# Cloquet Forestry Center

# 2005 Covertype Mapping Project

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# Abstract

This report describes the methods and results for preparation of a forest covertype map updated to 2005 for the University of Minnesota's Cloquet Forestry Center. We reassessed and verified all stand boundaries and attributes. We initially assessed stand boundaries compared to recent (2003) high-resolution (0.6-meter) color infrared QuickBird satellite imagery followed by field verification. Field verification involved walking all stand boundaries and checking stand attributes using field GIS and GPS equipment. We collected stand attribute data, including tree species, basal area, diameter, and density, at three nonpermanent plots per stand. The plot data were averaged per stand to determine the stand attributes. We assessed stand accuracy using a separate independent data set consisting of approximately two plots per stand. The overall accuracy of the map was determined to be 74 percent. The covertype map and attribute data are available as GIS data files from either the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory or the Cloquet Forestry Center.

## Introduction: Purpose and Goals

Our primary objective was to update the existing covertype map for the Cloquet Forestry Center (CFC) to represent changes in the stand boundaries and attributes that have occurred since the creation of the last covertype map. In addition, we wanted to: (1) increase the spatial and attribute accuracy and detail of the map by incorporating GIS and GPS technology with quantitative field methods of assessing species, size and stocking attributes of all stands, and (2) increase the credibility of the map for the purposes of scientific research by performing a detailed accuracy assessment using an independent set of randomly sampled data.

## Methods

This mapping project involved four stages. First, we edited the most recent version of the CFC covertype map using forest management records, input from CFC staff, and photo interpretation. Second, we verified all upland sites, and most lowland sites in the field. Then, we conducted post processing of the updated CFC map to improve quality. Finally, we used an independent set of random points to assess the accuracy of the map.

### Initial Edits to Most Recent CFC Covertype Map

The initial edits to the CFC map involved generating poster maps that were reviewed by CFC staff, compared against forest management records and photo interpreted. Edits were marked directly on the poster map and included adjustment of stand boundaries, addition of stands, and updates to stand attributes. We transferred these edits to the digital covertype map using ArcMap GIS software.

The initial covertype maps for the CFC, prepared under the direction of Professor Merle Meyer, were created from interpretation of stereo photography in 1977. These paper maps at a scale of 1:15,840 were developed from 1:9,600 scale spring leaf-off panchromatic photography and 1:15,840 scale summer infrared black and white photography flown in 1975. The map was updated in 1982 and was later hand digitized and then periodically updated with forest harvest and planting changes, but not growth. We used the most recently updated (2002) digital covertype map as the starting point for map improvement based on photo interpretation of QuickBird satellite imagery and aerial photographs.

We used pan-sharpened (0.6 meter pixels) QuickBird satellite imagery (blue, green, red, near infrared spectral bands), acquired on September 13, 2003, as the primary imagery used in photo interpretation and stand delineation. This imagery was rectified to an RMSE of 3.7792 pixels (2.2695 meters) using 26 ground control points and the Cloquet Forestry Center Roads file (provided by A. Jenks and C. Kramer, 2004) as the rectification base map.

We also used black and white aerial photographs (< 0.5 meter spatial resolution) acquired on March 14, 2003, to supplement the satellite imagery during the initial stand identification phase. These photographs were taken as part of an image acquisition project performed by the adjacent Fond du Lac Reservation. These photographs were mosaiced using the ERDAS Imagine mosaicing tool to create a single image covering the entire CFC. This imagery was used in the photo interpretation and stand delineation process to separate deciduous and confer stands.

Projections for all imagery and geospatial files are Universal Transverse Mercator, Geodetic Reference System 80, UTM Zone 15. Units of measure are meters.

## Field Verification

We conducted fieldwork with GPS-capable field GIS units (PDAs) equipped with ArcPad software. This equipment allowed field technicians to view the high-resolution satellite imagery and the covertype map in the field and, therefore, track their exact location via the real time GPS location curser.

Field data collection consisted of: (1) verification of stand boundaries and (2) stand attribute data acquisition. We conducted verification of stand boundaries by walking the physical perimeter of the stand and comparing the GPS location to the covertype map illustrated on the PDAs. We marked adjustments to stand boundaries and/or addition of new stands on quarter-section field maps (Figure 1). After walking the boundary of a stand, we collected stand attribute data at three randomly selected, representative, nonpermanent plots within that stand. We entered these plot data into the field GIS using custom ArcPad data collection forms created with ArcStudio software (Figure 2).

We collected the following data at each plot: basal area of the three primary species (primary species were determined by basal area), diameter at breast height (dbh) of the most dominant (based on basal area) tree species, and stocking of the dominant species using stocking charts and tables (based on dbh and BA). After data were collected for three plots, we summarized the plot-level data and determined the overall stand type (dominant stand species), size (average dbh of dominant species), and stocking class. The overall stand type was assigned based on the "Forest Covertype Classification System" guidelines and recorded in the field GIS (Appendix 1). We recorded new stand data on the quarter-section field maps for subsequent entry.

We performed final edits to both the stand boundaries and stand attributes in the lab using ArcMap software. We transcribed all boundary adjustments and new stand additions that were marked on the field maps to the final GIS map. Also, attribute data for new stands were entered.

## Post Processing

We performed several postprocessing steps to ensure spatial and attribute integrity of the new covertype map. These steps included logical consistency tests, completeness tests, and horizontal and vertical positional accuracy tests.

The logical consistency tests included: (1) a test of valid values within each forest type, (2) a visual check of the maps to detect gaps or slivers between polygons and to correct line feature sharpness, and (3) a topological consistency check performed using GIS software (ArcMap) to detect flaws in spatial data structure. This ensured that polygons were closed, nodes formed at the intersection of lines, all adjacent boundary lines matched, and slivers were removed.

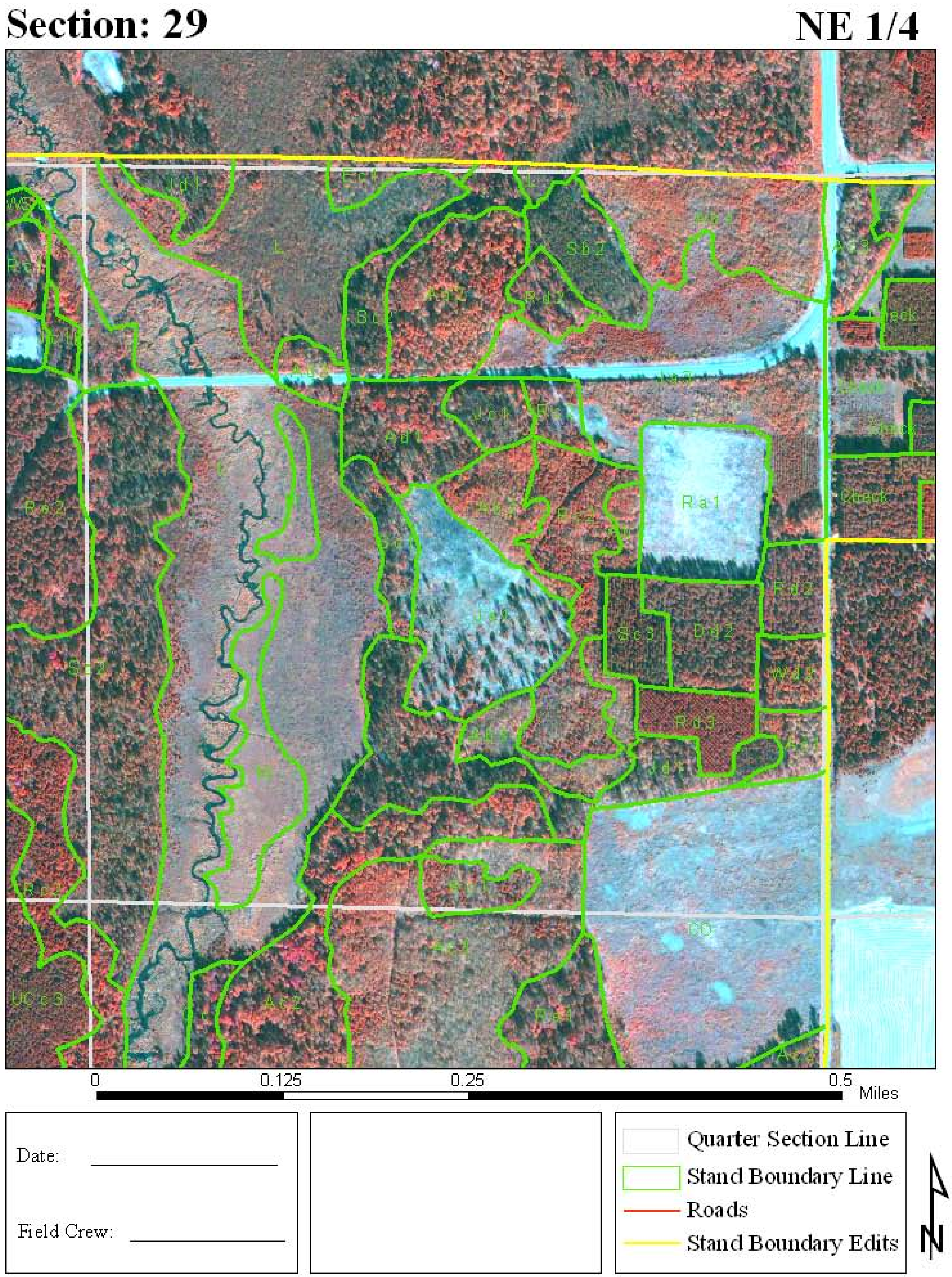


**Figure 1.** Example quarter-section field map on QuickBird false color image.

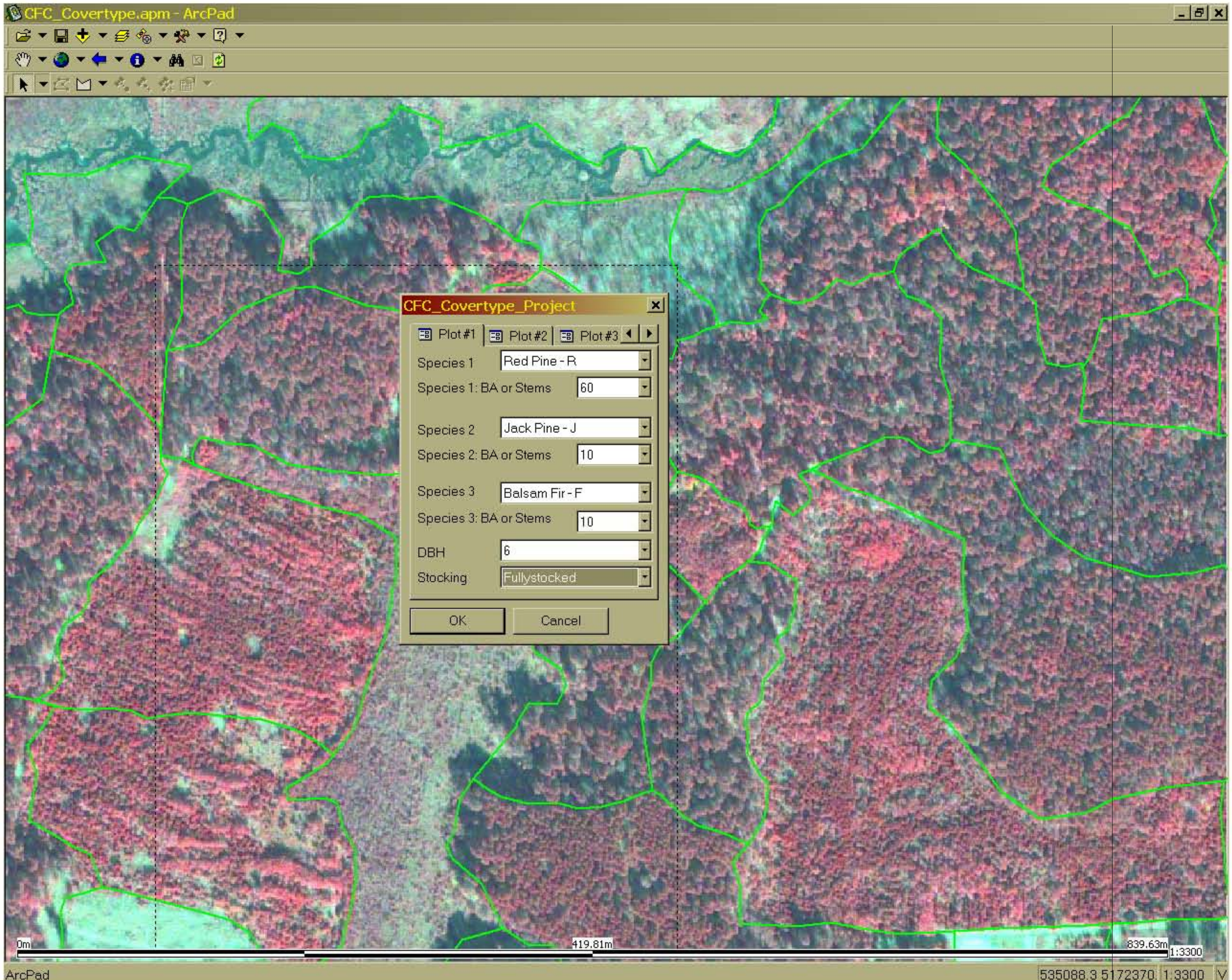


**Figure 2.** Custom ArcPad form for field data collection.

We checked completeness by visual inspection. First, we visually inspected the covertype map against the CFC boundary file to check for holes or missing stands, and verified that the covertype map included the entire extent of the CFC. Second, we visually inspected the attribute table of the covertype map to search for missing, incomplete, or inappropriate stand records.

Horizontal and vertical positional accuracy depended on two factors: image rectification and GPS positional accuracy. Covertype boundaries were initially delineated from rectified high-resolution (<1 meter pan-sharpened) color infrared satellite imagery via on screen digitizing with ESRI ArcMap GIS software. Image rectification horizontal positional accuracy was 1.6868 pixels (1.0129 meters) and vertical positional accuracy is 3.3819 pixels (2.0309 meters). Following on-screen digitizing, we transferred the data to the field GIS equipment (PDAs). Field technicians walked all stand boundaries to verify stand attributes and spatial extent. Necessary adjustments were marked on quarter-section maps in the field and then transferred to the covertype map in the lab using ArcMap GIS. Horizontal accuracy in the field was dependent on the GPS accuracy. The GIS equipment utilized WAAS differential correction.

### Accuracy Assessment

We performed accuracy assessment for the CFC covertype map using two or more randomly selected points per stand (forest or nonforest). Accuracy assessment points originated from two data sources: (1) randomly generated points and (2) ruffed grouse research data. For all non-aspen stand types we used Hawth's analysis tools (Beyer, 2004) extension in ArcMap 9.0 to randomly generate two accuracy checkpoints in each of the stands. If the two random points landed within 20 meters of one another, we eliminated the second point and generated another one. We obtained accuracy assessment sites for aspen stands from vegetation data collected at ruffed grouse drumming logs for the ruffed grouse research project. Although non-aspen covertype data were collected for this project, we could not use it to assess non-aspen covertypes because previous research indicates that grouse preferentially select aspen and may actively search for small patches of aspen within stands of other forest types. Such habitat selection would bias the accuracy checks in non-aspen forest stands by artificially increasing the amount of aspen represented in those stands. Thus, only the data from the ruffed grouse project that fell within aspen stands were used in the accuracy assessment of the CFC covertype. All sites meeting that criterion were utilized in the accuracy assessment.

For consistency, we collected the stand variables for the accuracy plots using the same techniques used while collecting field data for the CFC covertype map. Further, the same cover-typing definitions and rules were used to assign a stand to a covertype class.

We set two distinctive methods to estimate accuracy of the CFC covertype map. First, we developed three traditional error matrices (Congalton and Green, 1999) to assess the accuracy of covertypes, size classes, and density classes. The covertype error matrix included the 24 covertypes in which random accuracy checkpoints were included. The size-class error matrix included all five size classes, and the density-class error matrix included all three stocking levels. The rows of each error matrix represented the covertype, size class, or stocking class indicated on the updated CFC covertype map. The columns of the error matrix represent the covertypes determined during field accuracy checks.

After computing the traditional error matrix, we felt that this method did not provide an entirely sufficient or accurate check of the CFC covertype map. This was because the minimum mapping unit of the map (1 ha) is larger than the spatial scale of the accuracy points (< 20 $m^2$). Such scale differences bias accuracy checks because a stand may be classified correctly (i.e., >66 percent of the stand is a single species), but the accuracy check point lands in a small area dominated by inclusions of an alternative species. However, this approach is confounded by variability within stands. We, therefore, conducted a second type of accuracy assessment in which we summed the basal area of tree species across categories that represented each of the covertypes. If our map was accurate according to our rules and the sample size of checkpoints in each of the covertypes was large enough, then 66 percent of the pooled basal area should be the covertype of that category. For example, we summed the basal area of all tree species recorded in the accuracy checkpoints that landed in red pine stands. We then divided the total basal area of those points by the basal area of red pine. If the percent was >66, then we assume that the map was accurate, whereas if the percent was <66, we concluded that the map was not accurate for that covertype, given the sample size of accuracy checkpoints. Because we considered basal area in this approach, we limited this accuracy check to forest stands with commercially valuable tree species.

## Results

### Covertype Map

A map of stand boundaries overlaid on the QuickBird image is shown in Figure 3. The final covertype map with size and stocking classes, shown in Figure 4, is complete in both coverage and attributes. The entire area of the CFC is included in the covertype map and each stand contains the appropriate attribute data.

Logical consistency tests for the final version of the CFC covertype map were all favorable. Our visual inspection indicated no gaps or slivers between polygons, and that line features were the proper sharpness. We detected no flaws in the spatial data structure during the topological consistency check. Also, we found that all polygons were closed, nodes formed at the intersection of lines, and all adjacent boundary lines matched.

Because we field verified all stand boundaries, the spatial accuracy of the boundary lines was dependent on the GPS positional accuracy. The GIS equipment used WAAS differential correction. The WAAS signal, which is reported to have minimal positional accuracy of 3 meters, was available for the majority of the fieldwork. However, we found the positional accuracy of the GPS to be less than the 3 meters for much of the boundary verification.

### Map Accuracy

The error matrix (Table 1) indicated great variability in accuracy (range of 14 to 100 percent) for the different covertypes. However, due to time constraints, we had extremely small sample sizes for several covertypes, so we suggest that accuracy assessment for some stand types be viewed with caution (e.g., cedar, birch, white pine). We also suggest that the results for classes containing mixes of multiple species (e.g., upland conifer, northern hardwoods) be viewed with caution because these stands contain a mix of different species and are therefore highly sensitive to relatively small sample sizes and spatial scales of the accuracy checkpoints. The error matrix

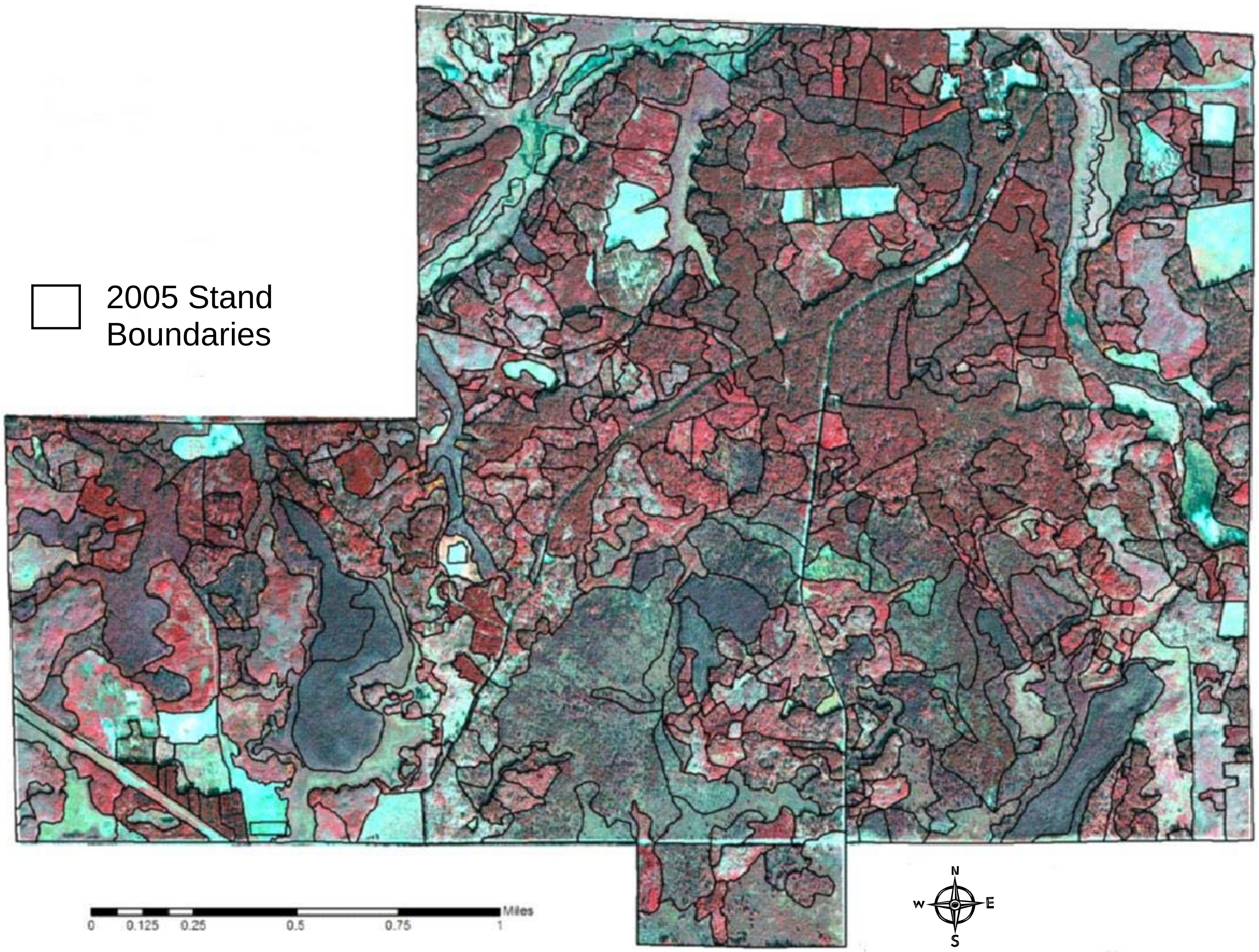


**Figure 3.** Updated 2005 Cloquet Forestry Center **s**tand boundaries overlaid on QuickBird false color image.

# Cloquet Forestry Center
## 2005 Cover Type Map

| Symbol | Cover Type | Symbol | Cover Type |
|---|---|---|---|
| A | Aspen | R | Red Pine |
| B | Paper Birch | S | Black Spruce |
| C | White Cedar | T | Tamarack |
| D | Scotch Pine | W | White Pine |
| E | Bottomland Hardwoods | WS | White Spruce |
| F | Balsam Fir | | |
| H | Black Ash | Sx | Non-productive Swamp |
| J | Jack Pine | U | Upland Brush |
| Q | Mixed Swamp Conifers | L | Lowland Brush |
| UC | Upland Conifers | M | Marsh |
| MS | Maple | G | Grass |
| N | Northern Hardwoods | CO | Current Cutover |
| NS | Norway Spruce | PX | Experimental Planting |
| O | Oak | AD | Administrative |
| HC | Mixed Hardwood/Conifer | | |

| Symbol | Size Class | Description |
|---|---|---|
| a | Seedlings | <1 inch DBH |
| b | Saplings | 1 – 4.9 inch DBH |
| c | Poles | 5 – 8.9 inch DBH |
| d | Small Sawtimber | 9 – 14.9 inch DBH |
| e | Large Sawtimber | >15 inch DBH |

| Symbol | Stocking Class | Poles and Sawtimber Basal Area* | Seedlings Stems/Acre** | Saplings Stems/Acre*** |
|---|---|---|---|---|
| 1 | Under | See | 200 – 799 | 175 – 399 |
| 2 | Fully | stocking | 800 – 1399 | 400 – 749 |
| 3 | Over | charts | > 1400 | > 750 |

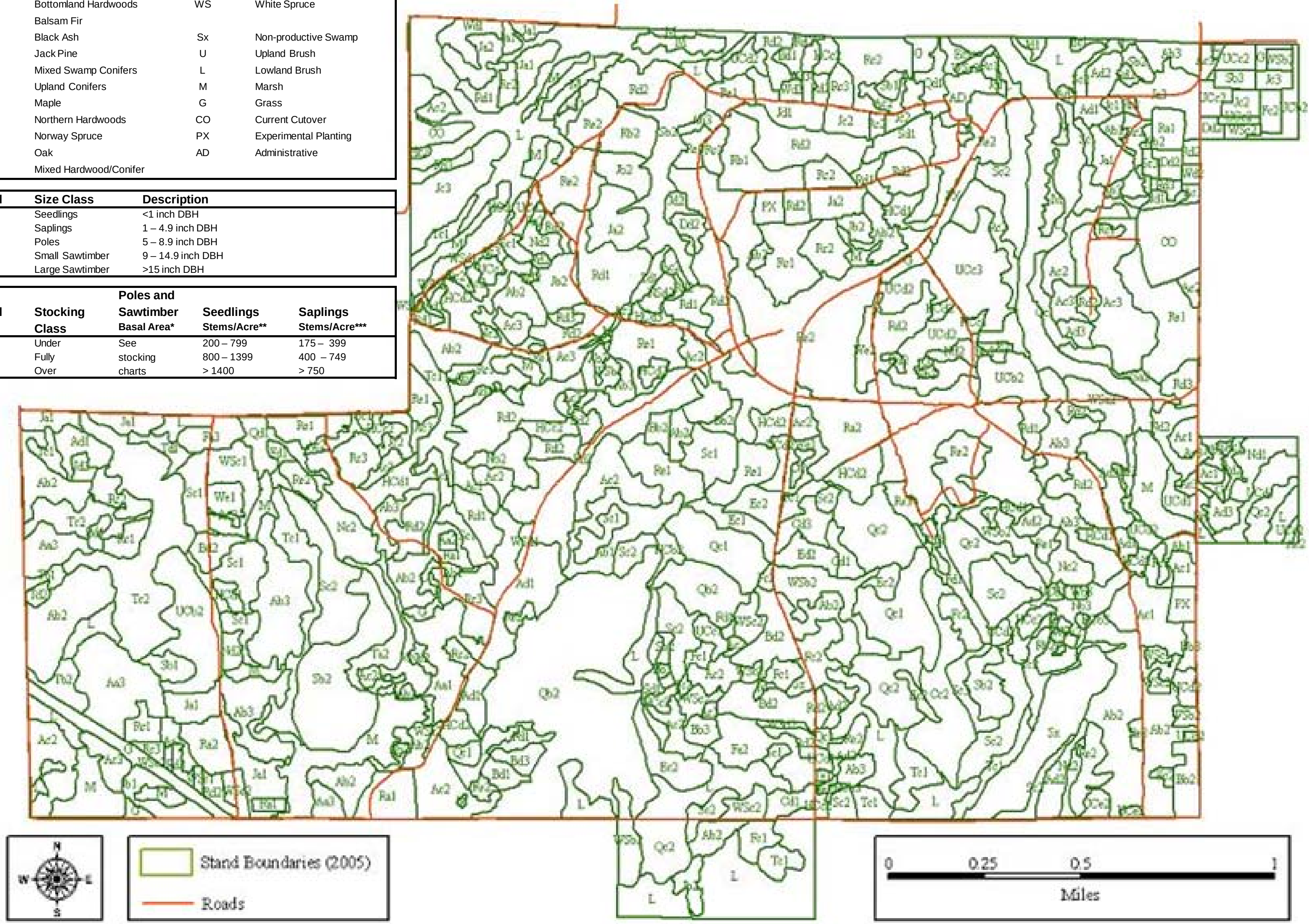


**Figure 4.** Updated 2005 Cloquet Forestry Center covertype map.

**Table 1.** Error matrix for covertype classes used in the CFC covertype map.

| Covertype | A | B | C | D | E | F | H | J | Q | UC | MS | N | O | HC | R | S | T | W | WS | Sx | U | L | M | G | CO | PX | AD | Total | Producers Acc. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 175 | 10 | | | | 4 | | 1 | | 8 | 2 | 7 | | 18 | 5 | | 1 | | 1 | | 47 | | | | | | | 279 | 63 |
| B | 4 | 8 | | | | | | | | | | 2 | | 2 | | | | | | | | | | | | | | 16 | 50 |
| C | | | 5 | | | 1 | 1 | | | | | | | 1 | | | | | | | | 1 | | | | | | 9 | 56 |
| D | | | | 4 | | | | | | | | | | | | | | | | | | | | | | | | 4 | 100 |
| E | | | | | 12 | | 2 | | | | | | | | | | | | | | | 2 | | | | | | 16 | 75 |
| F | | 1 | | | 1 | 4 | | | | | 1 | | | 3 | | 4 | | | | | 1 | 4 | | | | | | 19 | 21 |
| H | | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | 4 | 100 |
| J | | 1 | | | | | | 31 | | 3 | | | | 2 | 3 | | | | | | 7 | | | | | | | 47 | 66 |
| Q | | | 2 | | | | | | 11 | | | | | | | 4 | | | | | 2 | 2 | | | | | | 21 | 52 |
| UC | 1 | | | 1 | | 2 | | 6 | | 4 | 1 | | | 2 | 8 | 1 | | | 2 | | | | | | | | | 28 | 14 |
| MS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 3 | 2 | | | | | | | | 1 | | 5 | | 2 | 2 | | | | | | | | | | | | | 15 | 33 |
| O | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HC | 1 | 2 | | | | 2 | | | | 4 | | | 1 | 4 | 5 | | 1 | | | | | 1 | | | | | | 21 | 19 |
| R | 6 | 1 | | | | | | 8 | | 10 | 1 | 1 | | 4 | 129 | | | 1 | 3 | | 1 | 1 | 1 | | 1 | | | 168 | 77 |
| S | 1 | | | | | 1 | | | 1 | 1 | | 1 | | | 1 | 48 | 3 | | | | | 6 | | 1 | | | | 64 | 75 |
| T | | | | | | | | | 1 | 1 | | | | | 1 | 4 | 20 | | | 2 | | 5 | 2 | | | | | 36 | 56 |
| W | | 1 | | | | 1 | | | | 1 | | | | | | | | 7 | | | | 1 | | | 2 | | | 13 | 54 |
| WS | 3 | | | | | | | | | | | 1 | | 4 | | 1 | 2 | | 22 | | | | | | | | | 33 | 67 |
| Sx | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | | 4 | 100 |
| U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L | | | | | | | 2 | 1 | | | | | | | | | | | 1 | | | 34 | 3 | | | | | 41 | 83 |
| M | 1 | | | | | | | | | | | | | | | | | | | | | 3 | 25 | | | | | 29 | 86 |
| G | | | | | | | | | | | | | | | 2 | | | | | | 1 | | | 4 | | | | 7 | 57 |
| CO | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | | 4 | 100 |
| PX | | | | | | | | | | | | | | | | | | | | | 2 | | | | | 2 | | 4 | 50 |
| AD | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 100 |
| Total | 195 | 26 | 7 | 5 | 13 | 15 | 9 | 47 | 13 | 33 | 5 | 17 | 1 | 42 | 156 | 62 | 27 | 8 | 29 | 6 | 61 | 60 | 31 | 5 | 7 | 2 | 1 | 651 | |
| User Acc. (%) | 90 | 31 | 71 | 80 | 92 | 27 | 44 | 66 | 85 | 12 | 0 | 29 | 0 | 10 | 83 | 77 | 74 | 88 | 76 | 67 | 0 | 57 | 81 | 80 | 57 | 100 | 100 | | |
| Overall Acc. (%) | 74 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

for size class indicated that smaller size classes were more accurate than larger size class (Table 2). The error matrix for density indicated that accuracy was low for all three stocking classes (Table 3).

Our second approach for assessing map accuracy (i.e., pooling basal area by covertype class) indicated that 10 of the 17 covertype classes assessed with this approach met our criteria given the sample size of accuracy checkpoints (Table 4).

**Table 2.** Error matrix for size class categories used in the CFC covertype map.

| **Size Class** | **a** | **b** | **c** | **d** | **e** | **Total** | **Producers Acc. (%)** |
|---|---|---|---|---|---|---|---|
| a | 25 | | 1 | 2 | | 28 | 89 |
| b | 4 | 65 | 3 | 3 | 1 | 76 | 86 |
| c | 2 | 19 | 129 | 32 | 3 | 185 | 70 |
| d | 2 | 2 | 23 | 97 | 28 | 152 | 64 |
| e | 1 | | 4 | 12 | 28 | 45 | 62 |
| Total | 34 | 86 | 160 | 146 | 60 | 344 | |
| **Users Acc. (%)** | 74 | 76 | 81 | 66 | 47 | | |
| **Overall Acc. (%)** | 71 | | | | | | |

**Table 3.** Error matrix for density classes used in the CFC covertype map.

| **Density** | **1** | **2** | **3** | **Total** | **Producers Acc. (%)** |
|---|---|---|---|---|---|
| 1 | 86 | 42 | 5 | 133 | 65 |
| 2 | 89 | 164 | 30 | 283 | 58 |
| 3 | 12 | 28 | 28 | 68 | 41 |
| Total | 187 | 234 | 63 | 278 | |
| **Users Acc. (%)** | 46 | 70 | 44 | | |
| **Overall Acc.** | 57 | | | | |

**Table 4.** Cumulative forest stand accuracy assessment.

| Covertype | Number of points | Proportion of covertype | Meets criteria |
|---|---|---|---|
| A | 279 | 0.70 | Yes |
| B | 28 | 0.60 | No |
| C | 20 | 0.65 | No |
| D | 2 | 0.89 | Yes |
| E | 13 | 0.81 | Yes |
| F | 27 | 0.27 | No |
| H | 5 | 0.71 | Yes |
| HC | 34 | none>66% | Yes |
| J | 23 | 0.59 | No |
| N | 19 | 0.57 | No |
| Q | 17 | 0.84 | Yes |
| R | 267 | 0.76 | Yes |
| S | 28 | 0.49 | No |
| T | 27 | 0.55 | No |
| UC | 59 | 0.85 | Yes |
| W | 17 | 0.60 | No |
| WS | 28 | 0.86 | Yes |

## Discussion

The CFC is composed of 506 stands totaling 3,428 acres and consists of a mix of conifer, hardwood, and mixed commercial stands along with a wide array of noncommercial stands (Figure 4). The following is a summary of these stands computed from the updated CFC covertype map.

Stands composed of commercial tree species (Figure 5) make up 2,894 acres (84.4 percent) of the CFC. Of the commercial stand area, 71.6 percent (2,073 acres) are conifer, 25.4 percent (734 acres) are hardwood, and 3.0 percent (87 acres) are mixed stands. The remaining 15.6 percent (534 acres) is made up of a mix of noncommercial covertypes. Most of the noncommercial area is either Lowland or Marsh (Table 5).

There are 286 conifer stands that total 2,073cres. Most conifer stands are dominated by a single species, red pine, which covers 778 acres of the CFC with 95 separate stands. The majority of the red pine stands are in the “d” and “e” size classes (9+ inches dbh) and are considered to be sawtimber. Black Spruce and Mixed Swamp Conifer are the next most abundant conifer stands, each covering an area of approximately 260 acres. Most of these stands are either sapling or pole size. Jack Pine, Tamarack, and Upland Conifer make up the majority of the remainder of the conifer area with about 150 acres each. There were surprisingly few white pine stands with only a total of 28 acres (Table 6).

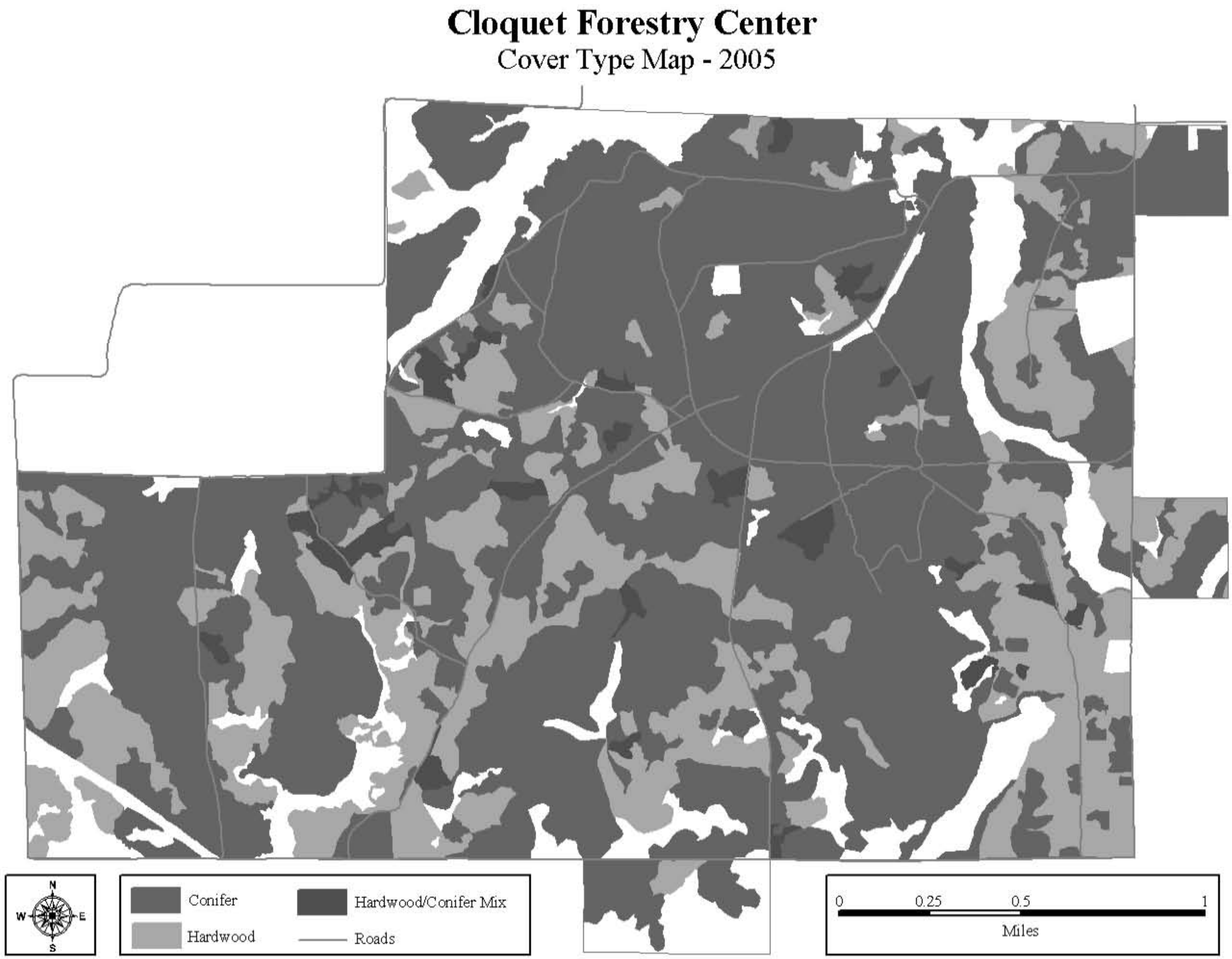


**Figure 5.** Generalized Cloquet Forestry Center covertype map—commercial tree species.

**Table 5.** Stand summary by covertype.

| Covertype | Total stands | Average size (acres) | Total area (acres) | Total area (%) |
|---|---|---|---|---|
| Conifer Stands | | | | |
| C | 4 | 10.5 | 42.0 | 1.2 |
| D | 4 | 2.4 | 9.5 | 0.3 |
| E | 8 | 5.1 | 40.5 | 1.2 |
| F | 15 | 4.8 | 72.0 | 2.1 |
| J | 31 | 5.8 | 180.1 | 5.3 |
| Q | 15 | 17.5 | 263.1 | 7.7 |
| R | 95 | 8.2 | 777.8 | 22.7 |
| S | 35 | 7.5 | 261.5 | 7.6 |
| T | 18 | 8.6 | 154.2 | 4.5 |
| UC | 26 | 5.6 | 146.7 | 4.3 |
| W | 9 | 3.1 | 27.7 | 0.8 |
| WS | 26 | 3.7 | 97.4 | 2.8 |
| *Total:* | *286* | | *2,072.6* | *60.5* |
| Hardwood Stands | | | | |
| A | 99 | 6.0 | 590.2 | 17.2 |
| B | 13 | 5.1 | 65.7 | 1.9 |
| H | 1 | 0.7 | 0.7 | 0.0 |
| N | 15 | 5.0 | 74.3 | 2.2 |
| NS | 1 | 3.3 | 3.3 | 0.1 |
| *Total:* | *129* | | *734.2* | *21.4* |
| Mixed Stands | | | | |
| HC | 24 | 3.6 | 87.1 | 2.5 |
| Noncommercial | | | | |
| AD | 1 | 8.2 | 8.2 | 0.2 |
| CO | 3 | 9.6 | 28.7 | 0.8 |
| G | 8 | 3.5 | 27.9 | 0.8 |
| L | 27 | 10.5 | 282.3 | 8.2 |
| M | 20 | 5.3 | 107.0 | 3.1 |
| PX | 3 | 4.1 | 12.2 | 0.4 |
| Sx | 3 | 21.4 | 64.1 | 1.9 |
| U | 2 | 2.0 | 4.1 | 0.6 |
| *Total:* | *67* | | *534.5* | *15.6* |
| **CFC Total:** | **506** | | **3,428.4** | |

Hardwoods were dominant in 129 stands covering 734 acres. Of this area, aspen was by far the most abundant with 99 stands totaling 590 acres. As expected, most of the aspen stands were in the sapling and pole timber size classes. Birch and northern hardwoods stands comprised much of the remaining hardwood area with approximately 15 stands and 70 acres each (Table 7).

**Table 6.** Conifer stand summary by covertype and size class.

| Covertype / Size | Total stands | Mean size (acres) | Total area (acres) |
|---|---|---|---|
| N. White Cedar (C) | | | |
| c | 1 | 26.2 | 26.2 |
| d | 3 | 5.3 | 15.8 |
| Scotch Pine (D) | | | |
| d | 4 | 2.4 | 9.5 |
| Balsam Fir (F) | | | |
| a | 2 | 11.5 | 23.0 |
| c | 9 | 3.8 | 34.3 |
| d | 4 | 3.7 | 14.7 |
| Jack Pine (J) | | | |
| a | 12 | 7.1 | 84.8 |
| b | 5 | 6.3 | 31.6 |
| c | 9 | 4.6 | 41.6 |
| d | 5 | 4.4 | 22.1 |
| Norway Spruce (NS) | | | |
| d | 1 | 3.3 | 3.3 |
| Mixed Swamp Conifers (Q) | | | |
| b | 2 | 67.2 | 134.4 |
| c | 11 | 10.5 | 115.2 |
| d | 2 | 6.8 | 13.5 |
| Red Pine (R) | | | |
| a | 6 | 8.3 | 49.8 |
| b | 3 | 8.3 | 24.8 |
| c | 23 | 5.5 | 127.6 |
| d | 39 | 6.7 | 259.6 |
| e | 24 | 13.2 | 316.0 |
| Black Spruce (S) | | | |
| b | 8 | 10.7 | 85.3 |
| c | 25 | 6.4 | 159.6 |
| d | 2 | 8.3 | 16.7 |
| Tamarack (T) | | | |
| a | 1 | 9.4 | 9.4 |
| b | 2 | 4.2 | 8.3 |
| d | 11 | 11.5 | 126.7 |
| c | 3 | 3.0 | 8.9 |
| e | 1 | 0.8 | 0.8 |
| Upland Conifers (UC) | | | |
| b | 4 | 10.9 | 43.7 |
| c | 8 | 5.3 | 42.7 |
| d | 12 | 4.7 | 56.5 |
| e | 2 | 1.8 | 3.7 |
| White Spruce (WS) | | | |
| a | 2 | 8.0 | 15.9 |
| b | 6 | 6.2 | 37.3 |
| c | 15 | 2.7 | 40.3 |
| d | 3 | 1.3 | 3.8 |
| White Pine (W) | | | |
| b | 2 | 0.6 | 1.3 |
| c | 1 | 1.5 | 1.5 |
| d | 3 | 3.3 | 9.9 |
| e | 3 | 5.0 | 15.1 |

**Table 7.** Hardwood stand summary by covertype and size class.

| Covertype / Size | Total stands | Mean size (acres) | Total area (acres) |
|---|---|---|---|
| Aspen (A) | | | |
| a | 6 | 9.9 | 59.6 |
| b | 37 | 6.9 | 255.0 |
| c | 40 | 4.8 | 191.3 |
| d | 16 | 5.3 | 84.3 |
| Birch (B) | | | |
| b | 5 | 3.6 | 18.2 |
| d | 8 | 5.9 | 47.5 |
| Bottomland Hardwoods (E) | | | |
| c | 7 | 4.9 | 34.0 |
| d | 1 | 6.5 | 6.5 |
| Black Ash (H) | | | |
| c | 1 | 0.7 | 0.7 |
| Northern Hardwoods (N) | | | |
| b | 6 | 4.7 | 28.0 |
| c | 3 | 6.1 | 18.2 |
| d | 6 | 4.7 | 28.0 |

**Table 8.** Mixed Hardwood/Conifer stand summary by size class.

| Covertype / Size | Total stands | Mean size (acres) | Total area (acres) |
|---|---|---|---|
| Mixed Hardwood/Conifer (HC) | | | |
| b | 3 | 1.5 | 4.5 |
| c | 7 | 2.7 | 19.1 |
| d | 14 | 4.5 | 63.5 |

## Summary and Data Availability

The forest covertype map for the CFC has been updated to 2005 using a combination of photo interpretation of QuickBird multispectral imagery and fieldwork. The covertype map and attribute data are available as GIS data files from either the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory at http://rsl.gis.umn.edu/ or the Cloquet Forestry Center at http://cfc.cfans.umn.edu/.

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## References

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# APPENDIX 1: Forest Covertype Classification System

## Covertypes: Commercial Tree Species

| Symbol | Covertype | Description |
|---|---|---|
| A | Aspen | More than 66% of total BA aspen. |
| B | Paper Birch | More than 66% of total BA paper birch. |
| C | White Cedar | More than 66% of total BA white cedar. |
| D | Scotch Pine | More than 66% of total BA scotch pine. |
| E | Bottomland Hardwoods | Lowland site with > 66% of total BA comprised of a mix of ash, cottonwood, willow and maple. No one species is greater than 66% of BA. |
| F | Balsam Fir | More than 66% of total BA balsam fir. |
| H | Black Ash | More than 66% of total BA black ash. |
| J | Jack Pine | More than 66% of total BA jack pine. |
| Q | Mixed Swamp Conifers | Lowland site with > 66% of total BA comprised of a mix of spruce, cedar, balsam and tamarack. No one species is greater than 66% of BA. |
| UC | Upland Conifers | Upland site with > 66% of total BA comprised of a mix of red pine, white pine, jack pine, spruce and balsam. |
| MS | Maple | More than 66% of total BA is maple. |
| N | Northern Hardwoods | Upland site with > 66% of total BA comprised of a mix of birch, maple, aspen and ash. No one species is greater than 66% of BA. |
| NS | Norway Spruce | More than 66% of total BA Norway spruce. |
| O | Oak | More than 66% of total BA is oak. |
| HC | Mix Hardwood/Conifer | Upland site with a mix of hardwood and conifer species with no one species having > 66% of BA. |
| R | Red Pine | More than 66% of total BA red pine. |
| S | Black Spruce | More than 66% of total BA black spruce. |
| T | Tamarack | More than 66% of total BA tamarack. |
| W | White Pine | More than 66% of total BA white pine. |
| WS | White Spruce | More than 66% of total BA white spruce. |

## Covertypes: Noncommercial Species or Development

| Symbol | Covertype | Description |
|---|---|---|
| Sx | Nonproductive Swamp | Spruce, tamarack or cedar bog which will not produce trees of pulpwood size in 100 years. |
| U | Upland Brush | Hazel, pin cherry, etc., with less than 10% stocked commercial tree species. |
| L | Lowland Brush | Alder, willow, etc., with less than 10% stocked commercial tree species. |
| M | Marsh | Grass, sedge—sometimes with some lowland brush. |
| G | Grass | Upland grass. |

| | | |
|---|---|---|
| CO | Current Cutover | Recent harvest with no replanting or establishment of natural vegetation cover. |
| PX | Experimental Planting | Arboretum, seed source study, etc. |
| AD | Administrative | CFC headquarters area. |

### Size Class – Apply only to commercial tree species covertypes

| Symbol | Class | Description |
|---|---|---|
| a | Seedlings | <1 inch DBH |
| b | Saplings | 1 – 4.9 inch DBH |
| c | Poles | 5 – 8.9 inch DBH |
| d | Small Sawtimber | 9 – 14.9 inch DBH |
| e | Large Sawtimber | >15 inch DBH |

### Stocking Class – Apply only to commercial tree species covertypes

| Symbol | Class | Poles and Sawtimber BA* | Seedlings Stems/Acre** | Saplings Stems/Acre*** |
|---|---|---|---|---|
| 1 | Under | See stocking charts | 200 – 799 | 175 – 399 |
| 2 | Fully | See stocking charts | 800 – 1399 | 400 – 749 |
| 3 | Over | See stocking charts | > 1400 | > 750 |

* Pole and Sawtimber stocking estimates are based on variable radius plots taken with 10 or 20 BAF angle gauges (prisms). Stocking charts are species specific. BA and DBH measures are used for referencing the stocking charts to determine stocking. BA stocking charts are taken from USDA Forest Service General Technical Reports NC-32, NC-33, NC-36, NC-37, NC-39, NC-98, NC-111 and NC-115; USDA Forest Service Research Paper NE-130; and USDA Forest Service Research Note NE-168.

** Seedling stocking estimates: based on a number of representatively located 1/1000 acre plots (3.7 feet diameter).

*** Saplings stocking estimates: based on a number of representatively located 1/100 acre plots (11.8 feet diameter).

### Minimum stocking requirements

For a covertype to be considered the primary covertype it must meet the following minimum stocking requirements:

Poles and Sawtimber: Basal Area > 55 sq ft
Seedlings: Stems/Acre > 200
Saplings: Stems/Acre > 175

### Minimum Mapping Unit

2.5 acres