017	0.002	-0.017	-0.027
7/11/2002	Band 1	0.017	0.120	-0.021	-0.149	0.053	0.017	0.098	-0.284	0.276	-0.289	0.132	0.006
	Band 2	-0.008	0.167	-0.002	-0.161	0.158	0.060	0.120	-0.414	0.066	0.069	0.291	0.542
	Band 3	0.037	0.232	-0.061	-0.234	0.100	0.098	0.162	-0.569	0.023	-0.118	-0.241	-0.256
	Band 4	-0.576	-0.005	0.503	0.263	0.545	-0.167	-0.070	-0.061	0.051	-0.026	0.007	-0.063
	Band 5	-0.041	0.081	-0.005	-0.031	0.086	0.047	0.056	-0.226	-0.259	0.180	-0.213	0.015
	Band 6	0.002	0.014	-0.006	-0.015	0.005	0.008	0.013	-0.040	-0.017	-0.008	-0.039	-0.033
10/5/2010	Band 1	-0.017	0.101	-0.030	0.035	-0.030	-0.027	0.190	-0.037	-0.019	0.388	0.572	-0.250
	Band 2	-0.089	0.133	-0.125	0.047	-0.058	-0.243	0.254	0.020	0.131	0.123	0.278	-0.458
	Band 3	-0.197	0.155	-0.239	0.125	-0.100	-0.524	0.584	0.127	-0.006	-0.175	-0.275	0.229
	Band 4	-0.242	0.173	-0.242	-0.056	-0.273	-0.512	-0.669	-0.242	-0.025	0.018	0.043	0.013
	Band 5	-0.048	0.070	-0.040	0.068	-0.039	-0.020	0.100	-0.025	-0.362	0.308	0.092	0.138
	Band 6	-0.025	0.038	-0.022	0.038	-0.021	-0.013	0.059	-0.014	-0.198	0.166	0.046	0.076
6/26/2011	Band 1	0.043	0.281	0.038	0.132	-0.034	0.075	-0.043	0.060	0.217	0.171	-0.128	0.039
	Band 2	0.086	0.558	0.076	0.261	-0.067	0.149	-0.087	0.120	0.421	0.327	-0.245	0.075
	Band 3	0.077	0.502	0.104	0.290	-0.095	0.165	-0.055	0.054	-0.347	-0.545	0.287	-0.091
	Band 4	-0.596	0.012	-0.604	-0.001	0.083	0.500	-0.028	0.124	0.054	-0.040	0.017	-0.009
	Band 5	-0.028	0.142	0.004	0.148	-0.031	0.075	-0.013	0.044	-0.408	-0.013	-0.100	0.133
	Band 6	0.005	0.041	0.006	0.035	-0.013	0.009	0.001	0.009	-0.070	-0.047	-0.016	-0.004

Table 3.16 – Eigenvectors for components 13 through 24 for the combined seasonal composite generated by ERDAS Imagine.

	Component											
	13	14	15	16	17	18	19	20	21	22	23	24
9/26/2001	0.633	-0.239	-0.014	-0.301	-0.105	-0.101	-0.055	0.001	-0.005	-0.001	-0.001	-0.001
	-0.252	-0.090	0.195	0.638	0.007	0.010	0.027	-0.003	0.012	0.001	0.009	0.000
	-0.320	0.304	-0.232	-0.284	0.203	0.155	0.175	0.000	-0.009	0.000	-0.021	-0.016
	-0.011	-0.009	0.002	-0.039	0.004	0.018	0.020	-0.001	-0.001	0.000	-0.003	0.001
	-0.100	0.126	0.194	-0.114	-0.485	-0.297	-0.644	0.003	0.013	-0.001	-0.005	-0.025
	-0.001	0.005	0.001	-0.003	-0.016	0.005	-0.005	-0.004	0.116	0.017	0.532	0.837
7/11/2002	0.221	0.752	0.195	0.137	-0.134	-0.025	0.051	0.001	-0.006	0.001	-0.003	0.001
	-0.228	-0.123	0.018	-0.505	0.070	0.117	-0.042	-0.003	0.023	0.000	0.019	0.002
	0.177	-0.363	-0.131	0.306	0.230	-0.071	-0.209	0.002	-0.023	-0.001	-0.046	0.019
	0.030	0.004	-0.032	0.034	0.046	-0.018	-0.022	0.000	0.004	0.000	0.006	0.000
	0.160	-0.148	0.178	0.009	-0.536	0.073	0.636	0.002	-0.021	-0.004	-0.072	0.031
	0.025	-0.027	0.009	0.018	-0.031	0.024	0.045	-0.009	0.197	0.021	0.808	-0.545
10/5/2010	0.144	0.041	-0.489	0.133	-0.252	0.238	-0.087	0.000	0.010	0.000	-0.002	-0.005
	-0.113	-0.166	0.656	-0.134	0.139	0.021	0.034	-0.005	-0.011	0.001	-0.006	-0.001
	-0.081	0.029	-0.216	0.035	-0.089	0.017	-0.023	0.006	-0.008	-0.001	-0.001	0.000
	0.021	0.002	-0.058	0.002	-0.017	0.018	0.000	-0.002	0.002	0.001	0.002	0.002
	0.272	0.181	0.009	0.000	0.401	-0.452	0.136	0.479	0.039	0.002	0.015	-0.004
	0.149	0.101	-0.002	0.000	0.214	-0.253	0.073	-0.877	-0.028	-0.003	0.009	-0.001
6/26/2011	0.016	0.015	-0.004	-0.002	0.009	-0.004	0.006	-0.004	0.019	0.890	-0.026	-0.001
	0.029	0.032	-0.007	-0.003	0.021	-0.005	0.011	0.001	-0.003	-0.454	0.020	0.003
	-0.174	-0.084	-0.061	-0.018	-0.113	-0.193	0.060	0.003	-0.045	0.006	0.009	-0.001
	-0.035	0.003	-0.019	0.004	-0.006	-0.020	0.004	-0.002	0.008	0.000	-0.002	-0.001
	0.305	0.101	0.239	0.035	0.186	0.690	-0.241	0.001	-0.151	0.006	0.021	0.000
	0.044	0.007	0.037	0.008	0.025	0.105	-0.026	-0.043	0.958	-0.025	-0.231	0.012

Table 3.17 – Covariance matrix for components 1 through 12 for the combined seasonal composite generated by ERDAS Imagine.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	437.108											
	Band 2	314.602	228.148										
	Band 3	173.151	126.638	73.391									
	Band 4	662.044	477.246	254.201	1085.972								
	Band 5	67.682	49.495	27.773	106.362	11.515							
	Band 6	10.791	7.801	4.369	16.232	1.706	0.278						
7/11/2002	Band 1	594.612	426.858	232.627	907.234	91.767	14.681	815.709					
	Band 2	438.392	315.701	172.871	670.005	68.391	10.850	600.642	443.950				
	Band 3	239.848	173.527	97.423	357.861	37.690	6.017	327.857	242.950	136.420			
	Band 4	928.243	668.097	355.465	1505.627	148.739	22.717	1273.374	940.924	501.339	2118.625		
	Band 5	90.872	65.966	36.377	143.358	15.044	2.279	124.367	92.590	50.984	201.586	20.470	
	Band 6	11.093	8.046	4.579	16.475	1.774	0.287	15.156	11.256	6.407	23.038	2.413	0.318
10/5/2010	Band 1	304.772	218.976	119.095	468.280	47.409	7.528	417.926	308.197	167.930	657.296	64.258	7.763
	Band 2	247.676	178.372	96.806	387.906	39.292	6.124	339.119	250.581	136.240	544.546	53.206	6.319
	Band 3	229.371	165.504	88.934	372.132	37.476	5.671	313.883	232.554	125.364	522.672	50.864	5.836
	Band 4	375.467	270.829	145.972	602.304	60.588	9.254	513.720	379.892	205.068	842.991	81.811	9.502
	Band 5	56.698	41.167	22.380	92.257	9.607	1.417	77.692	57.884	31.465	129.319	12.960	1.475
	Band 6	28.867	20.971	11.405	47.093	4.916	0.722	39.558	29.492	16.037	66.022	6.632	0.753
6/26/2011	Band 1	400.894	288.590	158.827	605.893	62.221	9.921	548.624	404.771	222.485	851.047	83.998	10.304
	Band 2	794.899	572.226	314.933	1201.374	123.376	19.672	1087.820	802.587	441.149	1687.472	166.553	20.429
	Band 3	235.174	171.000	97.344	345.734	37.323	5.899	320.315	237.797	134.199	485.406	49.892	6.289
	Band 4	758.861	545.648	290.092	1233.826	122.430	18.670	1041.376	769.709	411.352	1731.770	166.467	19.021
	Band 5	92.353	66.955	37.010	143.972	15.143	2.306	126.221	93.718	51.602	202.441	20.396	2.421
	Band 6	13.295	9.701	5.617	19.323	2.158	0.339	18.079	13.455	7.712	27.168	2.883	0.370

Table 3.18 – Covariance matrix for components 13 through 24 for the combined seasonal composite generated by ERDAS Imagine.

	Component											
	13	14	15	16	17	18	19	20	21	22	23	24
9/26/2001												
7/11/2002												
10/5/2010	215.566											
	175.506	146.234										
	163.794	139.948	140.624									
	265.695	222.993	216.385	351.095								
	40.846	34.550	34.324	53.507	9.135							
	20.830	17.660	17.620	27.354	4.680	2.460						
6/26/2011	281.960	228.607	210.808	344.708	52.855	26.932	373.761					
	559.074	453.281	417.983	683.497	104.805	53.402	741.049	1469.391				
	165.468	133.769	122.058	199.075	31.809	16.245	224.352	444.875	145.686			
	539.051	452.327	441.525	705.959	108.874	55.664	693.085	1374.255	390.861	1462.376		
	65.619	54.240	51.713	82.842	13.530	6.933	87.113	172.739	54.309	166.582	21.995	
	9.397	7.634	7.019	11.284	1.896	0.973	12.923	25.627	8.805	21.818	3.295	0.590

Table 3.19 – Factor loading matrix for Summer composite. Highlighted components are those that were removed from the composite.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
6/2/2011	Band 1	0.019	0.059	0.038	0.028	-0.071	-1.203	0.022	-0.012	0.007	0.000	0.000	0.001
	Band 2	-0.002	0.088	0.027	0.038	0.005	-0.211	-0.041	-0.004	-0.007	0.000	0.000	-0.004
	Band 3	0.039	0.115	0.088	0.048	0.048	0.530	0.019	0.010	-0.014	0.000	0.000	0.011
	Band 4	-0.483	0.081	-0.426	0.007	-0.014	-0.025	0.003	0.001	-0.002	0.000	0.000	-0.001
	Band 5	-0.033	0.048	0.011	0.015	0.104	1.012	0.002	-0.006	0.038	0.000	0.000	0.013
	Band 6	0.002	0.007	0.007	0.003	0.011	0.092	0.002	0.000	0.002	0.001	0.001	-0.189
7/11/2002	Band 1	0.046	0.158	0.006	-0.007	-0.103	0.256	0.000	-0.001	0.000	0.000	0.042	0.003
	Band 2	0.091	0.313	0.011	-0.014	-0.200	0.485	0.000	-0.001	0.000	0.000	-0.021	-0.002
	Band 3	0.083	0.285	-0.014	-0.017	0.207	-0.891	-0.002	0.006	0.009	0.000	0.000	-0.001
	Band 4	-0.509	0.044	0.412	-0.008	-0.010	-0.099	-0.001	0.001	0.001	0.000	0.000	0.000
	Band 5	-0.019	0.087	0.008	-0.012	0.163	0.543	0.006	-0.014	-0.028	-0.001	0.000	-0.005
	Band 6	0.006	0.024	0.000	-0.003	0.033	0.031	0.002	-0.001	-0.004	0.006	-0.001	0.036

Table 3.20 – Factor loading matrix for Fall composite. Highlighted components are those that were removed from the composite.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	0.009	-0.150	-0.232	0.000	-0.238	0.813	-0.035	-0.029	-0.011	0.006	0.000	0.000
	Band 2	0.033	-0.162	-0.277	0.000	-0.028	0.098	-0.004	0.061	0.000	-0.002	0.000	0.001
	Band 3	-0.003	-0.203	-0.296	0.000	0.108	-0.826	0.028	-0.030	0.013	-0.009	0.000	-0.003
	Band 4	0.524	0.203	-0.251	-0.008	-0.001	0.064	0.002	-0.004	0.001	-0.001	0.000	0.000
	Band 5	0.042	-0.048	-0.068	-0.001	0.159	-0.898	-0.001	0.000	-0.021	0.028	0.000	-0.002
	Band 6	0.000	-0.006	-0.007	0.000	0.007	-0.047	0.001	-0.002	0.000	0.001	0.000	0.080
10/5/2010	Band 1	0.029	-0.061	0.008	-0.020	0.249	1.411	-0.003	-0.003	0.038	0.009	0.000	0.000
	Band 2	0.111	-0.109	0.110	-0.024	0.045	1.054	0.033	-0.002	-0.044	-0.003	-0.001	0.000
	Band 3	0.232	-0.152	0.273	-0.053	-0.168	-0.761	-0.004	0.003	0.018	0.002	0.001	0.000
	Band 4	0.291	-0.158	0.226	0.071	0.019	0.115	-0.001	0.000	0.005	0.000	0.000	0.000
	Band 5	0.058	-0.040	0.046	-0.012	0.245	-0.312	-0.040	-0.002	-0.017	-0.012	0.048	0.000
	Band 6	0.031	-0.022	0.026	-0.007	0.132	-0.182	-0.022	-0.002	-0.009	-0.007	-0.089	0.000

Table 3.21 – Factor loading matrix for combined seasonal composite for components 1 through12. Highlighted components are those that were removed from the composite.

		Component											
		1	2	3	4	5	6	7	8	9	10	11	12
9/26/2001	Band 1	0.011	0.132	0.003	-0.059	0.211	-0.728	-0.005	0.050	0.020	-0.006	0.026	0.063
	Band 2	-0.009	0.165	0.040	-0.064	0.239	-0.461	-0.005	0.034	-0.009	0.003	0.055	0.599
	Band 3	0.030	0.200	0.005	-0.068	0.297	-0.284	-0.003	0.020	-0.035	0.002	-0.063	-0.677
	Band 4	-0.494	0.019	0.461	-0.053	-0.838	1.210	0.016	0.001	0.003	0.000	-0.009	0.009
	Band 5	-0.036	0.062	0.014	-0.014	0.079	0.112	0.000	-0.004	-0.045	0.007	-0.048	-0.081
	Band 6	0.001	0.006	-0.002	-0.002	0.006	0.008	0.001	0.000	-0.003	0.000	-0.005	-0.049
7/11/2002	Band 1	0.020	0.094	-0.020	-0.024	0.068	0.115	0.011	-0.036	0.045	-0.008	0.037	0.011
	Band 2	-0.009	0.131	-0.002	-0.026	0.203	0.412	0.013	-0.053	0.011	0.002	0.081	0.982
	Band 3	0.043	0.182	-0.060	-0.037	0.129	0.680	0.017	-0.073	0.004	-0.003	-0.067	-0.463
	Band 4	-0.664	-0.004	0.489	0.042	0.700	-1.156	-0.008	-0.008	0.008	-0.001	0.002	-0.114
	Band 5	-0.048	0.063	-0.004	-0.005	0.111	0.328	0.006	-0.029	-0.042	0.005	-0.059	0.028
	Band 6	0.002	0.011	-0.005	-0.002	0.007	0.052	0.001	-0.005	-0.003	0.000	-0.011	-0.059
10/5/2010	Band 1	-0.020	0.079	-0.029	0.006	-0.039	-0.185	0.021	-0.005	-0.003	0.011	0.158	-0.452
	Band 2	-0.103	0.104	-0.122	0.008	-0.075	-1.683	0.027	0.003	0.021	0.004	0.077	-0.829
	Band 3	-0.228	0.121	-0.232	0.020	-0.128	-3.621	0.063	0.016	-0.001	-0.005	-0.076	0.415
	Band 4	-0.279	0.135	-0.235	-0.009	-0.350	-3.544	-0.072	-0.031	-0.004	0.001	0.012	0.024
	Band 5	-0.055	0.055	-0.039	0.011	-0.050	-0.139	0.011	-0.003	-0.059	0.009	0.026	0.249
	Band 6	-0.029	0.030	-0.021	0.006	-0.027	-0.092	0.006	-0.002	-0.032	0.005	0.013	0.137
6/26/2011	Band 1	0.050	0.220	0.037	0.021	-0.044	0.517	-0.005	0.008	0.035	0.005	-0.035	0.071
	Band 2	0.099	0.437	0.074	0.041	-0.087	1.033	-0.009	0.015	0.068	0.009	-0.068	0.137
	Band 3	0.089	0.393	0.101	0.046	-0.122	1.138	-0.006	0.007	-0.056	-0.016	0.080	-0.165
	Band 4	-0.687	0.009	-0.587	0.000	0.107	3.460	-0.003	0.016	0.009	-0.001	0.005	-0.017
	Band 5	-0.032	0.111	0.003	0.023	-0.040	0.515	-0.001	0.006	-0.066	0.000	-0.028	0.240
	Band 6	0.006	0.032	0.006	0.006	-0.017	0.064	0.000	0.001	-0.011	-0.001	-0.005	-0.007

Table 3.22 – Factor loading matrix for combined seasonal composite for components 13 through 24. Highlighted components are those that were removed from the composite.

	Component											
	13	14	15	16	17	18	19	20	21	22	23	24
9/26/2001	0.046	-0.019	-0.001	-0.012	-0.025	-0.039	-0.001	0.000	0.000	0.000	0.000	0.000
	-0.018	-0.007	0.014	0.026	0.002	0.004	0.001	0.000	0.000	0.000	0.000	0.000
	-0.023	0.024	-0.016	-0.012	0.048	0.060	0.005	0.000	0.000	0.000	-0.001	-0.002
	-0.001	-0.001	0.000	-0.002	0.001	0.007	0.001	0.000	0.000	0.000	0.000	0.000
	-0.007	0.010	0.014	-0.005	-0.115	-0.115	-0.017	0.000	0.000	0.000	0.000	-0.003
	0.000	0.000	0.000	0.000	-0.004	0.002	0.000	0.000	0.002	0.000	0.019	0.100
7/11/2002	0.016	0.059	0.014	0.006	-0.032	-0.010	0.001	0.000	0.000	0.000	0.000	0.000
	-0.016	-0.010	0.001	-0.021	0.017	0.045	-0.001	0.000	0.000	0.000	0.001	0.000
	0.013	-0.028	-0.009	0.013	0.055	-0.027	-0.005	0.000	0.000	0.000	-0.002	0.002
	0.002	0.000	-0.002	0.001	0.011	-0.007	-0.001	0.000	0.000	0.000	0.000	0.000
	0.012	-0.012	0.013	0.000	-0.127	0.028	0.016	0.000	0.000	0.000	-0.003	0.004
	0.002	-0.002	0.001	0.001	-0.007	0.009	0.001	0.000	0.004	0.000	0.028	-0.065
10/5/2010	0.010	0.003	-0.035	0.006	-0.060	0.092	-0.002	0.000	0.000	0.000	0.000	-0.001
	-0.008	-0.013	0.047	-0.006	0.033	0.008	0.001	0.000	0.000	0.000	0.000	0.000
	-0.006	0.002	-0.015	0.001	-0.021	0.007	-0.001	0.000	0.000	0.000	0.000	0.000
	0.002	0.000	-0.004	0.000	-0.004	0.007	0.000	0.000	0.000	0.000	0.000	0.000
	0.020	0.014	0.001	0.000	0.095	-0.174	0.003	0.004	0.001	0.000	0.001	0.000
	0.011	0.008	0.000	0.000	0.051	-0.098	0.002	-0.007	-0.001	0.000	0.000	0.000
6/26/2011	0.001	0.001	0.000	0.000	0.002	-0.001	0.000	0.000	0.000	0.005	-0.001	0.000
	0.002	0.002	-0.001	0.000	0.005	-0.002	0.000	0.000	0.000	-0.003	0.001	0.000
	-0.013	-0.007	-0.004	-0.001	-0.027	-0.075	0.002	0.000	-0.001	0.000	0.000	0.000
	-0.003	0.000	-0.001	0.000	-0.001	-0.008	0.000	0.000	0.000	0.000	0.000	0.000
	0.022	0.008	0.017	0.001	0.044	0.266	-0.006	0.000	-0.003	0.000	0.001	0.000
	0.003	0.001	0.003	0.000	0.006	0.041	-0.001	0.000	0.020	0.000	-0.008	0.001

3.3.2 Resulting Land Cover Map for Study Area

Figure 3.4 depicts the final classification. After completion, the classification was saved as an .img file in order that it could be imported into other programs for use. Enlargements of the classified image are depicted in Figure 3. 5 which also display the effect the 3x3 majority filter had on the final results and the reduction of the salt and pepper effect.

3.3.3 Error Matrices

Table 3.23 displays the error matrix which depicts the breakdown of points collected by information class for the entire image. Displaying how the ground data differed from the field collected accuracy points, the major diagonal axis, highlighted in yellow, shows how many of the field collected points were classified correctly for each category.

Table 3.23 – Maximum likelihood classification error matrix.

Classified Imagery	Ground Truthed Field Data: Aspen	Conifer	Deciduous	Emergent Wetland	Jack Pine	Mixed	Open	Tamarack	Water	Woody Wetland	**Sum Row**
Aspen	38	1	-	-	-	-	-	1	-	-	**40**
Conifer	2	10	-	-	-	4	-	-	-	1	**17**
Deciduous	3	4	43	-	-	1	-	1	-	2	**54**
Emergent Wetland	-	-	-	43	-	-	-	3	2	-	**48**
Jack Pine	-	2	-	-	35	1	-	-	1	-	**39**
Mixed	-	10	2	-	-	26	-	1	-	4	**43**
Open	2	1	3	2	2	2	43	12	-	1	**68**
Tamarack	-	-	-	-	-	-	1	31	-	-	**32**
Water	-	1	-	1	-	-	-	-	46	-	**48**
Woody Wetland	1	18	2	4	3	13	1	1	1	40	**84**
Sum Colum	**46**	**47**	**50**	**50**	**40**	**47**	**45**	**50**	**50**	**48**	**473**

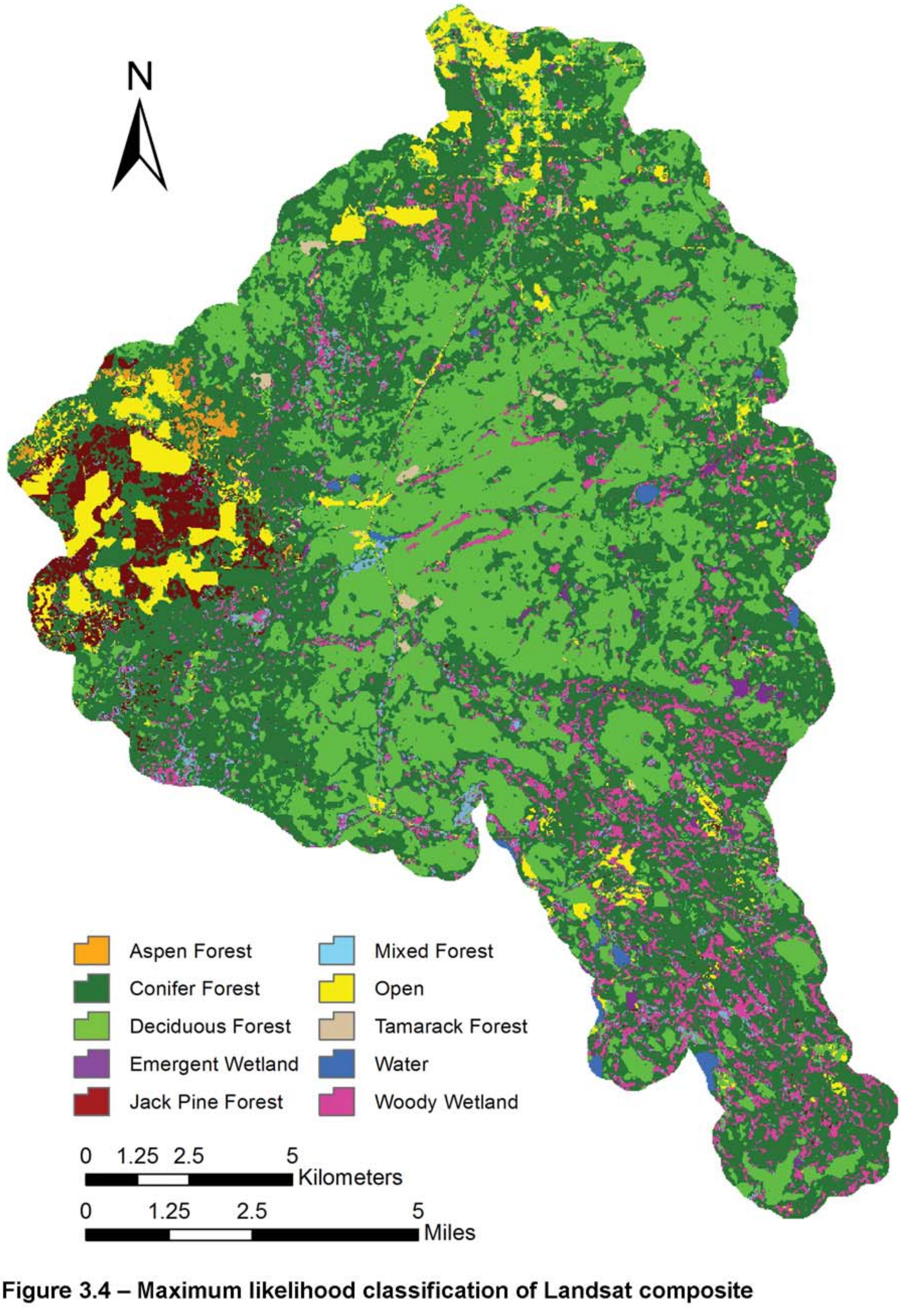

Figure 3.4 – Maximum likelihood classification of Landsat composite

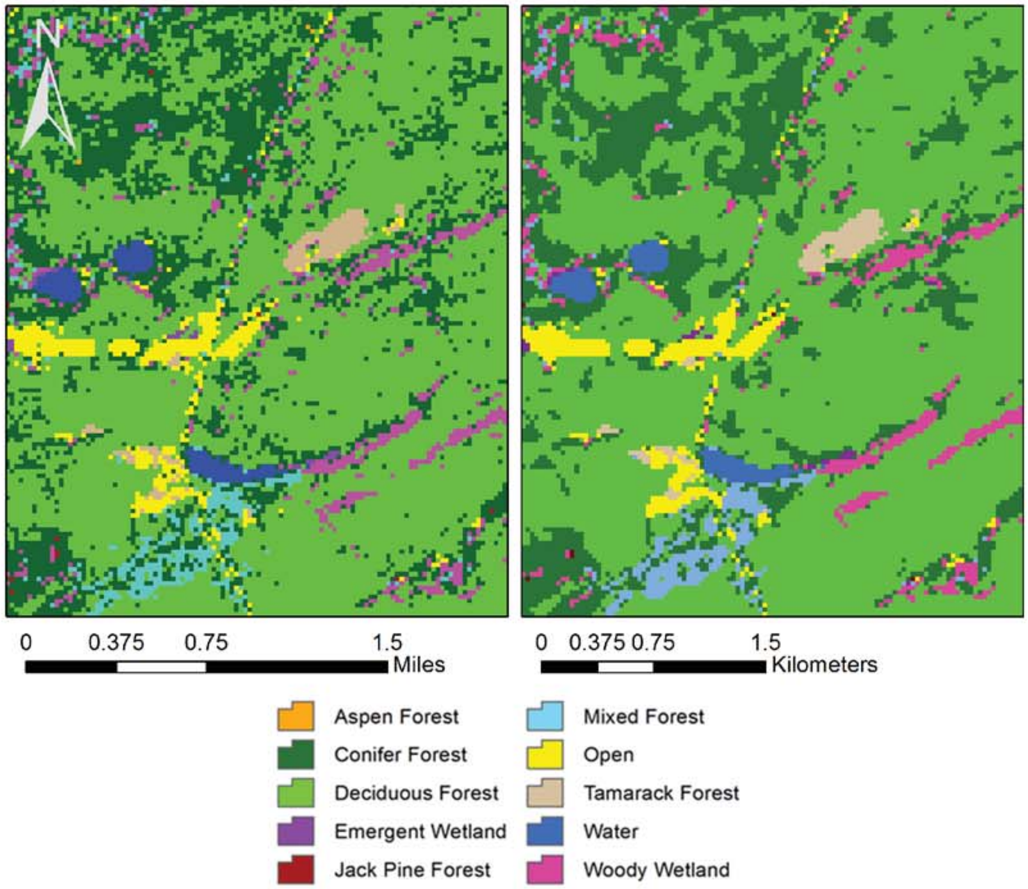

Figure 3.5 – Enlargements of maximum likelihood classification of Landsat composite near Alberta, Michigan before the 3x3 majority filter was run (left) and after (right).

The normalized error matrix used to calculate the Margfit analysis is depicted in percentages in Table 3.24. The major diagonal axis, again highlighted in yellow, represent the proportional percentage of points that were correctly classified in each information class. Overall the normalized values represent strong or moderate agreement between the classified points and the field accuracy data except for the Conifer class at 21.28% which indicates there is poor agreement.

Table 3.24 – Normalized maximum likelihood classification error matrix.

	Normalized Error Matrix									
	Aspen	Conifer	Deciduous	Emergent Wetland	Jack Pine	Mixed	Open	Tamarack	Water	Woody Wetland
Aspen	82.61%	2.13%						2.00%		
Conifer	4.35%	21.28%				8.51%				2.08%
Deciduous	6.52%	8.51%	86.00%			2.13%		2.00%		4.17%
Emergent Wetland				86.00%				6.00%	4.00%	
Jack Pine		4.26%			87.50%	2.13%			2.00%	
Mixed		21.28%	4.00%			55.32%		2.00%		8.33%
Open	4.35%	2.13%	6.00%	4.00%	5.00%	4.26%	95.56%	24.00%		2.08%
Tamarack							2.22%	62.00%		
Water		2.13%		2.00%					92.00%	
Woody Wetland	2.17%	38.30%	4.00%	8.00%	7.50%	27.66%	2.22%	2.00%	2.00%	83.33%

The overall accuracy of the final classification represents a moderate agreement between the classification and the field truthed ground data with a value of 75.05%. The results of the Kappa analysis was slightly lower at 72.28% while the Margfit analysis was slightly higher at 75.16% though both still represent a moderate agreement (Table 3.25).

Table 3.25 – Overall statistics associated with the error matrix.

Assesment Method	Result
Overall Accuracy	75.05%
Kappa Analysis	72.28%
Margfit analysis	75.16%

Table 3.26 depicts the producer's and user's accuracy broken down by information class for the final classification. Once again there was considerably more variation in the accuracy values dependent on the information class and statistic being tested. Overall, each information class represents either a strong or moderate agreement between the classification and field accuracy points except for the Conifer class which had a producer's accuracy of 21.28% which represents a poor agreement. Another particularly low class was

the Woody Wetland and Conifer user's accuracy at 47.62% and 58.82%, respectfully, as well as the Mixed producer's accuracy at 55.32%. While these three values still represent moderate agreement, they are still on the lower end of the value range.

Table 3.26 – Producer's and user's accuracy statistics associated with the error matrix.

Classification Category	Producer's Accuracy	User Accuracy
Aspen	82.61%	95.00%
Conifer	21.28%	58.82%
Deciduous	86.00%	79.63%
Emergent Wetland	86.00%	89.58%
Jack Pine	87.50%	89.74%
Mixed	55.32%	60.47%
Open	95.56%	63.24%
Tamarack	62.00%	96.88%
Water	92.00%	95.83%
Woody Wetland	83.33%	47.62%

3.4 Discussion

3.4.1 Accuracy assessment

Overall the maximum likelihood classification for the multiple classification technique worked rather well. Utilizing multiple images from two seasons enabled the extraction of far more data than using a single scene would have. By using the multiple scenes, more overstory species were able to be extracted and classified correctly generating a more useful classification map for land owners.

However, there was still considerable classification confusion between overstory species, especially between the Conifer and Woody Wetland classes. This was likely due to the amount of black spruce found within the Woody Wetland class being spectrally similar to species found within the Conifer class. Additionally, as the species in question were all

evergreens, there would have been little difference between the summer and fall images for these classes which would not improve the classification. The same issue occurred where there was confusion between the Mixed and Woody Wetland classes also likely due to the same situation.

3.4.2 Potential sources of error and variability

Again, while attempts were made to reduce bias and error across the data collection and processing, there are still potential sources of error that should be mentioned. While the points were randomly generated via stratified random sampling, a total of 27 points were located on land that was either posted as private land or areas that were otherwise inaccessible. This left portions of the westernmost area of the image largely unverified and it is uncertain how accurate the classification is for that part of the study site.

Another possible source of error is the imagery acquisition dates. Since cloud free imagery was required, the relevant scenes were spread out over ten years. With the most recent image acquisition being in 2011 and the field accuracy points being collected in 2015, there is some discrepancy between what is shown on the composite versus what is found in the field. This is not a problem unique to this study and must be considered anytime historical imagery is utilized. It is commonly accepted that there is 10 year window when change can be detected in the field and needed corrections made determining what past conditions were (Maclean and Cleland, 2003).

3.5 Conclusions

For larger scale, lower spatial resolution imagery, the maximum likelihood classification method produced the highest overall accuracy. While it would be best if imagery could be collected in the same year and at approximately the same time as data

collection, utilizing the multi-temporal Landsat TM data with multiple seasons and years still managed to do an excellent job classifying the area of interest. Additionally, the combination of unsupervised and supervised classification greatly improved classification ease as the user was not limited to attempting to find the ‘perfect pixels’ to represent each information class.

CHAPTER 4

APPLICATION OF THE RIPARIAN BUFFER DELINEATION MODEL ON THE HICKEY CREEK/STURGEON RIVER AND FALLS RIVER WATERSHEDS

4.1 Introduction

The word riparian comes from the ancient Latin word *ripa,* commonly translated as 'the bank of a stream' which was further modified in the 6^{th} to 10^{th} century by the church to the uncommonly used word *ripensis* which means 'situated or stationed on a river bank' (Lewis and Short, 1956). However, in the modern age the precise nature of what a riparian area is can vary greatly. Research by Verry *et al.* (2004) notes the history and variety of definitions used to define a riparian ecotone. However, these definitions vary greatly depending on region, agency, and scientific discipline. For this project the definition by the USDA in their 2004 amended Forest Service Manual is used. The manual defines a riparian ecosystem as "a transition area between the aquatic ecosystem and the adjacent terrestrial ecosystem; identified by soil characteristics or distinctive vegetation communities that require free or unbound water." This definition was chosen because it takes into consideration the concept that both flora and soils can be used to identify and define the riparian ecotone.

The idea that riparian ecotones are transitional areas defined by their soils, flora, and proximity to running water is affirmed in other studies (Brosofske, 1997; National Research Council, 2002; Naiman *et al.,* 2005) yet the question as to how to best define riparian ecotones in the field remains. Traditionally, state resource management agencies have

relied on voluntary best management practices (BMPs) for forested or agricultural lands but these guidelines vary greatly by state. For Michigan, the BMPs are based on a fixed width buffer around the river or stream that varies dependent on slope. Within the buffered area, activity is discouraged or landowners are advised to take extra precautions in order to protect water quality (Michigan DNR, 2009).

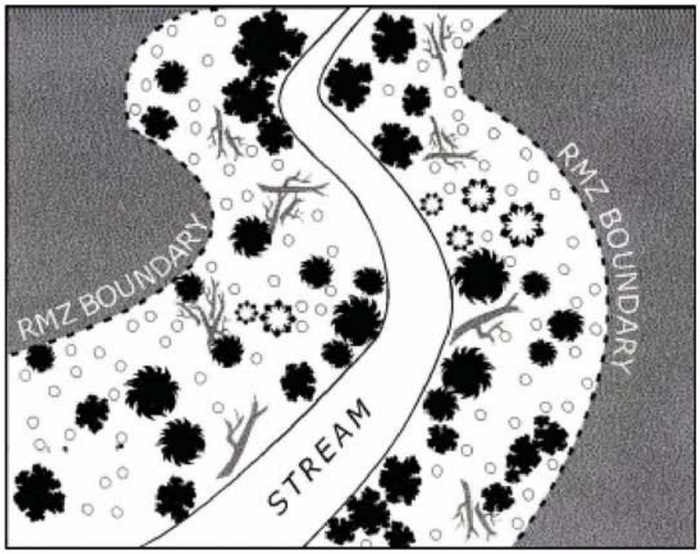

Figure 4.1: Example of a riparian buffer zone utilizing Michigan best management practices (BMPs) taken from the Michigan DNR *Sustainable soil and water quality practices on forest land* manual.

While fixed width buffers are easy to apply in the field, studies have shown that this approach does not always include the entire riparian ecotone (Lee *et al.,* 2004; MacNally *et al.,* 2008). With the advent of geospatial programs such as ArcMap® it has become easier to create realistic and more accurate variable-width buffers. The work by Aunan *et al.* (2005) was one of the first to apply the principles published by Ilhardt *et al.* (2000) and Skally and Sagor (2001) to create a variable-width riparian buffer utilizing geospatial programs. However, their model was based solely on the topography surrounding the rivers and streams and they were limited to a 30 meter digital elevation model (DEM) which generated

buffers that overestimated the area of the actual riparian ecotone. Holmes and Goebel (2011) also looked at the issue of generating variable-width buffers, but they were also hindered by the lack of availability of high spatial resolution DEMs. Their manually generated results did protect more of the riparian ecotone than a fixed width buffer, but the process to generate the buffer is exceedingly time-consuming, and again they were limited to using a 30 meter DEM. Mason (2007) and Abood (2011) evaluated the impact the DEM spatial resolution had on a variable-width riparian buffering model and found that results were dependent on the spatial resolution.

Utilizing the research completed by Mason (2007), Abood (2011) took the variable-width topographic model and integrated soils, wetland, and landcover data sets to it. This model, takes into consideration not only the changes in elevation around the river or stream but also its soil and flora characteristics. While computationally intensive, this program is faster and more cost effective then field mapping riparian areas. Thus, the objective of this project was to implement the model created by Abood on the Ford Research Forest lands, using it to identify riparian zones.

4.2 Methods

4.2.1 The Riparian Buffer Delineation Model

The Riparian Buffer Delineation Model (RBDM) utilizes ArcGIS® Desktop 10.2 (ESRI 1999-2015). This program is used for all analyses, data input, and data management for the model. Additionally, ArcMap's Spatial Analyst extension must be available for the model to run. All data used by the model must be stored within a single ArcMap File Geodatabase (FGDB).

The RBDB Manual written by Maclean and Abood (2011) was closely followed for this project. A majority of the data used for this model is freely available from state or federal

geospatial clearing houses, Table 4.1 shows which data inputs were used and their sources. The 2 meter LiDAR DEM is the property of the Geospatial Analysis Laboratory (GAL) of the MTU School of Forest Resources and Environmental Science. After downloading the requisite geospatial data it was clipped to the borders of the study area.

Table 4. 1 - Riparian Buffer Delineation Model data inputs and sources.

Input Data	Sources
Streams, Watersheds, Lakes	The National Map Viewer viewer.nationalmap.gov/
National Wetland Inventory	National Wetlands Inventory (NWI) http://www.fws.gov/wetlands/data/Mapper.html
Digital Soil Data	USDA - Web Soil Survey http://websoilsurvey.sc.egov.usda.gov/
2m Digital Elevation Model	Michigan Technological University
National Land Cover Database	The National Map Viewer viewer.nationalmap.gov/

There was an issue with the delineation of the streams and lakes layers downloaded from the National Map Viewer. These layers did not accurately represent the current ground conditions, most likely due to the layers being delineated using coarser spatial resolution imagery and/or DEMs. In order to correct for this issue the streams and lakes layers were re-digitized using the 2012 one meter image and a 1998 leaf-off three-band (MDNR) to correct stream and lake boundaries.

Model flood heights were taken from Abood *et al.* (2012) which suggested flood heights of 0.5m and 1m be used to represent minimum and average flood heights for watersheds in the Upper Midwest. For each model the ‘Length of Transects Vector (Meters)’ value was 203 meters. The model was run a total of four times for the study area, twice for each watershed at each of the designated flood heights.

Abood *et al.* (2012) has a detailed explanation on how the RBDM processes data and generates its results. In summary the model creates sample points along the stream's watercourse. The distance between each sample point is calculated by the model to be 75% of the DEM's spatial resolution to avoid spatial autocorrelation. After the sample points are generated, transects are produced around each point for 360º. Once the transects are generated, the model compares the transect points to the initial sample point. If a transect point has an elevation change greater than the specified flood height, the transect point is considered to be outside of the riparian flood zone and deleted.

The model repeats this process for each sample point and every transect point until the riparian zone boundary is determined. The model then transforms the designated riparian zone into a raster, smooths the edges, and converts the raster into a vector polygon. A simple buffer of 30 meters is also placed around all stationary waterbodies such as lakes and ponds based on the recommendation by Verry *et al.* (2004). When the model is run, multiple feature classes are outputted that display buffer results based on various inputs. For the purposes of this project, the buffer results based on solely the topographic DEM and the complete model (which in addition to the DEM, incorporates hydric soil and wetland data) were compared to determine the riparian zone.

4.2.2 Data Collection

Streams in the study area were walked to determine the riparian corridor based on field conditions. The riparian corridor was determined by a variety of conditions, but was primarily delineated by understory vegetation, overstory cover, and soil moisture. A Trimble Juno 3B unit was used to automatically track the walked path with a progress point taken every 30 seconds. While the user attempted to stay directly on the border between riparian and upland ecosystems, occasionally a buffer had to be put around the riparian zone due to

terrain changes or other ground conditions. This occurred most notably around the Surgeon River (Figure 4.2) due to portions of the river having steep rugged slopes and other sections bounded by a wide wet floodplain.

Figure 4.2 – The Sturgeon River, the largest river running through the study area.

Data collection was done from late May to mid June 2014 to capture the growth and flowering of the spring ephemerals before their summer senescence. The edges of the riparian zone were determined by the presence and absence of various ground flora species as well as presence of absence of various overstory species as well. Riparian corridor species included but were not limited to jack-in-the-pulpit (*Arisaema triphyllum*) (Figure 4.3), cinnamon fern (*Osmunda cinnamomea*) (Figure 4.3), marsh marigold (*Caltha palustris*) (Figure 4.4), sensitive fern (*Onoclea sensibilis*), ostrich fern (*Pteretis pensylvanica*), and duck-potato (*Sagittaria latifolia*). Upland species included but were not limited to yellow bead lily (*Clintonia borealis*) (Figure 4.5), false solomon's seal (*Maianthemum racemosum*)

(Figure 4.5), interrupted fern (*Osmunda claytoniana*) (Figure 4.6), nodding trillium (*Trillium cernuum*) (Figure 4.6), partridge berry (*Mitchella repens*), and large-leaf aster (*Eurybia macrophylla*).

Figure 4.3 – Riparian corridor species found on the Ford Research Forest lands. Jack in the pulpit (left), cinnamon fern (right).

Figure 4.4 – Marsh marigold found on the Ford Research Forest

Figure 4.5 – Upland species found on the Ford Research Forest. Yellow bead lily (left), false solomon's seal (right).

Figure 4.6 – Additional upland species found on the Ford Research Forest. Interrupted fern (left), nodding trillium (right).

Besides the riparian zone delineated by the RBDM, a simple fixed width buffer of 100 feet was generated around the streams to represent the guidelines suggested by MDNR Best Management Practices. The results of the RBDM, fixed width buffer, and the walked riparian zone were then clipped to the study area and their area calculated via ArcMap.

4.3 Results

Primary attention was paid to sections 18, 19, and 30 of the Ford Research Forest as these areas were most affected by rivers and streams. Figures 4.7, 4.8, and 4.9 show the riparian buffer calculated from the 1 and 0.5 m flood heights RDBM model compared with the fixed width buffer and field mapped riparian corridor for the Sturgeon River and Plumbago Creek areas. The total area included within these zones is displayed in Table 4.2. The results of the RDBM labeled as 'elevation' depict the results generated by the model which only take into account topographic elevation change in the DEM while the results labeled as 'complete' take into account the full model which includes hydric soils and wetland feature classes.

Table 4.2 – RDBM, fixed width buffer, and riparian zone results (in hectares) for the Ford Research Forest properties.

Model	Ogemaw Creek	Plumbago Creek	Sturgeon River & Unnamed Creeks	Total
Fixed width 100 ft buffer	3.5	5.6	37.6	46.7
RDBM - 1 m, elevation	3.3	19.9	46.2	69.4
RDBM - 1m, complete	3.3	19.9	59.9	83.1
RDBM - 0.5 m, elevation	2.6	12.3	23.3	38.2
RDBM - 0.5m, complete	2.6	12.4	46.0	61
Field mapped riparian zone	2.9	6.7	51.1	60.7

Overall, the results of the RDBM model found that the fixed width buffer leaves out a considerable amount of potential riparian land. The Plumbago Creek area is where this was

most evident with the fixed width buffer encompassing only 5.6 hectares while the RDBM 0.5 meter, elevation only results were 12.3 hectares and the RDBM 1 meter, elevation only results were 19.9 hectares. However, in the Ogemaw Creek area the RDBM actually encompassed less land with the 1 meter, elevation only results being 3.3 hectares and the 0.5 meter, elevation only results were 2.6 hectares while the fixed width buffer encompassed 3.5 hectares of land.

The effect of the complete RDBM was most evident in the Sturgeon River and unnamed creek area. When the model was run only utilizing elevation values the 0.5 meter and 1 meter results were 23.3 and 46.2 hectares, respectfully. After including wetland and hydric soil information into these results the numbers increased to 46.0 and 59.9 hectares.

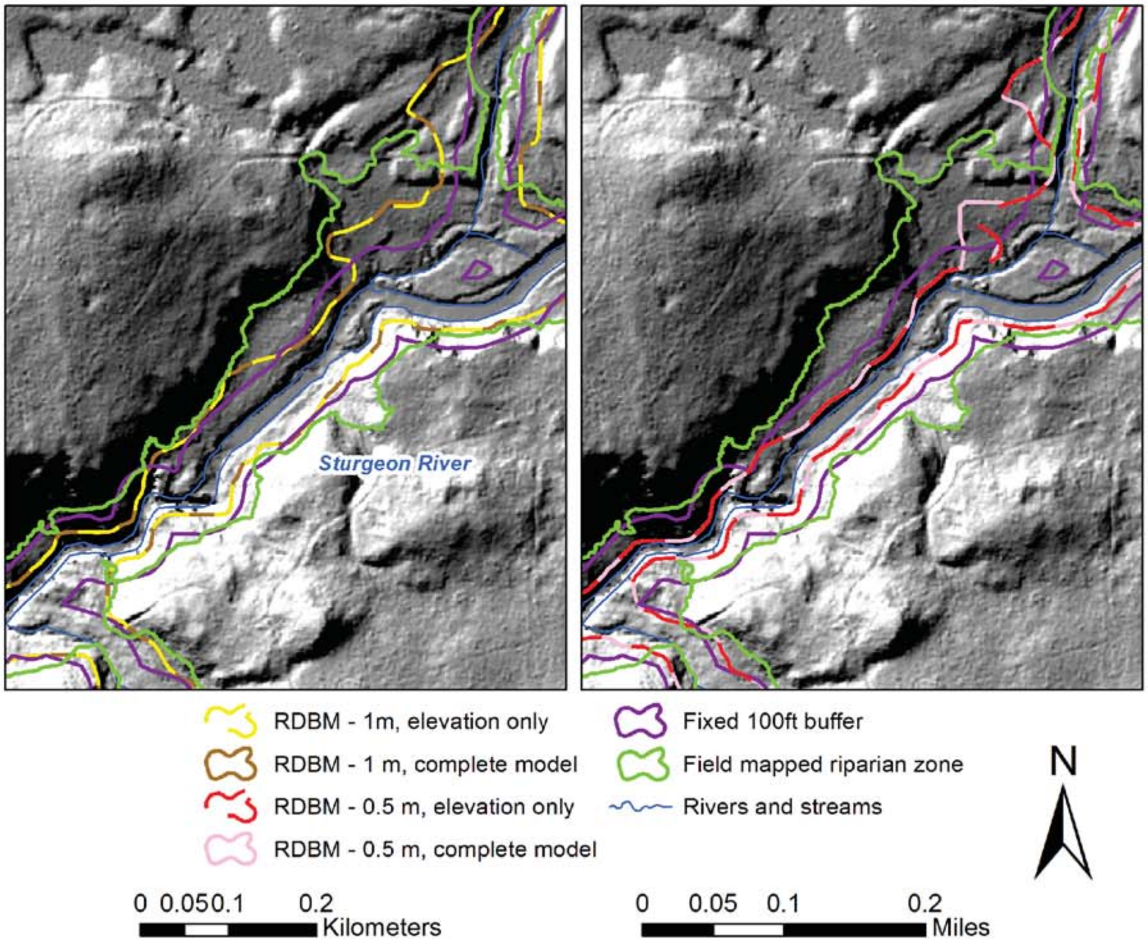

Figure 4.7 – RDBM elevation only, RBDM all input parameters, fixed width buffer, and field mapped riparian zones for the Sturgeon River area.

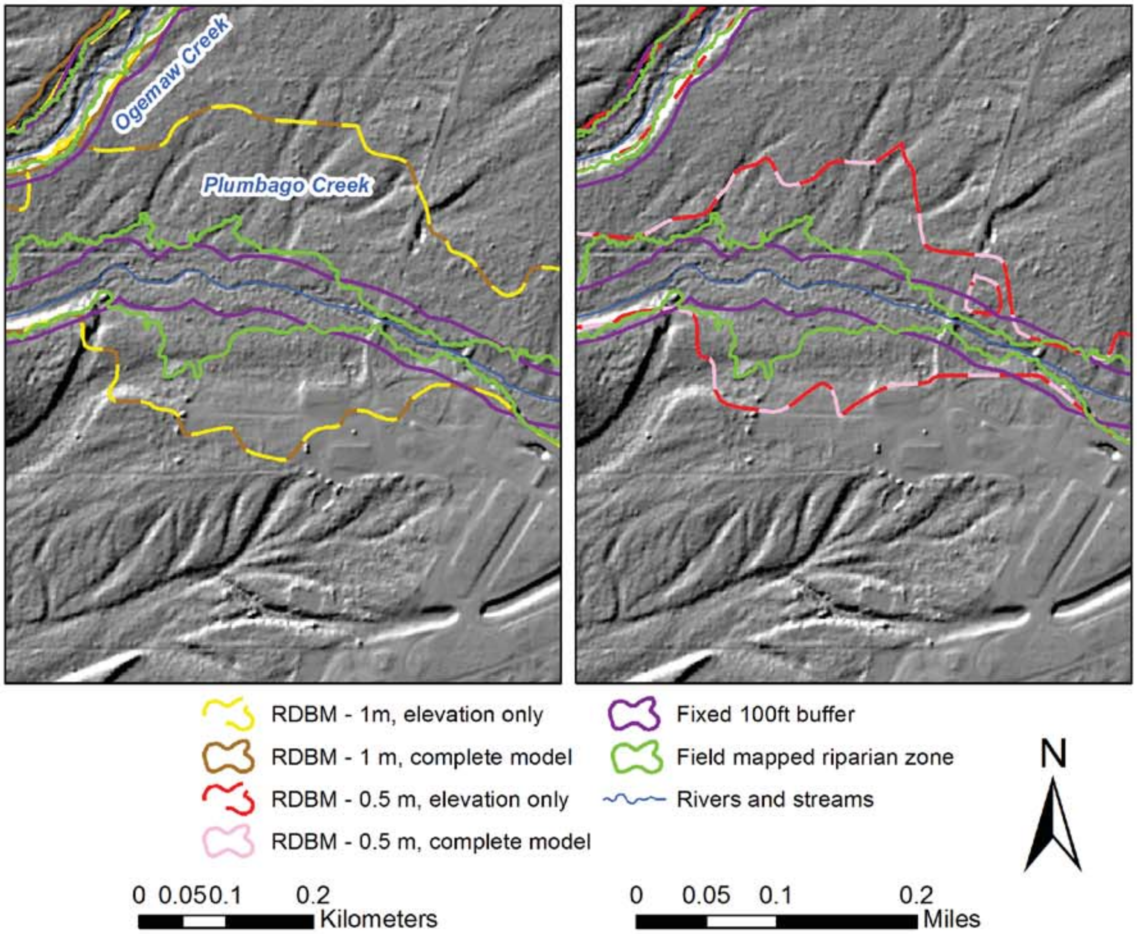

Figure 4.8 – RDBM, fixed width buffer, and field mapped riparian zone results for the Plumbago Creek and Ogemaw Creek area.

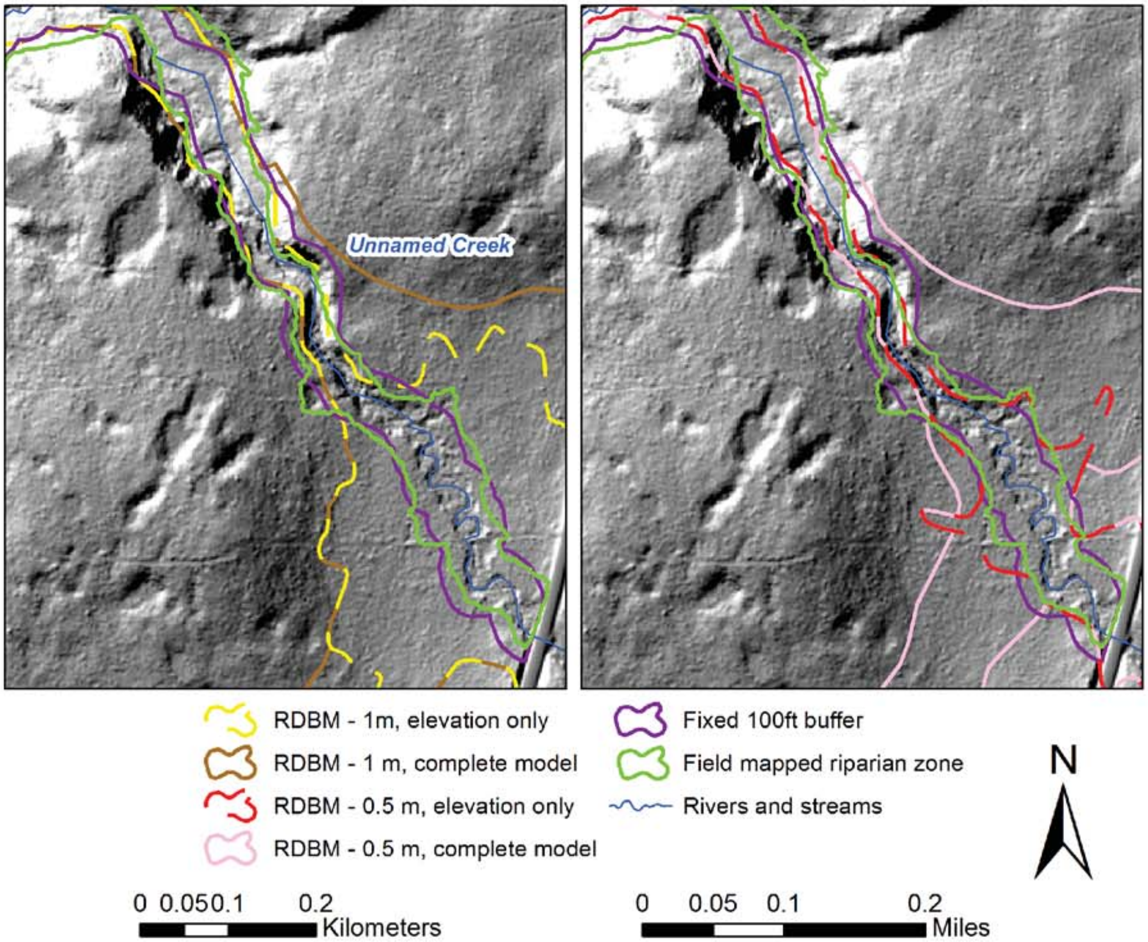

Figure 4.9 – RDBM, fixed width buffer, and field mapped riparian zone results for an unnamed creek south of the Sturgeon River.

In general, the walked riparian zone area most closely followed the RDBM 0.5 meter complete model in terms of total amount of hectares delineated as riparian. However, it should be noted that while the total hectares was roughly equivalent, the actual boundaries between the field mapped and 0.5 meter complete model were not the same.

4.4 Discussion

4.4.1 Fixed width buffer vs. the RDBM

Generally, it was found that the fixed width buffer was not adequate for determining the extent of the riparian zone. As Figures 4.7 and 4.8 show, the boundary of the riparian zone is variable and does not consistently remain 100 feet away from the watercourse. To best protect riparian zones, the RDBM is a better determinant of riparian zones and boundaries.

Determining which RDBM boundary best replicates field conditions is a more difficult. Generally, it would be recommended that landowners utilize the 0.5 or 1 meter complete model boundaries. As the complete model takes into account not only the topology but also the soils and wetlands adjacent to rivers and streams, it enables landowners to determine areas that may need further protection in order to preserve stream water quality and delicate hydric soils. Ideally, the 1 meter complete model boundary, which generated the largest riparian buffer, should be used to delineate riparian zones to determine a "conservative" riparian zone. By utilizing a more conservative riparian zone landowners should be able to best protect stream water quality and reduce overflow runoff from logging or other activities taking place on their property.

In addition to the RDBM being capable of generating multiple buffers based on available data, it also should be noted that the model is easy to run with a minimum of effort. This ease of use enables landowners or other users of the model to quickly determine the riparian corridors in a format that can be quickly applied to the field via a hand-held GPS unit. With the model preserving a far more conservative riparian zone and the model being simple and relatively quick to complete, it is highly recommended that landowners consider this model for logging or other activities on their holdings.

3.4.2 Potential sources of error and variability

The RDBM buffer is highly dependent on the quality of the data entered into it. Differences in area between the elevation only and complete RDBM models were due to available wetland and hydric soil data which may not always be accurate and/or consistently mapped. For example, north of the Sturgeon River, much of the gorge area is identified as a Champion Series soil (Figure 1.2) which is classified as a well-drained soil. However, this area during data collection was found to be mucky with occasional vernal pools with an overstory of balsam fir and other woody wetland species. While no attempt was done to identify soil types or assess the soil map's accuracy, it should still be noted the impact this information has on the delineated riparian zones. When the RDBM runs, it inspects the provided feature classes for data on hydric soils and wetlands and, in the case of the complete model, incorporates this data into the final results. If either the soil or wetland feature classes are inaccurate, these inaccuracies are passed on to the final results. Hence the user should take care to try and provide the model with the most accurate data possible. If errors in the associated feature classes are considerable and the user is unable to correct these errors prior to the model being run, it may be best to determine the riparian zone based solely on the elevation values if an accurate, high spatial resolution DEM is available.

Besides potential issues with the available data, the next largest source of potential error is with the field mapped riparian zones. While attempts to reduce data collection bias were made, the field mapped path is highly dependent on the user and the field conditions at the time. There were multiple times where the user was forced to take detours, backtrack, or deviate from the perceived riparian boundary due to inaccessibility. This issue was most prevalent in the area surrounding the Sturgeon River due to its rapid elevation changes, swampy areas, and the gorge.

Additionally, determining the boundary of a riparian zone can be very difficult to determine in the field. The herbaceous species used to delineate the field mapped boundaries can vary in their locations due to changes in climate or human activity and it can be difficult to determine a precise border between riparian and upland zones. Additionally, while species were identified as being more likely to appear in either riparian or upland areas, due to ground conditions, the flora were not always found in their designated areas. Jack-in-the-pulpit was found in upland areas, usually in areas of small depressions due to micro-topology, and false Solomon's seal was occasionally found along stream banks. This made the delineation between the riparian and upland areas far more arbitrary and up to the data collector to determine the boundary. Digging soil pits and identifying soil types along the riparian corridor may aid in identifying riparian zones, but this would dramatically increase field work and lab work. Overstory tree species, due to their longer presence on the landscape, may be a better indicator of riparian corridors, but only if they have not been greatly impacted by human activity.

4.5 Conclusions

While the RDBM is highly dependent on accurate data to provide the best results, it still provides landowners with a better and more accurate riparian zone then the fixed width buffer. To reduce errors, model users should attempt to assess data accuracy and correct issues before the model is run. While the user is ultimately the one to decide which version of the model best suits their goals, it is recommended that the 1 meter, complete model is used to delineate riparian boundaries as it encompasses the greatest amount of area and would better protect steam water quality from runoff related issues.

CHAPTER 5

RECOMMENDATIONS FOR THE FORD RESEARCH FOREST

5.1 Application of the RBDM on the Ford Research Forest

As the RDBM does the best job of mapping riparian corridors, it is recommend managers utilize a combination of it with a minimum 30.5 m (100 ft.) buffer to protect the Ford Research Forest waterways. A minimum buffer of 30.5 m between harvesting activity and the watercourse is especially critical in the Sturgeon River gorge where there are areas the RBDM does not map the buffer >30.5 m. While the steep slopes in the Sturgeon River gorge would protect such areas from flooding, overland runoff from logging activities would be better intercepted by the larger buffer and reduce the risk of sediment contamination. Harvesting activities should be limited to winter in order to reduce soil compaction and runoff.

Ideally, the soil maps of the area should be refined. Especially in the Sturgeon River area they are not accurate with numerous inclusions of different soils within a polygon. For example, during field work many muck soils areas were found within the Champion cobbly silt loam, which is classified as well drained. While undertaking a complete soil resurvey is economically infeasible, having a soil scientist complete spot checks for obvious inclusion areas would be useful. As the results of the RBDM model are dependent on accurate soil and wetland maps, investing time into improving the data inputs is justifiable.

5.2 Suggestions for future remote sensing endeavors on the Ford Research Forest

Further remote sensing classification research is advisable. The technology of remote sensing is currently undergoing dramatic changes as computer processing times

and costs continue to decrease. Data acquisition costs are also decreasing particularly with the use of Unmanned Aerial Vehicles (UAV). Dependent on goals and funding several types of imagery should be considered.

5.2.1 Hyperspectral Remote Sensing

Ideally, should acquire, analyze and classify hyperspectral imagery of the Ford Research Forest and potentially other Michigan Tech forested properties. This is a project the School should give serious consideration. Utilizing satellite based hyperspectral imagery could reduce image collection costs and building a hyperspectral library would be an excellent project for a Masters or PhD student. Hyperspectral remote sensing does seem to be a key component of the future of remote sensing.

5.2.2 Reoccurring classifications

Periodic updating of the forest cover type data should be implemented. This would be far more cost effective than utilizing traditional field methods and provide detailed and synoptic coverage of the area. It is also suggested that future mapping efforts keep imagery acquisition and field accuracy data collection dates as concurrent as possible. The methods detailed in Chapters 2 and 3 did a very good job of classifying the Ford Research Forest, but more concurrent image and field data collection could possibly increase accuracy. Reclassifying the property on a regular basis could be an excellent way of tracking and quantifying land use and land cover changes both for the Ford Center and for the larger landscape as a whole.

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APPENDIX A

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
1	Aspen	Conifer	384401.125	5167724
2	Aspen	Aspen	382897	5169101
3	Aspen	Aspen	385235.8125	5167569
4	Aspen	Aspen	383787.9063	5168956
5	Aspen	Aspen	385329.375	5167946
6	Aspen	Deciduous	387645.9375	5166964
7	Aspen	Aspen	383197.75	5169782
8	Aspen	Aspen	385092	5168080.5
9	Aspen	Aspen	383369.375	5169108
10	Aspen	Aspen	383372.375	5169153
11	Aspen	Aspen	383292.3438	5169161
12	Aspen	Deciduous	387812.125	5167194.5
13	Aspen	Aspen	382900.1875	5169657.5
14	Aspen	Aspen	383061.6875	5170306
15	Aspen	Aspen	387836.25	5165295
16	Aspen	Aspen	383188.8438	5169189
17	Aspen	Deciduous	387279.4375	5164208.5
18	Aspen	Aspen	387751.0313	5166439.5
19	Aspen	Aspen	384818.625	5166165
20	Aspen	Aspen	385253.9375	5167926
21	Aspen	Deciduous	386637.9688	5163753
22	Aspen	Deciduous	386098.9688	5163453
23	Aspen	Deciduous	387356.5313	5165793.5
24	Aspen	Aspen	382699.7188	5170512
25	Aspen	Aspen	387839.6875	5165263
26	Aspen	Aspen	382699.9375	5170140.5
27	Aspen	Aspen	383017.625	5169651.5
28	Aspen	Aspen	382959.9375	5169199
29	Aspen	Deciduous	383936.6563	5168962
30	Aspen	Aspen	382830.25	5170211.5
31	Aspen	Aspen	383387.3125	5169200
32	Aspen	Aspen	383814.8125	5168625.5
33	Aspen	Aspen	383031.4375	5170286.5
34	Aspen	Aspen	382979.7188	5169707
35	Aspen	Deciduous	386753.25	5165824.5
36	Aspen	Aspen	383343.9688	5169261.5
37	Aspen	Aspen	382984.125	5170040.5
38	Aspen	Aspen	383770.8438	5169001.5
39	Aspen	Aspen	385241.0625	5167524
40	Aspen	Aspen	382588.4688	5170860

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
41	Aspen	Aspen	385498.25	5167810.5
42	Aspen	Aspen	385078.1563	5166277
43	Aspen	Aspen	383085.25	5169388.5
44	Aspen	Aspen	383128.3125	5169779.5
45	Aspen	Aspen	383251.9375	5169296.5
46	Aspen	Deciduous	387835.7813	5166935.5
47	Aspen	Aspen	382527.4375	5170812.5
48	Aspen	Aspen	387772.2813	5166424
49	Aspen	Aspen	382585.1563	5170671.5
50	Aspen	Aspen	383486.9063	5169203.5
51	Conifer	Conifer	384467.7188	5167574.5
52	Conifer	Woody Wetlands	381854.5	5164741
53	Conifer	Open	384338.75	5166949
54	Conifer	Conifer	383908.4688	5168330
55	Conifer	Woody Wetlands	382376.7188	5165065.5
56	Conifer	Jack Pine	384198.0938	5166041
57	Conifer	Aspen	384789.3125	5166100
58	Conifer	Woody Wetlands	382083.5	5164860.5
59	Conifer	Woody Wetlands	382410.1875	5165173
60	Conifer	Conifer	383636.875	5170186.5
61	Conifer	Conifer	384938.0313	5167996
62	Conifer	XXXX	381116.875	5165332
63	Conifer	XXXX	381399.0313	5164602
64	Conifer	Conifer	384717.875	5167791
65	Conifer	Conifer	384818.7188	5167668
66	Conifer	XXXX	383577.875	5164501.5
67	Conifer	Woody Wetlands	382007.625	5164827
68	Conifer	Conifer	384236.6563	5167853.5
69	Conifer	Conifer	383850.0625	5169649.5
70	Conifer	XXXX	383691.0938	5164940.5
71	Conifer	Conifer	384683.75	5166073.5
72	Conifer	Conifer	384139.9375	5167941.5
73	Conifer	Jack Pine	383954.6875	5167443
74	Conifer	XXXX	383472.5625	5164884.5
75	Conifer	Conifer	383923.75	5167889.5
76	Conifer	Conifer	385047.9688	5168206
77	Conifer	Woody Wetlands	384610.8438	5166930.5
78	Conifer	XXXX	382497.7813	5164658.5
79	Conifer	Conifer	384459.125	5168175
80	Conifer	Conifer	384001.375	5169024.5
81	Conifer	XXXX	384254.8125	5164621
82	Conifer	Conifer	384719.9375	5168120
83	Conifer	Aspen	384426.6875	5165672
84	Conifer	Conifer	384166.6875	5167985
85	Conifer	Aspen	384356.5313	5165563

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
86	Conifer	Conifer	383918	5168046.5
87	Conifer	Conifer	384100.25	5168217.5
88	Conifer	Conifer	384876.1563	5168129.5
89	Conifer	Conifer	384642.2813	5167648.5
90	Conifer	Conifer	383862.4063	5169319
91	Conifer	Conifer	384785.1875	5168002.5
92	Conifer	Conifer	384060.4375	5168029
93	Conifer	Conifer	384502.2813	5167460
94	Conifer	XXXX	383245.6563	5165393.5
95	Conifer	XXXX	380870.0938	5164823
96	Conifer	Woody Wetlands	385410.4688	5168236
97	Conifer	Mixed	384438.8438	5165233.5
98	Conifer	Jack Pine	383996.5	5166639
99	Conifer	Conifer	383705.75	5169368.5
100	Conifer	Conifer	384792.6563	5168185
101	Deciduous	Deciduous	385713.9375	5163993
102	Deciduous	Aspen	383762.2188	5168906.5
103	Deciduous	Deciduous	387166.0938	5164848.5
104	Deciduous	Deciduous	386691.4688	5164863
105	Deciduous	Deciduous	387235.3438	5163919.5
106	Deciduous	Deciduous	387346.625	5164745
107	Deciduous	Deciduous	386781.8125	5163850.5
108	Deciduous	Conifer	384492.5938	5167420
109	Deciduous	Deciduous	382573.6875	5168988
110	Deciduous	Woody Wetlands	384976.3125	5165788
111	Deciduous	Deciduous	387496.25	5166943
112	Deciduous	Deciduous	386505	5165694
113	Deciduous	Deciduous	387327.4375	5162667.5
114	Deciduous	Deciduous	382506.1563	5170658.5
115	Deciduous	Deciduous	387429.9375	5163563.5
116	Deciduous	Deciduous	386408.0625	5167280.5
117	Deciduous	Deciduous	387844.2188	5167614.5
118	Deciduous	Deciduous	386324.8438	5166371.5
119	Deciduous	Deciduous	386735.2813	5165611
120	Deciduous	Woody Wetlands	385804.4688	5165508.5
121	Deciduous	Deciduous	386089.875	5166643
122	Deciduous	Deciduous	387790.9688	5163343.5
123	Deciduous	Deciduous	387557.1875	5167402
124	Deciduous	Deciduous	386330.8125	5162519.5
125	Deciduous	Deciduous	386066.2188	5166989.5
126	Deciduous	Deciduous	386648.8438	5162396.5
127	Deciduous	Deciduous	386625.0313	5162932.5
128	Deciduous	Conifer	384806.9063	5167506
129	Deciduous	Deciduous	387121.8438	5164095.5
130	Deciduous	Aspen	385105.4063	5167985.5
131	Deciduous	Deciduous	385935	5163192.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
132	Deciduous	Deciduous	387042.2188	5164911.5
133	Deciduous	Deciduous	385643.0938	5166311
134	Deciduous	Deciduous	386576.375	5165340
135	Deciduous	Deciduous	386603.375	5165361.5
136	Deciduous	Deciduous	386982.3438	5165360
137	Deciduous	Deciduous	385693.0313	5163534
138	Deciduous	Deciduous	386859.9375	5163351.5
139	Deciduous	Deciduous	386613.75	5162645.5
140	Deciduous	Mixed	386974.25	5163917
141	Deciduous	Deciduous	385736.0938	5163714.5
142	Deciduous	Deciduous	386775	5163497
143	Deciduous	Deciduous	387337.6563	5164223
144	Deciduous	Deciduous	387026.0625	5164617.5
145	Deciduous	Mixed	384827.4375	5168493
146	Deciduous	Deciduous	387027.9688	5163626
147	Deciduous	Deciduous	386741.5	5165036
148	Deciduous	Deciduous	386444.0938	5162950
149	Deciduous	Deciduous	382641.0938	5169171.5
150	Deciduous	Deciduous	386885.75	5162419.5
151	Jack Pine	Jack Pine	384229.3125	5166184.5
152	Jack Pine	Jack Pine	382673.9063	5166281.5
153	Jack Pine	Jack Pine	381740.625	5166254
154	Jack Pine	Jack Pine	383363.125	5165546
155	Jack Pine	Jack Pine	382987.9063	5167127
156	Jack Pine	Jack Pine	383715.5938	5167522
157	Jack Pine	Jack Pine	381076.5	5167018
158	Jack Pine	Jack Pine	380781.6563	5165887.5
159	Jack Pine	Jack Pine	383380.2188	5166427
160	Jack Pine	Woody Wetlands	382291.2813	5165104
161	Jack Pine	Jack Pine	383170.5938	5165561.5
162	Jack Pine	Jack Pine	382388.0938	5166668
163	Jack Pine	XXXX	383803.1875	5164491
164	Jack Pine	Jack Pine	381214.875	5166671
165	Jack Pine	Conifer	383653.1563	5165909
166	Jack Pine	Jack Pine	382277	5167057
167	Jack Pine	Jack Pine	382870.5	5166953.5
168	Jack Pine	Jack Pine	382295.3438	5167301
169	Jack Pine	Jack Pine	382854.8438	5167407.5
170	Jack Pine	Jack Pine	381277.125	5165997.5
171	Jack Pine	XXXX	381260.0625	5165491
172	Jack Pine	Jack Pine	381002.4063	5166679
173	Jack Pine	Jack Pine	381743.2188	5167402.5
174	Jack Pine	Jack Pine	382039.0938	5166755
175	Jack Pine	Jack Pine	382932.5	5165936.5
176	Jack Pine	Jack Pine	381156.3438	5167587.5
177	Jack Pine	Jack Pine	381498.1563	5167399.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
178	Jack Pine	Jack Pine	381570.5938	5166218
179	Jack Pine	Jack Pine	382855.4063	5166021.5
180	Jack Pine	Jack Pine	381962.7188	5166262.5
181	Jack Pine	Jack Pine	381908.1563	5166371.5
182	Jack Pine	Jack Pine	381508.5938	5166384.5
183	Jack Pine	Jack Pine	382415.2188	5165621.5
184	Jack Pine	Jack Pine	382625.3125	5166272.5
185	Jack Pine	Jack Pine	384040.2813	5165528.5
186	Jack Pine	Jack Pine	383990.9375	5165717.5
187	Jack Pine	Woody Wetlands	382010.5	5165059.5
188	Jack Pine	Jack Pine	383775.5625	5167069
189	Jack Pine	Jack Pine	382494.9063	5167033.5
190	Jack Pine	Jack Pine	381932.375	5166277.5
191	Jack Pine	Open	382715.1563	5166095
192	Jack Pine	Jack Pine	381718.0313	5167611.5
193	Jack Pine	XXXX	382095.1563	5164436
194	Jack Pine	Jack Pine	381898.5	5167222
195	Jack Pine	Jack Pine	383675.7188	5165625.5
196	Jack Pine	Jack Pine	382889.0313	5167181
197	Jack Pine	Woody Wetlands	382407.1563	5165213
198	Jack Pine	Jack Pine	382686.0938	5168002
199	Jack Pine	Jack Pine	383275.1563	5165538.5
200	Jack Pine	Jack Pine	382555.9063	5168357.5
201	Mixed	Mixed	383600.7813	5170529.5
202	Mixed	Open	387328.4688	5165410
203	Mixed	Mixed	383241.4375	5170467
204	Mixed	Mixed	387541.2813	5162617.5
205	Mixed	Mixed	386374.9375	5165884
206	Mixed	Mixed	387431.7188	5166596
207	Mixed	Deciduous	385583.1875	5166738.5
208	Mixed	Mixed	387259.1563	5163669
209	Mixed	Woody Wetlands	385441.125	5168234
210	Mixed	Mixed	386434.7188	5166095
211	Mixed	Mixed	387003.7813	5166490
212	Mixed	Mixed	383419.2188	5170336.5
213	Mixed	Mixed	383522.7813	5170086.5
214	Mixed	Mixed	385733	5166663.5
215	Mixed	Mixed	387142.4063	5166757.5
216	Mixed	Woody Wetlands	385508.5313	5168164.5
217	Mixed	Woody Wetlands	387117.3438	5164464.5
218	Mixed	Woody Wetlands	387397.125	5165034.5
219	Mixed	Deciduous	385566.1563	5167359
220	Mixed	Deciduous	386435.0625	5167359
221	Mixed	Mixed	387149.8125	5163080
222	Mixed	Mixed	386582.625	5167660.5
223	Mixed	Mixed	387406.75	5163159

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
224	Mixed	Open	387326.75	5165402.5
225	Mixed	Mixed	387090.8125	5166812.5
226	Mixed	Mixed	387202.5313	5164375.5
227	Mixed	Mixed	387074.625	5165854.5
228	Mixed	Woody Wetlands	387134.0625	5164420.5
229	Mixed	Mixed	385225.9688	5168392
230	Mixed	Mixed	385174.75	5168370
231	Mixed	Mixed	385214.5313	5166679
232	Mixed	Mixed	386650.375	5166127.5
233	Mixed	Woody Wetlands	385602.75	5166797.5
234	Mixed	Mixed	386465.7813	5166171
235	Mixed	Mixed	385487.7188	5168266
236	Mixed	Mixed	387113.6875	5166848.5
237	Mixed	Woody Wetlands	385476.125	5168159
238	Mixed	Mixed	385197.5	5166434
239	Mixed	Deciduous	387192.0313	5166165
240	Mixed	Mixed	386947.875	5166511.5
241	Mixed	Mixed	387382.0625	5166454
242	Mixed	Woody Wetlands	387035	5164285.5
243	Mixed	Mixed	387158.6875	5163101.5
244	Mixed	Mixed	386786	5165903.5
245	Mixed	Woody Wetlands	387502.2813	5164536.5
246	Mixed	Mixed	383645.25	5170850
247	Mixed	Mixed	387290.4063	5162978.5
248	Mixed	Mixed	386779.3125	5166321
249	Mixed	Mixed	386676.5625	5166279.5
250	Mixed	Deciduous	386857.0625	5166785.5
251	Open	XXXX	381578.25	5164766
252	Open	Open	383626.3438	5166448.5
253	Open	Paved	386888.25	5167601.5
254	Open	Open	382244.5	5165728.5
255	Open	Open	382338.8125	5166673
256	Open	Open	382640.4688	5166468.5
257	Open	XXXX	381546.1875	5165111
258	Open	Open	383018.25	5167601
259	Open	XXXX	381027.75	5165143.5
260	Open	Open	384314.9063	5166891
261	Open	Open	382838.8125	5168850.5
262	Open	Open	382736.75	5170852.5
263	Open	Open	381092.2188	5165817.5
264	Open	Open	386654.7813	5166778
265	Open	Open	383514.8125	5166040.5
266	Open	Open	384020.8125	5166528.5
267	Open	Open	381272.5938	5167450
268	Open	Open	387847.3438	5167455
269	Open	Open	386908.2813	5166472

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
270	Open	Open	382594.25	5166087
271	Open	Open	381566.5938	5165651
272	Open	Open	387186.8125	5166313
273	Open	Open	381502.375	5165470
274	Open	Open	382963.7813	5168511
275	Open	Open	383368.6563	5167491
276	Open	Open	384461.7188	5167134
277	Open	Jack Pine	381047.25	5167254
278	Open	Open	384010.0938	5166342
279	Open	Woody Wetlands	385320.7813	5166470
280	Open	Jack Pine	381886.25	5167693.5
281	Open	Open	381386.5	5167329.5
282	Open	Open	383724.9688	5166171
283	Open	Open	382868.4688	5170551.5
284	Open	Open	381249.8438	5167099
285	Open	Open	385506.5	5163464
286	Open	Open	383449.2188	5166398.5
287	Open	Open	381709.2813	5165400.5
288	Open	Open	382247.125	5165757.5
289	Open	XXXX	381274.4688	5165030
290	Open	XXXX	381528.4375	5164874
291	Open	XXXX	381173.9375	5165174
292	Open	Open	383519.875	5166534.5
293	Open	Open	382603.6563	5166060.5
294	Open	Woody Wetlands	384783.625	5165350.5
295	Open	Open	382994.3125	5167943.5
296	Open	Open	387429.4688	5165000.5
297	Open	Open	382707.9063	5165595.5
298	Open	Open	381036.5938	5165868
299	Open	Paved	382793.5938	5169706.5
300	Open	Open	382119.5938	5167201
301	Paved	Paved	387307.7188	5165504.5
302	Paved	Paved	385701.4375	5167439.5
303	Paved	Paved	384331.625	5166838
304	Paved	Paved	386000.5	5167458
305	Paved	Paved	386167.4688	5167442
306	Paved	Paved	381735.375	5166726.5
307	Paved	Paved	385842.8125	5167509
308	Paved	Paved	387415.1563	5163970
309	Paved	Paved	383960.1875	5166594.5
310	Paved	Open	386335.4375	5166755
311	Paved	Paved	387157.9688	5167588
312	Paved	Paved	386470.4375	5166727.5
313	Paved	Paved	387329.9688	5163450.5
314	Paved	Paved	387288.4688	5167605
315	Paved	Paved	387427.3438	5164153

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
316	Paved	Paved	386290.375	5167480.5
317	Paved	Paved	386649.9063	5166737.5
318	Paved	Paved	387214.4375	5167586
319	Paved	Paved	386055.125	5167471.5
320	Paved	Paved	386992.0938	5167617
321	Paved	Paved	386963.1875	5167534
322	Paved	Paved	387168	5167674.5
323	Paved	Paved	387443.8438	5164895
324	Paved	Paved	386238.25	5167434
325	Paved	Paved	386654.4375	5167197.5
326	Paved	Paved	386538.4063	5166711
327	Paved	Paved	385833.4063	5167529.5
328	Paved	Paved	387425.25	5165124.5
329	Paved	Paved	387198.5625	5167645
330	Paved	Paved	387128.375	5162705.5
331	Paved	Paved	386289.25	5167461.5
332	Paved	Paved	386189.3125	5167417.5
333	Paved	Paved	385394.125	5167547
334	Paved	Paved	386857.2188	5167176.5
335	Paved	Paved	384355.6875	5166802.5
336	Paved	Paved	386401.75	5167454.5
337	Paved	Paved	385707.4688	5167467
338	Paved	Paved	386865.7813	5167185.5
339	Paved	Paved	386908.4688	5166302.5
340	Paved	Paved	386642.875	5166537
341	Paved	Paved	385827.5938	5167461
342	Paved	Paved	387278.1563	5163258
343	Paved	Paved	387245.3438	5167609.5
344	Paved	Paved	385800.8125	5167548.5
345	Paved	Paved	386240.3438	5167473
346	Paved	Paved	387195.4063	5165751.5
347	Paved	Paved	387332.0938	5165432.5
348	Paved	Paved	385896.3438	5167532
349	Paved	Paved	386869	5167180.5
350	Paved	Paved	384445.4375	5166541
351	Tamarack	Aspen	382948.125	5169119
352	Tamarack	Deciduous	385472.4375	5167552
353	Tamarack	Aspen	383198.0625	5169610
354	Tamarack	Aspen	385225.0625	5167815
355	Tamarack	Mixed	383419.9375	5170064
356	Tamarack	Aspen	383900.9063	5168557.5
357	Tamarack	Tamarack	387823.4375	5165028
358	Tamarack	Mixed	382462.0313	5170788.5
359	Tamarack	XXXX	382636.6875	5168622.5
360	Tamarack	Aspen	383698.5938	5168855
361	Tamarack	Mixed	385373.8438	5168267.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
362	Tamarack	Deciduous	385515.1875	5167105.5
363	Tamarack	Woody Wetlands	384286.1563	5167842.5
364	Tamarack	Deciduous	385534.75	5167103
365	Tamarack	Aspen	383114.8438	5169154.5
366	Tamarack	Woody Wetlands	385810.5625	5164130
367	Tamarack	Tamarack	387583.25	5164980.5
368	Tamarack	Aspen	383210.25	5169490.5
369	Tamarack	Aspen	382667.3125	5170323
370	Tamarack	Mixed	385253.5	5166084
371	Tamarack	Aspen	383348.5625	5169408.5
372	Tamarack	Tamarack	387720.7188	5165137
373	Tamarack	Tamarack	387603.125	5165224
374	Tamarack	Tamarack	387840.5313	5165060
375	Tamarack	Aspen	383731.5625	5168686.5
376	Tamarack	Mixed	383373.4688	5169937
377	Tamarack	Mixed	383393.0938	5169685.5
378	Tamarack	Aspen	383156.5313	5170334.5
379	Tamarack	Tamarack	387642	5164129.5
380	Tamarack	Aspen	385271.3438	5167803
381	Tamarack	Aspen	382696.375	5170361
382	Tamarack	Woody Wetlands	385707.3438	5164199.5
383	Tamarack	Aspen	385296.9063	5167891.5
384	Tamarack	Tamarack	387634.75	5165254
385	Tamarack	Aspen	382567.0625	5170696
386	Tamarack	Tamarack	387608.5	5165053.5
387	Tamarack	XXXX	383035.0625	5168272
388	Tamarack	Aspen	383042.375	5169596.5
389	Tamarack	Aspen	383136.375	5169131
390	Tamarack	Aspen	385421.7188	5167986
391	Tamarack	Tamarack	387522.125	5164041
392	Tamarack	Tamarack	387693	5165018
393	Tamarack	XXXX	382649.4688	5168633
394	Tamarack	Aspen	383329.9688	5169386
395	Tamarack	Aspen	383642.375	5168570.5
396	Tamarack	Deciduous	385423.5	5166947.5
397	Tamarack	Tamarack	387632.4688	5163966
398	Tamarack	Mixed	383578.9375	5170792.5
399	Tamarack	Aspen	382847	5170005.5
400	Tamarack	Woody Wetlands	385653.5625	5165692
401	Water	Water	385162.1875	5165995
402	Water	Water	387330.125	5166636
403	Water	Water	386971	5166698.5
404	Water	Water	387012.0938	5166638
405	Water	Water	386405.125	5164151
406	Water	Conifer	383722.9063	5170078
407	Water	Water	387549.7813	5166674.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
408	Water	Water	387351.1875	5166610.5
409	Water	Water	387816.25	5164533
410	Water	Water	385102.1875	5166896
411	Water	Water	387635.2188	5164737.5
412	Water	Open	385936.9063	5167334
413	Water	Water	384750.0625	5165898
414	Water	Water	387796.5313	5164604.5
415	Water	Open	387104.5625	5165868
416	Water	Conifer	383695.0313	5169966.5
417	Water	Water	386908.0313	5164224.5
418	Water	Mixed	385243.8125	5166517
419	Water	Paved	387122.4063	5167647
420	Water	Water	384777.375	5166975.5
421	Water	Water	384528.7188	5165673
422	Water	Water	387193.375	5166565.5
423	Water	Water	387244.25	5164487
424	Water	Mixed	384763.5938	5166932.5
425	Water	Water	387770.8438	5164639
426	Water	Water	387234.4375	5164495.5
427	Water	Water	387242.6563	5166609
428	Water	Mixed	386987.1563	5166555.5
429	Water	Water	386930.0938	5166613
430	Water	Water	386860.125	5166629.5
431	Water	Open	387199.3438	5165682
432	Water	Water	386860.9063	5166698
433	Water	Open	387104.5625	5165854
434	Water	Water	385212.7188	5166217.5
435	Water	Water	387303.7813	5166633.5
436	Water	Water	384935.8125	5167075.5
437	Water	Water	387116.2813	5166627.5
438	Water	Water	386943.4375	5166593.5
439	Water	Water	386902.5938	5166689.5
440	Water	Water	387176.375	5166634
441	Water	Water	387217.125	5166593.5
442	Water	Water	385035.125	5166954
443	Water	Water	387071.0625	5166574.5
444	Water	Water	387030.2188	5164350
445	Water	Conifer	385029.0313	5168249
446	Water	Deciduous	385600.8125	5167402.5
447	Water	Water	387373.8125	5164541
448	Water	Water	385030.25	5166953.5
449	Water	Open	386849.2188	5166431
450	Water	Open	385424.4063	5167343
451	Woody Wetlands	Woody Wetlands	385973.75	5165641.5
452	Woody Wetlands	Woody Wetlands	386264.6563	5164044.5
453	Woody Wetlands	Woody Wetlands	385115.9375	5164679

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
454	Woody Wetlands	Jack Pine	382801.125	5167832.5
455	Woody Wetlands	Mixed	387674.4688	5162563
456	Woody Wetlands	Deciduous	386075.9688	5163105
457	Woody Wetlands	Deciduous	386086.5938	5163383
458	Woody Wetlands	XXXX	383812.4375	5164579
459	Woody Wetlands	Mixed	383381.9688	5170634
460	Woody Wetlands	Woody Wetlands	386834.7188	5163204
461	Woody Wetlands	XXXX	382802.1563	5164854.5
462	Woody Wetlands	XXXX	383893.2813	5164605
463	Woody Wetlands	Mixed	387114.4375	5166369
464	Woody Wetlands	Woody Wetlands	382376.5	5164819.5
465	Woody Wetlands	Woody Wetlands	385420.4063	5165828.5
466	Woody Wetlands	Deciduous	385931.375	5162365
467	Woody Wetlands	Woody Wetlands	384840.2813	5165053.5
468	Woody Wetlands	Woody Wetlands	385658.8438	5166022.5
469	Woody Wetlands	Woody Wetlands	385394.6875	5165288.5
470	Woody Wetlands	Mixed	387350.1563	5162477
471	Woody Wetlands	Woody Wetlands	384620.8125	5165887.5
472	Woody Wetlands	Deciduous	385554.5313	5163256.5
473	Woody Wetlands	XXXX	383237.8438	5164435
474	Woody Wetlands	Mixed	387022.0625	5165805
475	Woody Wetlands	Woody Wetlands	384983.9063	5165005
476	Woody Wetlands	Conifer	385001.9688	5167590
477	Woody Wetlands	Jack Pine	384144.5625	5166863
478	Woody Wetlands	Deciduous	386103.125	5162791
479	Woody Wetlands	Deciduous	387203.5625	5167492.5
480	Woody Wetlands	Deciduous	385910.375	5162610
481	Woody Wetlands	Woody Wetlands	387037.75	5163163
482	Woody Wetlands	XXXX	383686.9375	5165042.5
483	Woody Wetlands	Woody Wetlands	383059.125	5170703.5
484	Woody Wetlands	Woody Wetlands	384918.0625	5165636.5
485	Woody Wetlands	Deciduous	386147.2813	5163028.5
486	Woody Wetlands	XXXX	384522.1563	5164374.5
487	Woody Wetlands	Deciduous	387365.8125	5167657.5
488	Woody Wetlands	Woody Wetlands	385356.7813	5164822
489	Woody Wetlands	XXXX	384561.4375	5164399
490	Woody Wetlands	Woody Wetlands	385420.9688	5165127
491	Woody Wetlands	Deciduous	385622.2813	5163280
492	Woody Wetlands	Mixed	383589.4063	5170182.5
493	Woody Wetlands	XXXX	382017.4375	5164665
494	Woody Wetlands	Woody Wetlands	385921.6875	5165247.5
495	Woody Wetlands	Woody Wetlands	386201.7188	5164865.5
496	Woody Wetlands	Woody Wetlands	384887.125	5164634.5
497	Woody Wetlands	Mixed	387337.3438	5162951.5
498	Woody Wetlands	Woody Wetlands	385700.1875	5165946.5
499	Woody Wetlands	Woody Wetlands	385354.6563	5165620

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
500	Woody Wetlands	Woody Wetlands	385139.3125	5164616.5

APPENDIX B

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
1	Tamarack	Open	389926.5938	5178842.5
2	Tamarack	Tamarack	385800.9688	5173663
3	Tamarack	Tamarack	388390.8125	5165176.5
4	Tamarack	Open	387521.0313	5167993.5
5	Tamarack	Tamarack	385316.6563	5173528.5
6	Tamarack	Tamarack	387614.4688	5164927
7	Tamarack	Open	391833.7813	5178577
8	Tamarack	Tamarack	388467.7188	5164979
9	Tamarack	Tamarack	387555.375	5165167
10	Tamarack	Tamarack	387772.9688	5168114
11	Tamarack	Tamarack	387706.1875	5164093.5
12	Tamarack	Tamarack	387634.7813	5163869
13	Tamarack	Tamarack	391442.4063	5169818
14	Tamarack	Tamarack	391200.0625	5170046.5
15	Tamarack	Emergent Wetland	386898.125	5160194.5
16	Tamarack	Deciduous	391601.375	5169772
17	Tamarack	Tamarack	391385.0313	5169871
18	Tamarack	Tamarack	387690.0313	5165106
19	Tamarack	Tamarack	387829.4375	5168326.5
20	Tamarack	Tamarack	391416.8438	5169839.5
21	Tamarack	Open	391819.375	5178580
22	Tamarack	Open	390651.6563	5176910.5
23	Tamarack	Tamarack	387748.625	5163920.5
24	Tamarack	Open	391905.1563	5178560
25	Tamarack	Tamarack	388456.1875	5165028.5
26	Tamarack	Tamarack	385432.4375	5173737
27	Tamarack	Woody Wetland	386878.6563	5160113.5
28	Tamarack	Tamarack	387695.0938	5165217
29	Tamarack	Tamarack	387890.875	5165004.5
30	Tamarack	Tamarack	387667.5	5165051.5
31	Tamarack	Open	390971.625	5175672
32	Tamarack	Tamarack	387650.125	5165119.5
33	Tamarack	Open	390330.4375	5175253
34	Tamarack	Tamarack	384197.5938	5170266
35	Tamarack	Tamarack	384375.4375	5170323
36	Tamarack	Open	392571	5178340
37	Tamarack	Mixed	393112.6875	5160564
38	Tamarack	Tamarack	387887.1875	5168327
39	Tamarack	Tamarack	387699.875	5163973.5
40	Tamarack	Open	393887.0938	5168793

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
41	Tamarack	Aspen	392446.375	5175939
42	Tamarack	Tamarack	384004.7813	5170510
43	Tamarack	Emergent Wetland	386202.8438	5166900.5
44	Tamarack	Tamarack	387763.1875	5168127
45	Tamarack	Tamarack	385262.7188	5173632.5
46	Tamarack	Tamarack	385263.2188	5173585
47	Tamarack	Open	388611.1875	5178251.5
48	Tamarack	Emergent Wetland	386954.6563	5160209.5
49	Tamarack	Tamarack	387644.4063	5163891.5
50	Tamarack	Open	388220.5625	5168298.5
51	Water	Water	397149.7813	5164544.5
52	Water	Water	395106.5	5153309
53	Water	Emergent Wetland	396261.1875	5170666.5
54	Water	Water	395683.5938	5170849
55	Water	Water	392269.4063	5156689
56	Water	Water	393231.9063	5156251.5
57	Water	Water	395199.125	5153895
58	Water	Water	397083.5313	5164922
59	Water	Water	387316.9375	5166649
60	Water	Water	395034.8438	5153493
61	Water	Water	385967.0938	5167923.5
62	Water	Emergent Wetland	391236.625	5178051.5
63	Water	Water	392374.2188	5153679
64	Water	Water	393477.3125	5167647.5
65	Water	Water	397173.0938	5164679
66	Water	Water	392357.2188	5153786
67	Water	Water	393712.125	5167707.5
68	Water	Water	395049.6563	5154088.5
69	Water	Water	392149.5938	5153803
70	Water	Water	394826.0625	5154062.5
71	Open	Open	396652.1563	5165724
72	Open	Open	380349.125	5167649
73	Open	Open	386125.6875	5174011.5
74	Open	Open	386002.8438	5173862
75	Open	Open	388464.25	5176436
76	Open	XXXX	379762.7813	5164978
77	Open	Open	381909.3438	5168489
78	Open	Open	390924.3438	5175907.5
79	Open	Open	386528.8125	5174055
80	Open	Open	388630.5938	5178719.5
81	Open	Open	388780.875	5176869.5
82	Open	Open	393322.0313	5178413
83	Open	Open	391493.25	5176576
84	Open	Open	394978.7813	5169769.5
85	Open	Open	382182.8438	5165938

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
86	Open	Woody Wetland	395860.7813	5156577
87	Open	Open	383266.5313	5166897.5
88	Open	Open	391628.5625	5173598
89	Open	Open	381761.2813	5165408
90	Open	Open	381758.8438	5169321.5
91	Deciduous	Deciduous	394858.4063	5164475.5
92	Deciduous	Open	390279.9688	5176913
93	Deciduous	Woody Wetland	393305.7188	5157699
94	Deciduous	Deciduous	388226.125	5161761.5
95	Deciduous	Deciduous	392895.0625	5164203
96	Deciduous	Deciduous	389539	5167541
97	Deciduous	Deciduous	394621.5	5171706
98	Deciduous	Deciduous	388810.4688	5162261.5
99	Deciduous	Deciduous	386201.1563	5167208.5
100	Deciduous	Deciduous	394537.1875	5171722.5
101	Deciduous	Open	392568.7813	5178273.5
102	Deciduous	Deciduous	395898.9375	5164898.5
103	Deciduous	Deciduous	386079.2813	5166228
104	Deciduous	Deciduous	392166.5313	5173743
105	Deciduous	Deciduous	392982.2188	5165235.5
106	Deciduous	Deciduous	392996.6563	5166045
107	Deciduous	Woody Wetland	394318.9063	5157362.5
108	Deciduous	Deciduous	388986.8438	5172366
109	Deciduous	Deciduous	388121.0625	5165152.5
110	Deciduous	Deciduous	394200.25	5165450.5
111	Conifer	Mixed	388432.4063	5168210
112	Conifer	Water	393168	5156564
113	Conifer	Woody Wetland	393825.5	5158754.5
114	Conifer	Mixed	397305.7188	5163241
115	Conifer	Woody Wetland	397056.9063	5152239.5
116	Conifer	Mixed	393064.1875	5154346.5
117	Conifer	Woody Wetland	392574.5	5154507.5
118	Conifer	Woody Wetland	396538.4688	5151636.5
119	Conifer	Deciduous	392349.0938	5177682
120	Conifer	Woody Wetland	397908.3438	5166877.5
121	Conifer	Woody Wetland	396764.4375	5156178.5
122	Conifer	Woody Wetland	391575.4375	5163044.5
123	Conifer	Woody Wetland	396384.9688	5163926.5
124	Conifer	Mixed	390400.0313	5170995
125	Conifer	Mixed	394035.6563	5155164
126	Conifer	Woody Wetland	394216.0938	5156741.5
127	Conifer	Woody Wetland	390913.0625	5171796
128	Conifer	Aspen	382928.2188	5170087
129	Conifer	Woody Wetland	391713.7813	5161814
130	Conifer	Conifer	380349.6563	5169875
131	Mixed	Conifer	385478.4375	5172812.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
132	Mixed	Conifer	390291.4375	5174637
133	Mixed	Mixed	386779.125	5165941
134	Mixed	Mixed	393683.75	5166669.5
135	Mixed	Jack Pine	381995.2813	5167794
136	Mixed	Woody Wetland	393019.7813	5156764
137	Mixed	Woody Wetland	397753.5	5153872.5
138	Mixed	Mixed	391908.9688	5163220
139	Mixed	Woody Wetland	388073.75	5160603.5
140	Mixed	Mixed	385116.0313	5167333.5
141	Mixed	Mixed	387122.4375	5166421.5
142	Mixed	Woody Wetland	395702.3438	5155918.5
143	Mixed	Open	386906.7813	5174636
144	Mixed	Mixed	394359.2188	5174998
145	Mixed	Mixed	394719.4688	5161182
146	Mixed	Mixed	395290.625	5154763.5
147	Mixed	Woody Wetland	391844.7813	5161822.5
148	Mixed	Woody Wetland	395294	5155104
149	Mixed	Mixed	386187.8438	5170350
150	Mixed	Conifer	385845.7813	5170640.5
151	Aspen	Aspen	388172.5938	5175064.5
152	Aspen	Aspen	388621.3438	5174855
153	Aspen	Aspen	389438.0313	5176334
154	Aspen	Aspen	382438.0313	5171047.5
155	Aspen	Aspen	382256.5625	5170543
156	Aspen	Aspen	382222.875	5170807
157	Aspen	Aspen	382262.1875	5170118
158	Aspen	Aspen	393512.375	5165406
159	Aspen	Aspen	381466.0625	5170534.5
160	Aspen	Aspen	382566.125	5169902.5
161	Aspen	Aspen	382659.9688	5168966.5
162	Aspen	Aspen	381119.625	5170227
163	Aspen	XXXX	381451.1875	5162379.5
164	Aspen	Aspen	391909.9063	5173769
165	Aspen	Aspen	392029.6875	5177117.5
166	Aspen	Aspen	382220.1563	5170502
167	Aspen	Aspen	379098.9688	5169505
168	Aspen	Aspen	380930.625	5170530.5
169	Aspen	Deciduous	382542.375	5169092.5
170	Aspen	Aspen	382417.5313	5170863
171	Jack Pine	Jack Pine	381481.2813	5166128.5
172	Jack Pine	XXXX	380865.2188	5170926
173	Jack Pine	Jack Pine	382042.125	5166394
174	Jack Pine	XXXX	380980.8438	5165709
175	Jack Pine	Woody Wetland	395091.875	5154280.5
176	Jack Pine	Jack Pine	381546.9063	5168130
177	Jack Pine	Jack Pine	382848.0625	5167003.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
178	Jack Pine	XXXX	383852.1875	5165176
179	Jack Pine	Jack Pine	379633.5	5168869.5
180	Jack Pine	Jack Pine	379671.875	5167499.5
181	Jack Pine	Jack Pine	379711.7188	5167632
182	Jack Pine	XXXX	380784.4375	5164866
183	Jack Pine	Woody Wetland	384659.8438	5165791
184	Jack Pine	Woody Wetland	381982.1563	5165453.5
185	Jack Pine	Jack Pine	381222.5	5168034
186	Jack Pine	Open	395117.1875	5159686
187	Jack Pine	Jack Pine	379956.5938	5168087.5
188	Jack Pine	Jack Pine	382911.0625	5167863
189	Jack Pine	XXXX	380362.0625	5170836
190	Jack Pine	Jack Pine	381716.4375	5166478
191	Woody Wetland	Woody Wetland	397545.3438	5155756
192	Woody Wetland	Woody Wetland	394361.0313	5162555
193	Woody Wetland	Woody Wetland	397686.125	5168504
194	Woody Wetland	Woody Wetland	395639.1563	5166222.5
195	Woody Wetland	Mixed	397130.5	5168454.5
196	Woody Wetland	Mixed	384692.7813	5173856
197	Woody Wetland	Deciduous	397353.25	5150968.5
198	Woody Wetland	Woody Wetland	391575.4063	5157160
199	Woody Wetland	Woody Wetland	394623.8125	5157011.5
200	Woody Wetland	Woody Wetland	390730.7188	5160720.5
201	Woody Wetland	Woody Wetland	395606.2188	5168127.5
202	Woody Wetland	Woody Wetland	386803.0625	5164065.5
203	Woody Wetland	Woody Wetland	384741.9063	5170036
204	Woody Wetland	Woody Wetland	397596.125	5150349
205	Woody Wetland	Woody Wetland	389359.375	5174850.5
206	Woody Wetland	Woody Wetland	389419.375	5166532.5
207	Woody Wetland	Woody Wetland	396116.2813	5153795
208	Woody Wetland	Woody Wetland	389090.7188	5174586.5
209	Woody Wetland	Woody Wetland	396707.0625	5155430.5
210	Woody Wetland	Mixed	394903	5159436
211	Emergent Wetland	Emergent Wetland	393297.1563	5155402
212	Emergent Wetland	Emergent Wetland	394758.4063	5163135
213	Emergent Wetland	Emergent Wetland	395766.875	5162878
214	Emergent Wetland	Emergent Wetland	394994.9688	5168308.5
215	Emergent Wetland	Open	396381.4063	5163072.5
216	Emergent Wetland	Emergent Wetland	392421.8438	5169870
217	Emergent Wetland	Woody Wetland	393052.8438	5155260
218	Emergent Wetland	Emergent Wetland	385311.4688	5166394.5
219	Emergent Wetland	Emergent Wetland	395895.5625	5162996
220	Emergent Wetland	Emergent Wetland	396195.9375	5170530
221	Emergent Wetland	Emergent Wetland	393636.6875	5154788.5
222	Emergent Wetland	Emergent Wetland	392100.5625	5156133.5
223	Emergent Wetland	Emergent Wetland	393135.7188	5155595.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
224	Emergent Wetland	Emergent Wetland	390491.5625	5164680
225	Emergent Wetland	Emergent Wetland	392981.375	5166211
226	Emergent Wetland	Emergent Wetland	394896.625	5162485
227	Emergent Wetland	Emergent Wetland	395651	5157472
228	Emergent Wetland	Emergent Wetland	389630.8125	5172189
229	Emergent Wetland	Emergent Wetland	395908.75	5163044.5
230	Emergent Wetland	Emergent Wetland	394643.5	5159833.5
231	Water	Water	392310.6563	5156650.5
232	Water	Water	390284.3125	5158903
233	Water	Water	395060.375	5153617
234	Water	Water	397149.4688	5164899
235	Water	Water	395137.0938	5153321
236	Water	Water	392314.8125	5153998
237	Water	Water	394721.375	5158757.5
238	Water	Water	392404.5625	5154947.5
239	Water	Water	392399.6875	5153655.5
240	Water	Water	392461.5313	5155100.5
241	Water	Water	393460.5625	5164454.5
242	Water	Water	392885.6875	5156500
243	Water	Water	385945.3438	5167835
244	Water	Water	392404.0938	5153826.5
245	Water	Water	393613.875	5167620
246	Water	Water	392283.2813	5157329
247	Water	Water	392370.125	5157298.5
248	Water	Water	389353.875	5171618
249	Water	Water	395081.3125	5153892.5
250	Water	Water	392336.7813	5153798.5
251	Water	Water	389311.0938	5171555
252	Water	Woody Wetland	395185.0938	5158136.5
253	Water	Water	392355.1875	5156741.5
254	Water	Water	395202.25	5153938
255	Water	Water	393490.2813	5167527
256	Water	Water	394895.0313	5153879
257	Water	Water	393661.0625	5167838.5
258	Water	Water	389328.7813	5171637
259	Water	Emergent Wetland	392893.1875	5156614
260	Water	Water	395212.0625	5153882.5
261	Open	Open	381468.7813	5167154
262	Open	Open	380256.6563	5167659
263	Open	Open	379265.25	5168261.5
264	Open	Open	396302.0625	5156935.5
265	Open	XXXX	379653.9688	5165260
266	Open	Open	389702.9688	5178893
267	Open	Open	385948.2813	5167501.5
268	Open	Open	380437.5625	5167099
269	Open	Open	378932.4375	5167815

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
270	Open	Open	388756.6875	5179081
271	Open	Open	385716.0938	5167461
272	Open	Open	390578.6563	5177618.5
273	Open	Open	396235.4688	5168558.5
274	Open	Open	392063.0313	5174671
275	Open	Open	391933.375	5157433
276	Open	Open	379586.8438	5166343
277	Open	Open	386793.5938	5166505.5
278	Open	Open	382290.5313	5165731.5
279	Open	Open	397499.8438	5150924.5
280	Open	Open	394965	5170020.5
281	Open	Open	390701.6563	5175292
282	Open	Open	381368.1563	5168644.5
283	Open	XXXX	379722	5165613.5
284	Open	XXXX	381518.875	5165201.5
285	Open	Open	382253.5	5166011.5
286	Open	Open	379908.5938	5166797.5
287	Open	Open	382270.6875	5168625
288	Open	XXXX	379793.2188	5164858.5
289	Open	Tamarack	387666.625	5164981
290	Open	Open	383004.7188	5165772.5
291	Deciduous	Deciduous	390982.3125	5165884
292	Deciduous	Deciduous	391112.2813	5160756
293	Deciduous	Deciduous	392105	5167409.5
294	Deciduous	Mixed	384824.4688	5171225.5
295	Deciduous	Deciduous	396226.3438	5172094.5
296	Deciduous	Deciduous	383080.2188	5171821
297	Deciduous	Deciduous	395760.5938	5163558.5
298	Deciduous	Deciduous	385418.3125	5161824.5
299	Deciduous	Deciduous	385589.9063	5161236
300	Deciduous	Deciduous	389149.4063	5168105
301	Deciduous	Deciduous	394996.6875	5157757.5
302	Deciduous	Deciduous	391446.8438	5167241.5
303	Deciduous	Deciduous	396934.4688	5172735.5
304	Deciduous	Open	390581.125	5175167
305	Deciduous	Deciduous	396913.6875	5151512
306	Deciduous	Deciduous	386214.8125	5163550.5
307	Deciduous	Deciduous	388154.3125	5168477.5
308	Deciduous	Deciduous	386260.8125	5165470.5
309	Deciduous	Deciduous	395086.0938	5167361
310	Deciduous	Deciduous	388420.0938	5168979.5
311	Deciduous	Deciduous	394584.875	5174227
312	Deciduous	Deciduous	390268	5167550
313	Deciduous	Deciduous	391155.7813	5164842
314	Deciduous	Deciduous	389732.9688	5161642.5
315	Deciduous	Deciduous	388816.375	5158829

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
316	Deciduous	Deciduous	390046.7813	5166545.5
317	Deciduous	Deciduous	386677.8438	5162051.5
318	Deciduous	Deciduous	395614.3125	5153459
319	Deciduous	Deciduous	385339.0938	5173142
320	Deciduous	Mixed	385982.4375	5171790
321	Conifer	Woody Wetland	395943.6563	5151804
322	Conifer	Mixed	390752	5176484
323	Conifer	Woody Wetland	392336.9375	5155746.5
324	Conifer	Woody Wetland	385193.0313	5164334
325	Conifer	Conifer	385466.4063	5159763.5
326	Conifer	Woody Wetland	389854.0313	5163596.5
327	Conifer	Conifer	388231.6563	5162857.5
328	Conifer	Jack Pine	381652.1875	5170335.5
329	Conifer	XXXX	383183.625	5162182.5
330	Conifer	Deciduous	387530.9063	5166743
331	Conifer	Deciduous	397725.1563	5167935.5
332	Conifer	Jack Pine	380775.6875	5168160
333	Conifer	Conifer	392981.2813	5173517
334	Conifer	Conifer	395883.2813	5161328
335	Conifer	Woody Wetland	397317.1563	5153557.5
336	Conifer	XXXX	381480.1875	5162220.5
337	Conifer	Conifer	384055.4688	5168733
338	Conifer	XXXX	381326.7813	5164705.5
339	Conifer	Open	386301.7813	5167504.5
340	Conifer	Woody Wetland	391963.3125	5156557
341	Conifer	Conifer	390343.3125	5178552
342	Conifer	Woody Wetland	396515.5313	5156182.5
343	Conifer	Deciduous	396934.5313	5162967.5
344	Conifer	Mixed	385355.7813	5160985
345	Conifer	Conifer	395159.4063	5153757
346	Conifer	Conifer	382415.125	5171715
347	Conifer	Mixed	397433.5625	5168137
348	Conifer	Mixed	392575.6875	5159944
349	Conifer	Mixed	392641.5938	5174026.5
350	Conifer	Conifer	393351.9375	5176323
351	Mixed	Mixed	386691.4688	5170165.5
352	Mixed	Mixed	387489.0625	5164267.5
353	Mixed	Mixed	395799.625	5159060.5
354	Mixed	XXXX	380948.2813	5165282.5
355	Mixed	Woody Wetland	393630.9688	5161256
356	Mixed	Mixed	395435.5625	5155162.5
357	Mixed	Woody Wetland	394312.0938	5155547
358	Mixed	Mixed	396026.3438	5163258
359	Mixed	XXXX	383836.3438	5164019.5
360	Mixed	Mixed	388747.7188	5176010
361	Mixed	Mixed	384298.3125	5171176

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
362	Mixed	Woody Wetland	385448.125	5172454.5
363	Mixed	Mixed	396160.3125	5155403.5
364	Mixed	Deciduous	395159.625	5166509
365	Mixed	Mixed	386172.75	5170762.5
366	Mixed	Mixed	396028.4063	5160252
367	Mixed	Mixed	391568.4688	5157181
368	Mixed	XXXX	381010.2813	5165597
369	Mixed	Mixed	395531.7188	5156740.5
370	Mixed	Mixed	397073.7188	5166064.5
371	Mixed	Woody Wetland	397082.3438	5154535
372	Mixed	Woody Wetland	389513.0313	5163209
373	Mixed	Conifer	385845.5313	5171017
374	Mixed	Mixed	386768.7813	5166076.5
375	Mixed	Mixed	386690.9063	5170168
376	Mixed	Open	387241.5313	5160067
377	Mixed	Mixed	388735.0625	5176029.5
378	Mixed	Woody Wetland	389065.5625	5159814
379	Mixed	Mixed	391616.3438	5169085
380	Mixed	Woody Wetland	394798.9688	5157056.5
381	Aspen	XXXX	382649.6563	5168653
382	Aspen	Aspen	383138.125	5169668
383	Aspen	Aspen	383111.875	5169445
384	Aspen	Aspen	382908.875	5169937
385	Aspen	Aspen	378986.3125	5169244
386	Aspen	Aspen	388385.6875	5175146
387	Aspen	Aspen	383020.875	5169407
388	Aspen	Aspen	378578.7813	5168599
389	Aspen	Aspen	383325.4375	5169134
390	Aspen	Aspen	385053.9375	5166386.5
391	Aspen	Aspen	378930.1875	5169124
392	Aspen	XXXX	382569.8438	5163011
393	Aspen	Aspen	382539.6563	5169380
394	Aspen	Deciduous	382690.0625	5169188.5
395	Aspen	Aspen	383462.4063	5169142.5
396	Aspen	Open	382922.125	5168671
397	Aspen	Aspen	382404.8125	5170148.5
398	Aspen	Aspen	382597.375	5169619
399	Aspen	Conifer	383704.625	5169929
400	Aspen	Deciduous	382609.9375	5169051
401	Aspen	Aspen	383285.1563	5169943
402	Aspen	Aspen	392661.5625	5176251.5
403	Aspen	Woody Wetland	394755.75	5160039.5
404	Aspen	Open	386106.7188	5174427
405	Aspen	Conifer	383686.125	5169456
406	Aspen	Aspen	392615.7813	5176043.5
407	Aspen	Aspen	383106.1563	5168664.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
408	Aspen	XXXX	382176.9375	5163389.5
409	Aspen	Aspen	382627.6563	5169837
410	Aspen	Aspen	378983.3125	5169366.5
411	Jack Pine	Jack Pine	382287.4375	5166737.5
412	Jack Pine	XXXX	381302.375	5165155.5
413	Jack Pine	Jack Pine	381509.4063	5167420
414	Jack Pine	Jack Pine	382169.7813	5167874.5
415	Jack Pine	XXXX	381062.7188	5165302.5
416	Jack Pine	Jack Pine	383784.3125	5166269
417	Jack Pine	Jack Pine	381140.3438	5168012
418	Jack Pine	Jack Pine	380882.5625	5169076.5
419	Jack Pine	XXXX	381713.3438	5163642
420	Jack Pine	Jack Pine	382558.125	5168266
421	Jack Pine	Jack Pine	380146.25	5168754
422	Jack Pine	Jack Pine	382049.9375	5167980.5
423	Jack Pine	Jack Pine	381663.7188	5166274
424	Jack Pine	Jack Pine	381055.6563	5167665.5
425	Jack Pine	Jack Pine	380101.0625	5168489.5
426	Jack Pine	Jack Pine	382036.4375	5166730
427	Jack Pine	Open	390877.625	5161566
428	Jack Pine	Jack Pine	381840.7813	5167942.5
429	Jack Pine	Jack Pine	382461.9375	5166335.5
430	Jack Pine	XXXX	384492.7813	5161882.5
431	Jack Pine	Jack Pine	379417.9375	5168544
432	Jack Pine	Jack Pine	382341.25	5166869
433	Jack Pine	Jack Pine	383617.125	5167364.5
434	Jack Pine	Jack Pine	381265.75	5166535
435	Jack Pine	XXXX	378995.0938	5165398.5
436	Jack Pine	Jack Pine	381169.2188	5168095
437	Jack Pine	Jack Pine	382931.9063	5167726.5
438	Jack Pine	Jack Pine	382725.0625	5167084
439	Jack Pine	Jack Pine	379628.5	5168556.5
440	Jack Pine	Jack Pine	379915.6875	5167991
441	Woody Wetland	Conifer	394622.5	5161337.5
442	Woody Wetland	XXXX	381547.1563	5161893.5
443	Woody Wetland	Woody Wetland	395886	5152527.5
444	Woody Wetland	Open	389791.25	5178117
445	Woody Wetland	Woody Wetland	397792.8125	5163225
446	Woody Wetland	Woody Wetland	385353.0625	5171634.5
447	Woody Wetland	Mixed	394688.3438	5172716
448	Woody Wetland	Woody Wetland	397539.9375	5166169.5
449	Woody Wetland	Woody Wetland	393938.9688	5158597.5
450	Woody Wetland	Woody Wetland	395787.3438	5151440
451	Woody Wetland	Woody Wetland	396444.9375	5157662
452	Woody Wetland	Woody Wetland	392581.0625	5172041
453	Woody Wetland	XXXX	381644.0625	5161468.5

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
454	Woody Wetland	Woody Wetland	391845.4063	5162307.5
455	Woody Wetland	Woody Wetland	396086.9688	5169057.5
456	Woody Wetland	Woody Wetland	397229.75	5152115.5
457	Woody Wetland	Deciduous	388653.4688	5166877
458	Woody Wetland	Woody Wetland	391571.4688	5162084.5
459	Woody Wetland	Woody Wetland	393167.7813	5154451.5
460	Woody Wetland	Woody Wetland	397654.2813	5156784
461	Woody Wetland	Woody Wetland	389442.5938	5163187
462	Woody Wetland	Woody Wetland	394047.5625	5159854
463	Woody Wetland	Woody Wetland	393125.625	5159071
464	Woody Wetland	Woody Wetland	385581.0625	5172378.5
465	Woody Wetland	Woody Wetland	397333.9063	5154794
466	Woody Wetland	Woody Wetland	391384.125	5160390.5
467	Woody Wetland	Woody Wetland	395926.375	5155122
468	Woody Wetland	Woody Wetland	389468.25	5160438
469	Woody Wetland	Woody Wetland	396226.25	5168214
470	Woody Wetland	Woody Wetland	388388.4063	5167926
471	Emergent Wetland	Emergent Wetland	396403.9063	5169406
472	Emergent Wetland	Emergent Wetland	394656.3125	5163275
473	Emergent Wetland	Emergent Wetland	397261.9063	5152664
474	Emergent Wetland	Emergent Wetland	393268.9375	5155462
475	Emergent Wetland	Emergent Wetland	395547.2813	5168619
476	Emergent Wetland	Emergent Wetland	395097.0313	5168374.5
477	Emergent Wetland	Emergent Wetland	393309.375	5164774.5
478	Emergent Wetland	Woody Wetland	396003.4375	5163215.5
479	Emergent Wetland	Emergent Wetland	396355.6563	5162860.5
480	Emergent Wetland	XXXX	380742.3125	5163737.5
481	Emergent Wetland	Emergent Wetland	395879.1875	5163164.5
482	Emergent Wetland	Emergent Wetland	393674.8125	5175372
483	Emergent Wetland	Woody Wetland	396491.2813	5162877
484	Emergent Wetland	Emergent Wetland	396917.6875	5155392
485	Emergent Wetland	Emergent Wetland	391202	5178036
486	Emergent Wetland	Emergent Wetland	395333.1563	5157655
487	Emergent Wetland	Emergent Wetland	385895.2813	5160534.5
488	Emergent Wetland	Emergent Wetland	394646.625	5159780.5
489	Emergent Wetland	Emergent Wetland	392283.2188	5162759
490	Emergent Wetland	Open	386978.1563	5174562
491	Emergent Wetland	Emergent Wetland	390647.2813	5164885
492	Emergent Wetland	Emergent Wetland	393991.5625	5158941
493	Emergent Wetland	Emergent Wetland	392762.3438	5166379
494	Emergent Wetland	Emergent Wetland	392254.4063	5156737
495	Emergent Wetland	Emergent Wetland	393455.75	5172361.5
496	Emergent Wetland	Woody Wetland	393010.7188	5156584
497	Emergent Wetland	Emergent Wetland	392281.3438	5162866.5
498	Emergent Wetland	Emergent Wetland	397213.9688	5152633.5
499	Emergent Wetland	Emergent Wetland	395870.5	5163151

ID Number	Classified As	Field Checked	X-coordinate	Y-coordinate
500	Emergent Wetland	Emergent Wetland	393205.125	5155468